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Review article/Orville Derby and his contribution to the geosciences

ORVILLE A. DERBY AND THE BRAZILIAN METEORITES: LIFE, SCIENCE AND LEGACY

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ABSTRACT

Orville Adelbert Derby (1851–1915), known as "The Father of Brazilian Geology", was also a pioneer of Brazilian meteoritic science. An American who lived in the country from 1870 onwards, he stood out for the creation of scientific institutions, the formation of geological and paleontological collections, and the production of seminal work for the national geosciences. In 1888, in his "Notes on the Brazilian Meteorites", Derby made the first survey gathering information about the meteorites then known in the country, classifying them as iron or stony, according to the international literature of the time. He also highlighted the uniqueness of the Angra dos Reis meteorite, which would later give rise to a new, and rare, class of meteorites, the "angrite". The study of the Bendegó meteorite is one of the main highlights in Orville Derby's work, representing not only a milestone in the history of Brazilian meteoritic science, but also an example of the intersection between science and culture in nineteenth-century Brazil. Derby reconstructed the history of the Bendegó and, although he did not participate directly, assisted in the planning and accompanied the efforts in the field to transport it from the hinterland of Bahia to Rio de Janeiro, actively working on its incorporation into the collection of the National Museum. On the Bendegó, Derby published in 1895 a comprehensive bilingual study (Portuguese and English) with structural, mineralogical and chemical descriptions, according to advanced systematics for the time. Derby also compared Brazilian meteorites with foreign specimens, such as the Cañon Diablo, and analyzed cases of "dubious" meteorites with all the technical rigors. In addition to its visionary pioneering, Derby's meteoritic legacy includes the development of a method that still sustains the area in Brazil: inventorying collections, reconstructing documents, and mobilizing local networks to record new falls and finds.

Keywords: Orville Derby; Brazilian meteorites; Bendegó; Meteoritics.

RESUMO

ORVILLE A. DERBY E OS METEORITOS BRASILEIROS: A VIDA, A CIÊNCIA E O LEGADO. Orville Adelbert Derby (1851–1915), conhecido como "O Pai da Geologia do Brasil", foi também pioneiro da meteorítica brasileira. Norte-americano radicado no país a partir de 1870, destacou-se pela criação de instituições científicas, pela formação de coleções geológicas e paleontológicas e pela produção de uma obra decisiva para a geociências nacional. Em 1888, em suas *"Notas sobre os Meteoritos Brasileiros"*, Derby fez o primeiro levantamento reunindo informações sobre os meteoritos então conhecidos no país, classificando-os como metálicos ou rochosos, de acordo com a literatura internacional da época. Destacou ainda a singularidade do meteorito Angra dos Reis, que mais tarde daria origem a uma nova, e rara, classe de meteoritos, o "angrito". O estudo do meteorito Bendegó é um dos principais destaques na obra de Orville Derby, representando não apenas um marco na história da ciência meteorítica brasileira, mas também um exemplo da intersecção entre ciência e cultura no Brasil do século XIX. Derby reconstruiu a história do Bendegó e, embora não tenha participado diretamente, auxiliou no planejamento e acompanhou os esforços em campo para transportá-lo do sertão da Bahia ao Rio de Janeiro, atuando ativamente na sua incorporação ao acervo do Museu Nacional. Sobre o Bendegó, Derby publicou em 1895 um amplo estudo bilíngue (português e inglês) com a descrição estrutural, mineralógica e química, segundo sistemática avançada para a época. Derby também comparou meteoritos brasileiros com exemplares estrangeiros, como o Cañon Diablo, e analisou casos de meteoritos "duvidosos" com todo o rigor técnico. Além de seu pioneirismo visionário, o legado meteorítico de Derby inclui o desenvolvimento de um método que ainda sustenta a área no Brasil: inventariar acervos, reconstruir documentos e mobilizar redes locais para registrar novas quedas e achados.

Palavras-chave: Orville Derby; Meteoritos brasileiros; Bendegó; Meteorítica.

RESUMEN

ORVILLE A. DERBY Y LOS METEORITOS BRASILEÑOS: VIDA, CIENCIA Y LEGADO. Orville Adelbert Derby (1851–1915), conocido como "El Padre de la Geología Brasileña", también fue un pionero de la meteórica brasileña. Estadounidense que vivió en el país desde 1870 en adelante, destacó por la creación de instituciones científicas, la formación de colecciones geológicas y paleontológicas, y la producción de una obra decisiva para las geociencias nacionales. En 1888, en sus *"Notas sobre los meteoritos brasileños",* Derby realizó el primer estudio recopilando información sobre los meteoritos entonces conocidos en el país, clasificándolos como metálicos o rocosos, según la literatura internacional de la época. También destacó la singularidad del meteorito Angra dos Reis, que más tarde daría lugar a una nueva y rara clase de meteoritos, el "angrito". El estudio del meteorito Bendegó es uno de los principales hitos en la obra de Orville Derby, representando no solo un hito en la historia de la ciencia meteórica brasileña, sino también un ejemplo de la intersección entre ciencia y cultura en el Brasil del siglo XIX. Derby reconstruyó la historia del Bendegó y, aunque no participó directamente, ayudó en la planificación y acompañó los esfuerzos de campo para transportarlo desde el interior de Bahía hasta Río de Janeiro, trabajando activamente en su incorporación a la colección del Museo Nacional. Sobre el Bendegó, Derby publicó en 1895 un amplio estudio bilingüe (portugués e inglés) con descripciones estructurales, mineralógicas y químicas, según los sistemas avanzados de la época. Derby también comparó meteoritos brasileños con ejemplares extranjeros, como el Cañón Diablo, y analizó casos de meteoritos "dudosos" con todo el rigor técnico. Además de su visionaria labor pionera, el legado meteórico de Derby incluye el desarrollo de un método que aún sostiene la zona en Brasil: inventariar colecciones, reconstruir documentos y movilizar redes locales para registrar nuevas caídas y hallazgos.

Palabras clave: Orville Derby; Meteoritos brasileños; Bendegó; Meteórico.

1 INTRODUCTION

Orville Adelbert Derby (1851-1915) (Figure 1) was one of the most prominent figures in the Geology of Brazil, which rightly earned him the epithet of "The Father of Geology of Brazil". The name *Derbyana* is a tribute to this pioneer of Brazilian geology. One of the primary sources of biographic information used in the preparation of this article was the book by Tosatto (2001), published in honor of the sesquicentenary of Derby's birth.

Born in Kelloggsville, New York, United States, on July 23, 1851, Derby came to Brazil in 1870 at the invitation of his then professor and tutor, Charles F. Hartt. At the age of 19, he was still a geology student at Cornell University, a course he completed in 1873, which would be followed by his Master of Science obtained in 1874. Derby was part of a generation of scientists forged in the North American geological tradition, marked by systematic fieldwork, stratigraphy and paleontology as central instruments for interpreting the territory.

FIGURE 1 – Orville A. Derby (1851-1915), in a photo taken in 1891 (source: https://catalogue.bnf.fr/ark:/12148/cb405873204).

Hartt's invitation was for Derby to join the Morgan Expedition, an important scientific research mission that traveled through several regions of Brazil, including Bahia, São Paulo, Minas Gerais and Pará. The results of this expedition were used to build the geological and historical knowledge of the country, contributing to official documentation and scientific education. The expedition also had a significant impact on Brazilian paleontology, with the collection of brachiopods that were the first fossils from the Devonian period found in Brazil (Fonseca, 2004; Tosatto, 2001). His contributions to Brazilian science and culture were significant and are an example of how scientific research can shape the country's knowledge and identity.

After Derby's first trip to Brazil, his destiny would never be disconnected from the country, neither intellectually nor emotionally. In the many years he lived and worked in Brazil, Derby served on the Geological Commission of the Empire, the National Museum, the Hydraulic Commission of the Empire, the Geographical and Geological Commission of São Paulo, the Historical and Geographical Institute of São Paulo, the Land and Mines Service of the State of Bahia and the Geological and Mineralogical Service of Brazil.

In the various positions he occupied, Derby developed pioneering geological works addressing the most diverse topics in practically all regions of Brazil. His professional and scientific career was totally dedicated to unveiling the geology of our territory, having produced seminal studies on Paleontology, Mineralogy, Petrography, Stratigraphy, Mineral Resources, among others.

Perhaps less known, however, is the pioneering spirit in the study of meteorites, fundamental for the development of meteoritic science in Brazil.

In this article we present a synthesis of his studies on meteorites in order to fill this gap about Derby's pioneering role in meteoritic science, complemented by historical information, with emphasis on the detailed work on the Bendegó meteorite, the largest meteorite found in Brazil. The work included chemical and metallographic analyses, accompanied by a detailed account of its discovery, transport, and historical context (Carvalho, 1888, 1928; Carvalho et al., 2011; Derby, 1888, 1895b). The National Museum fire in 2018 destroyed Derby's handwritten cards describing various meteorites that were part of the collection; for this reason, we have included an Appendix to this article with images of some of these cards.

2 ORVILLE DERBY AND HIS RELATIONSHIP WITH BRAZIL AND ITS GEOLOGY

In his initial contacts with the Brazilian geology, during the Morgan Expedition, Derby made important paleontological collections in Pernambuco and the Amazon, collecting specimens especially in the Maria Farinha and Itaituba formations, contributing in a pioneering way to the knowledge of sedimentary stratigraphy and carboniferous fossils. These initial works resulted in his master's thesis on carboniferous brachiopods from the Tapajós River region. This research, completed in 1874, is considered one of the first systematic paleontological studies carried out in Brazil by a researcher with specialized academic training.

In 1875, as Hartt's assistant, he joined the Geological Commission of the Empire, the first state initiative aimed at producing comprehensive geological knowledge of the Brazilian territory. In this commission, he developed regional studies in Bahia, Sergipe, Pará and in the São Francisco River basin, laying the foundations for the understanding of regional geology and the country's mineral resources.

The Commission would last only a few years, having been extinguished in 1877 due to political changes. In 1878, Charles Hartt, Derby's master and intellectual father figure, died prematurely from yellow fever, leaving him isolated and living in an institutionally vulnerable situation.

The dissolution of the Commission, combined with Hartt's death, meant for Derby not only the loss of a job, but the real risk that the entire scientific collection produced by the team led by Hartt, consisting of fossils, rocks, maps, manuscripts, would be irretrievably dispersed due to the negligence of a bureaucratic structure that did not value the treasured and voluminous body of knowledge.

This moment was decisive for Derby in his trajectory in Brazil. Between fear and responsibility, he made the decision to remain in Brazil and took on a fundamental role in the institution that would play a central role in his career, the National Museum of Rio de Janeiro. Testimony to his selflessness and dedication is the fact that Derby took on these tasks without salary and without the promise of a contract. If Derby had, on the one hand, no guarantee of the future, on the other hand, he knew that, if he did not do so, probably all the scientific collection gathered until then would be lost.

At that time, the Museum operated in the then called Campo de Santana, currently Praça da República, and only in 1892, after the Proclamation of the Republic, it would move to the Imperial Palace of Quinta da Boa Vista.

At the National Museum, he found a safe place to preserve the Geological Commission's collection, consisting of thousands of rock samples, precious fossils, reports and collections that testified to years of work. In 1879 he was appointed Director of the 3rd Section (equivalent to the Department of Geology and Paleontology), with the mission of organizing and systematizing collections of mineralogy and paleontology, contributing to the consolidation of the Museum as a center for scientific research and training of specialists in geosciences.

In 1886 Derby was invited to head the Geographical and Geological Commission of the Province of São Paulo, a position he accumulated with that of Director of the 3rd Section of the National Museum until 1890. That year, due to a new regulation of the Museum that did not allow the accumulation of positions, Derby was dismissed and began to dedicate himself exclusively to the Commission in São Paulo. There are records, however, that he remained voluntarily working with the Museum at least until 1892.

Under his leadership, the Geographical and Geological Commission of the Province of São Paulo, a fundamental institution for the scientific knowledge of the territory of São Paulo, carried out, between 1886 and 1905, systematic cartographic and geological surveys of the then Province, using modern methods of geodetic triangulation aimed at territorial planning, agricultural expansion and the rational exploitation of mineral and other natural resources.

Derby's work in this context highlights the close relationship between science and the State, to the extent that the geological knowledge produced by the commission subsidized public policies and economic development strategies. At the same time, Derby participated in the founding of the Historical and Geographical Institute of São Paulo, inserting himself in the intellectual debates on the construction of regional and national identities.

In 1905, Derby decided to leave the São Paulo Commission when he realized that he no longer had the political and financial support to continue with the mission he had established for this institution. In doing so, he was invited by the Government of the State of Bahia to reorganize the Land and Mines Service of the State of Bahia and to study the geology of that state (Lamego, 1951; Tosatto, 2001; Pires & Cabral, 2001). Derby remained in this task until the end of 1906, having carried out important studies on the diamond, manganese and petroleum resources of Bahia (Derby, 1905a, 1905b, 1905c).

At this stage of his career, Derby received an important invitation from the Federal Government to establish the Geological and Mineralogical Service of Brazil, a precursor body to the current Geological Survey of Brazil/CPRM. Beginning his work in January 1907, Derby then devoted himself to studies of economic geology, with emphasis on research on manganese and diamond deposits, in addition to coordinating the preparation of the Geological Map of Brazil, presented in 1915, which synthesized the geological knowledge accumulated until then (Pires & Cabral, 2001; Tosatto, 2001).

Orville Derby's scientific production is extensive and diversified in theme, totaling more than one hundred and fifty published works, covering general geology, mineralogy, paleontology, cartography and physical geography. This production contributed decisively to the professionalization of geological activity in Brazil and to the consolidation of geosciences as an autonomous scientific field.

On November 27, 1915, in Rio de Janeiro, Derby ended his own life (A Noite, 1915). In his last years, he lived under intense pressure, with institutional demands, political and financial difficulties, and unattainable expectations. Having lived an existence of relative isolation, he, who had dedicated forty years to Brazil and had barely returned to his homeland (only twice, in 1883 and 1890), Derby carried within him a deep loneliness.

3 METEORITES IN ORVILLE DERBY'S WORK

Orville A. Derby was a pioneer in the study of meteorites and responsible for the first systematic survey of these celestial bodies found in the country. His publication "Notes on Brazilian Meteorites" (Derby, 1888) represents the first systematic effort to gather what was known about Brazilian meteorites.

Derby begins his article with a piece of data that reveals, at the same time, the international relevance and the documentary fragility of the theme: in foreign museums and in the specialized literature, there were only three meteorites attributed to Brazil: the Bendegó (discovered in 1784), Macau (fall in 1836) and Santa Catharina (discovered in 1875). At the time, the National Museum had in its collections samples of four other meteorites: Itapicuru-Mirim (fall observed in 1879), Santa Bárbara (fall observed in 1873), Minas Gerais (or Minas Geraes, without precise information), and Angra dos Reis (fall observed in 1869). Therefore, the total number of Brazilian meteorites was, at that time, seven.

From a technical point of view, Derby organizes the "Seven known Brazilian meteorites" into two large groups, using the current terminology of the period: iron meteorites (*Eisenmeteoriten* by the German authors, *Holosiderites* by Daubrée) for Bendegó and Santa Catharina, and stony meteorites (*Steinmeteoriten* by the Germans, with *Sporosyderites and asyderites* de Daubrée) for the other specimens. Even considering that the nomenclature has changed over time, the reasoning used by him remains: iron meteorites as masses of metallic iron-nickel and stony meteorites as silicates with dispersed metallic fraction. For him, the Angra dos Reis meteorite would be an exceptional case due to its mineralogical particularity and absence of apparent metal. This did not allow it to fall into either of these two categories, which led Derby to consider it as a singular object. In fact, the Angra dos Reis meteorite ended up, over time, defining a specific and rare type of achondrite-type meteorite, the *angrite*, a category of which only 67 specimens are known on Earth to date, with Angra dos Reis being the only recorded fall (The Meteoritical Society, 2026).

Derby showed that he was connected to the international geoscientific scene, citing and corresponding with European authors, museums and periodicals. At the same time, he was trying to establish a tradition of systematic description and conservation of samples in Brazil.

It is worth noting that, when Derby developed his studies on Brazilian meteorites in the nineteenth century, meteoritic science was still in its early stages of development. Although the symbolic milestone of the birth of meteoritics as a science is the meteorite shower that took place in L'Aigle in 1803, which represented the empirical confirmation of the extraterrestrial origin of meteorites (Biot, 1803), the cosmic hypothesis had already been formulated a few years earlier by Ernst Florenz Friedrich Chladni. By analyzing the so-called "Pallas iron", Chladni (1794) proposed that these mixed masses, metal and rock, did not have terrestrial origin, but came from space, contrary to the then dominant volcanic explanations (Marvin, 1996). The research conducted by Biot in L'Aigle, on behalf of the French Academy of Sciences, finally provided the observational proof to support Chladni's theory, consolidating the scientific acceptance of the extraterrestrial origin of meteorites.

At that time, little was known about meteorites and Biot's report established the first classification milestones, as well as the initial bases for the investigation of other possible extraterrestrial specimens. Thus, here Derby's pioneering spirit emerges again in his studies on the meteorites found in Brazil, including what was then the second largest meteorite known in the world, the Bendegó with its 5.36 tons.

Derby also studied the Cañon Diablo (or Canyon Diablo) meteorite, found in 1891 in Coconino County, Arizona, United States, and in 1895 published an article with the results of chemical analyses and comparing it with other similar meteorites, such as the Bendegó (Derby, 1895a).

We present below a synthesis of these comparative studies conducted by Derby on Brazilian meteorites and the Cañon Diablo.

4 THE BENDEGÓ METEORITE

In the publication "Notes on the Brazilian Meteorites" (Derby, 1888), the author reconstructs the discovery of the Bendegó and the attempts to transport it from the interior of Bahia to the National Museum, gathering historical, mineralogical and institutional data.

"Bendegó – This remarkable meteorite that is on its way to the National Museum, thanks to the initiative of the Hon. Messrs. Baron of Guahy and Commendador José Carlos de Carvalho, is, by size, the second known (in a single mass) being only surpassed by that of Tucumán in the Argentine Republic. Discovered in 1784 in the district of Monte Santo in the province of Bahia, it was brought to the attention of the scientific world by a letter addressed to the famous Dr. Wollaston, Secretary of the Royal Society of London, and published in the Philosophical Transactions of 1816. The author of the letter, Mr. A. F. Mornay, being commissioned by the governor general of Bahia in 1810 to examine some sources of mineral water in the hinterland of that province and having news of a mysterious stone in the same direction, suspected that it was a meteorite, and decided to examine it. Searching first in the archives of Bahia for the history of the discovery, he learned that it was found in 1784 by Bernardino de Motta Botelho and that the governor, influenced by the news that spread that the stone was composed of silver, ordered it to be moved to the capital.

With a lot of effort, he was mounted in a four-wheeled cart in 1785 and moved about 150 steps, when passing the bed of the Bendegó stream the car got stuck and the transport had to be abandoned. Mr. Mornay found the stone in January 1811 still on top of the car and calculated its contents, at 28 cubic feet, being 7 feet long by 4 feet wide and 2 feet high.

The weight was calculated at 14,000 pounds.

From the samples taken by Mr. Mornay, Dr. Wollaston found that the mass had the characteristics of meteoric irons, being composed of iron and metallic nickel in the proportion of 95.1 % of the former to 3.9 % of the former.

Another piece of news was given in the work of Spix and Martius, who examined the mass on their trip through Bahia and calculated the weight at more than 9,600 kilos, or about 50% more than Mornay's estimate.

The samples taken by Mornay and Spix and Martius weigh about 9 kilograms and are distributed among the museums of Munich, London, Vienna, Göttingen, St. Petersburg, Berlin, Erlangen and Copenhagen, the largest piece, weighing 3,115 grams, preserved in the Munich Museum. Until a few months ago this meteorite was not known in the Brazilian collections, but thanks to the initiative of Dr. Luiz da Rocha Dias, Chief Engineer of the extension of the Railroad from Bahia to São Francisco, the National Museum recently received a fragment weighing 1,868 grams and another a little smaller, went to the collection of His Majesty the Emperor.

A polished surface treated with acid shows in great perfection the figures called Widmannstätten characteristic of most metallic meteorites.

These figures clearly show that the mass is composed almost exclusively of beam-like fibers about 2mm wide, interspersed in a way that resembles the texture of a fabric. This beam iron (Balkeneisen or Kamesito) predominates to the point of entirely excluding the two other qualities of iron which with it enter into the composition of almost all meteoric irons. Rare and small nodules of pyrite (Troilite) and microscopic crystals of iron phosphorede (Rhabdite) are also noticed."

In this work, Derby emphasizes the historical reconstruction of the discovery and the attempts at transport, without explicitly mentioning his own previous role in the technical and institutional articulation that would enable the removal of the mass – an aspect later detailed by Carvalho (1928).

In 1883, as director of the 3rd Section of the National Museum, Derby expressed his concerns about the future of the meteorite. Fearing that he might have been buried by the floods linked to following the heavy rains that hit the hinterland of Bahia at that time, he asked engineer Theodoro Sampaio, a member of the commission in charge of the works to improve the São Francisco River, to obtain precise information about his situation. The report of December 31, 1883 confirmed that the mass was still visible and widely known in the region of Monte Santo, located on the Bendegó farm, on the banks of the homonymous stream, a tributary of the Vaza-Barris river, about 12 to 14 leagues (58 to 67 km) from the village of Monte Santo and 27 to 30 leagues (130 to 145 km) from Queimadas. This last location was already reached by railroad, which would later serve as the initial point of shipment of the meteorite to Rio de Janeiro.

In early 1886, at Derby's request, the then director of the National Museum, counselor Ladislau Netto, sought to obtain new information. The engineer Vicente José de Carvalho Filho was then appointed by the direction of the Bahia to São Francisco Railroad to evaluate the technical means necessary for its removal to the National Museum. Derby understood that the success of the operation would depend on the combination of scientific knowledge and transport infrastructure.

That same year, while in Paris, the Emperor of Brazil, D. Pedro II, was convinced by members of the French Academy of Sciences to arrange for the transfer of the meteorite to the National Museum. The emperor possibly intuited that this would represent a historical fact, as it would be the largest meteorite exhibited in a museum in the world, so he committed to act in this direction when he returned to Brazil.

It should be noted that the Bendegó was, for almost 90 years, the largest meteorite in a single fragment known in the world, being dethroned in 1863 by the discovery in Mexico of the Bacubirito meteorite weighing about 20 tons, which remained at the site of the find until the end of the twentieth century. a fact that lasted until 1897 when a fragment with 31 tons of the Cape York meteorite (also called Ahnighito), was transported to the American Museum in New York. This meteorite, found in 1894 in Greenland, has a total recovered mass of 58.2 tons. However, this did not take away Bendegó's pioneering role.

In 1887, already back in Brazil, the Emperor put Commander José Carlos de Carvalho in charge of the removal and transport operation, determining that he should go to Bahia to reconnoiter the area and gather the information obtained by Derby about the first attempts to transport the mass. The Geographical Society took on the logistical arrangements necessary for the execution of the commission, which also had the patronage of the Baron of Guahy, the Bahian Joaquim Elísio Pereira Marinho (Carvalho, 1888, 1928).

In the same period, the National Museum received, for the first time, a fragment of 1.86 kg from the Bendegó, sent by Luiz da Rocha Dias, director of the railway extension, accompanied by a report detailing the logistical difficulties faced in the hinterland. The incorporation of the copy into the Museum's collection was finally a reality (Carvalho, 1888).

The transport from Bendegó to Rio de Janeiro was a milestone in the history of meteoritics and for transport logistics in general, as illustrated by photos from the time (Figures 2a - d). A historical account of this remarkable undertaking is presented by Carvalho et al. (2011). The main difficulty lay in the lack of adequate routes for transporting such exceptional and heavy cargo. It was necessary to design and build a special car made of reinforced wood with hardware, supported on temporary rails laid along the route when the road did not provide conditions. The crossing of the irregular terrain, between the place where the rock was to the nearest railway station,

FIGURE 2 – Set of historical photographs documenting the transport of the Bendegó. (a) Record of the 15th day of work during the removal of the meteoritic mass in the Bahia hinterland. (b) Passage of the meteorite on improvised rails in the Jacuricy River, evidence of the complex land transportation effort carried out by local teams and engineers. (c) The meteorite after falling from the cart into the Chico stream. (d) Boarding of the meteorite on the so-called "Ingleza Road", an important stage of the journey to Salvador. (e) An old monument erected at the site of the find, later destroyed by the local population. (f) "Barão de Guahy" landmark that records the point of boarding of the meteorite still preserved. (g) The Bendegó meteorite during the cutting process carried out at the Navy Arsenal, in Rio de Janeiro. These images document different moments in the history of the largest meteorite ever found in Brazil and illustrate the logistical difficulties and scientific interest associated with its transport and study at the end of the nineteenth century. Authorship attributed to Antunes Saraiva and/or Marc Ferrez originally published in the reports of Carvalho (1888, apud Lago, 2008).

Jacuricy, located in the current municipality of Itiúba (BA), marked by dry river beds, sandy areas and steep slopes, required constant adaptation of the improvised infrastructure.

A monument was erected at an uncertain date at the supposed location of the Bendegó find (Figure 2e). However, it was later destroyed by the local population in protest against the drought of 1888, attributing the climatic disaster to the removal of the meteorite.

The meteorite arrived at the Jacuricy station on May 14, 1888. On May 16, the cornerstone of the Barão de Guahy Landmark was laid (Figure 2f).

The most critical step involved the removal of the mass of more than 5 tons from the bed of the Bendegó stream, where it had remained since the failed attempt of 1785 reported by Derby (1888) (Figure 2a). The movement required systems of levers, jacks and pulleys, as well as coordination between local workers, engineers and military personnel. The scarcity of modern mechanical resources and the need for progressive transport to the rail embarkation point imposed a slow pace on the operation. The transport itself lasted 126 days, time it took to overcome 113.4 km with ascents, descents and ramps of up to 30°, in addition to rivers and lagoons. There were several interruptions for various reasons, such as several falls of the meteorite from the top of the truck, heavy rains and breaks in the vehicle's axle (Figure 2c).

After the initial terrestrial phase, the meteorite went by rail to Salvador and, later, by sea aboard the steamer "Arlindo" to Rio de Janeiro, where it was incorporated into the collection of the National Museum (Carvalho, 1888, 1928). The success of the enterprise resulted from the articulation between technical planning, institutional support and private financing (rail and maritime transport were not charged), demonstrating the convergence between science, logistics and imperial politics at the end of the 19^{th} century, with Derby having assumed a fundamental role in this process.

After it arrived in Rio de Janeiro, a one meter long cut was made at the Navy Arsenal along the meteorite, which allowed the exposure of a large internal surface. Polished and attacked with dilute nitric acid, this surface clearly revealed the Widmanstätten figures, whose Derby geometry accurately describes, along with the parallel inclusions of troilite and other minerals. Of this slice cut in 1888, several samples of various weights and sizes are part of the collections of almost three dozen museums and academic institutions around the world (Carvalho et al., 2011).

In 1895 Derby published an extensive study on the Bendegó meteorite in the Revista do Museu Nacional do Rio de Janeiro (Derby, 1895b), followed by abridged versions later published in international journals (Derby, 1898a, b). It was the first systematic work on mineralogy and meteoritic crystallography carried out in Brazil and on par with the state of the art of this science in the scientific world at the time. The wide international circulation of this study projected Bendegó and the National Museum into the global scientific debate.

The Bendegó mass has imposing dimensions, with a maximum length of about 2.2 m, a width of 1.45 m and a thickness of approximately 0.58 m, weighing 5.36 tons (Figure 3). The overall shape is described as flattened, with slight anterior projection and evident parallelism between some opposing faces. Derby noted that the recurrence

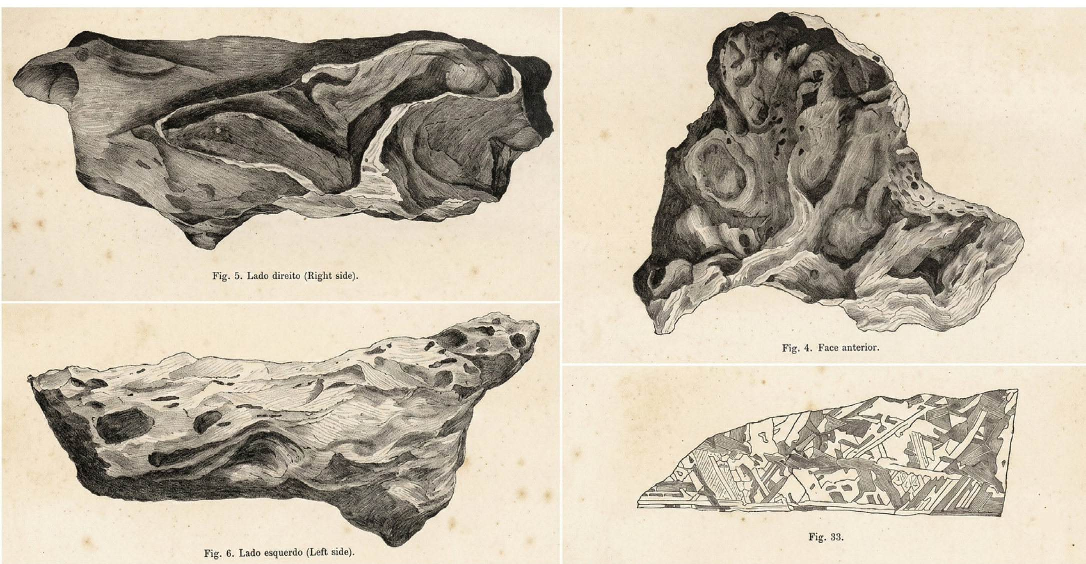

FIGURE 3 – Sketches of the Bendegó meteorite probably made by Derby himself. In the sketch of the lower right corner he reproduces the Widmänstatten pattern on a slice of the meteorite (Derby, 1895a).

of nearly parallel planes and roughly orthogonal edges could hardly be attributed to chance. For him, the external morphology reflected internal structural control, suggesting correspondence with crystallographic directions of the cubic system.

Derby describes in detail the internal structure and the main minerals that make up the Bendegó. The metallic mass, with 93% iron and about 7% nickel and cobalt, is essentially made up of *kamacite*, or α iron, poor in nickel, forming crystalline bars that make up almost all the metal in the meteorite. These bars clearly reveal the Widmanstätten figures, typical metallic meteorite structures formed by the slow cooling of the iron-nickel alloy inside planetary bodies.

Taenite, or iron γ, the most nickel-rich iron-nickel phase, appears only in small amounts, usually as very thin blades or as sheaths associated with kamacite bars. The same occurs with *plessite*, which is a mixture of phases α and γ, typical of octahedrites. Derby also measured the width of the kamacite lamellae between 1.5 and 3 mm, a data that reinforces the classification as coarse octahedrite.

Among the accessory minerals, one of the most important is *troilite* (FeS), present as numerous dark nodules aligned horizontally by the metal mass. Many of these nodules also appear associated with cavities on the surface of the meteorite, formed by the alteration or loss of sulfide. Troilite often has inclusions or associations with other minerals, such as cohenite and schreibersite. Secondary minerals such as daubréelite ($FeCr_{2S4}$) and phosphides of various metals are also associated.

The metal phosphide schreibersite $(Fe,Ni)_3P$ occurs both in granular form and as small needles of rhabdite $(Fe,Ni)_3P$, distributed among the kamacite bars. These minerals are important because they concentrate phosphorus on the metal alloy. In addition to them, Derby also identified rare accessory minerals such as *daubreelite* ($Fe^{2+}Cr^{3+}2$ S_4), *chromite* ($FeCr_2S_4$), small amounts of *carbon* and phosphet-rich metal globules.

Derby also identified the presence of the mineral *cohenite* ($((Fe,Ni,Co)_3C$ in Bendegó, which had been described for the first time a few years earlier by Cohen (1898) and Weinschenk (1889), who recognized cohenite as a metallic carbide present in meteorites such as those of Magura and Wichita. Derby observed that these masses often organize themselves around troilite nodules (Figure 4). Chemical analyses confirmed significant carbon content, while crystallographic measurements conducted by Eugen Hussak confirmed crystallization in the holohedral cubic system (Derby, 1895b). Derby also discusses the relationships between the minerals schreibersite and rhabdite, recognizing morphological variations of iron and nickel phosphides.

Particularly interesting is Derby's description of the black spherical globules, strongly magnetic,

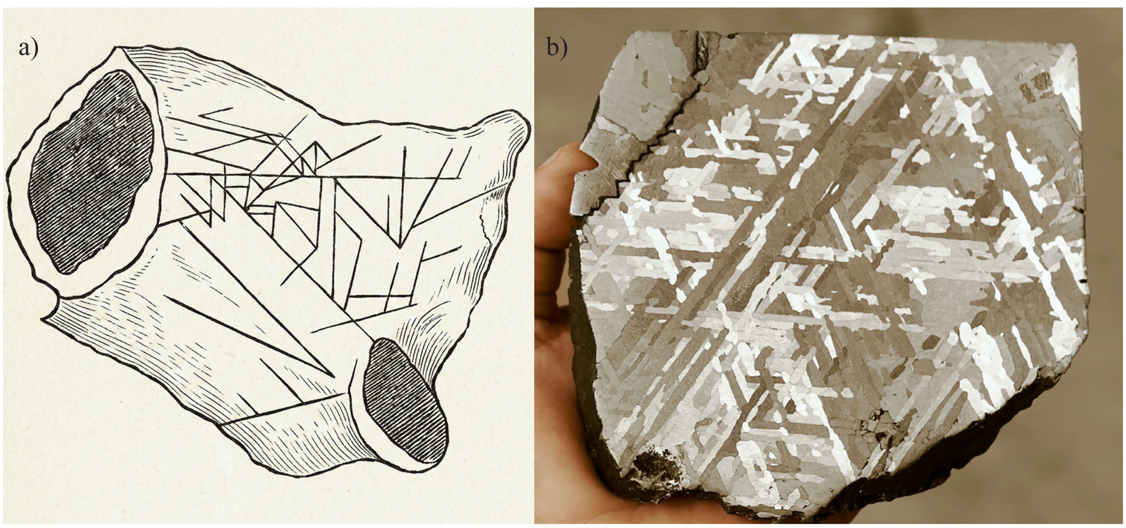

FIGURE 4 – Representation of a section of the Bendegó meteorite showing cohenite nodules and the Bendegó lines (Neumann lines) (source: Derby, 1898). Above left are the so-called Wollaston lines. On the right, slice of the Bendegó showing the structure of Widmanstätten (credit: E. M. Zucolotto).

revealed by the acid treatment of rhabdite-rich fragments. Some of them have a hollow or lamellar structure, releasing internal metal globules during dissolution. Derby even compared such structures to spherules described in deep ocean sediments as “cosmic dust”, suggesting genetic identity.

In the residues of the troilite nodules and the metallic mass, isometric chromite crystals were also identified. The microscopic study also revealed maclas in the kamacite that he called “Bendegó lines”, interpreted as raised lamellae associated with maclation planes parallel to the faces of the hexakis octahedron and that were correlated with crystallographic planes of the Widmanstätten structure, Neumann lines and lime traces, recognizing genetic unity between these features (Figure 4a).

Derby also identified important structural planes in the metal mass in Bendegó. The so-called *Wollaston lines* (Figure 4b) correspond to natural fracture surfaces within the meteorite. Rather than representing true crystallographic cleavage, these planes are interpreted as junctions between different crystallographic individuals, indicating that the meteorite is formed by a polycrystalline set of interlaced metallic crystals. Along these planes there is less cohesion of the metallic mass, which explains the natural fragmentation and certain features of the external shape of the meteorite, something that can happen in the fragmentation of large metallic masses during its passage through the Earth’s atmosphere.

Chemical analyses of all phases found at Bendegó were done in collaboration with Franz Wilhelm Dafert and Guilherme Florence and crystallographic analyses and descriptions of the minerals were in collaboration with Eugen Hussak (Derby, 1895b).

The set of observations led him to propose that the Bendegó meteorite would be a polycrystalline aggregate, separated by planes of less cohesion, which would explain both its external morphology and the preferential orientation of the internal inclusions.

By integrating macroscopic description, chemical analysis, crystallography, and complete structural interpretation into a metallic meteorite, something very advanced for the time and still under discussion today, Derby inserted the Bendegó into the international scientific debate not only as an enormous metallic mass, but as an object of high-level scientific investigation.

5 THE SANTA CATHARINA METEORITE

The first Brazilian metallic meteorite analyzed by Derby was the Santa Catharina (Derby, 1885). The author observed that the most accurate designation for this meteorite would be São Francisco do Sul, a location close to the place of occurrence, but recognized that the name consecrated by use was already consolidated in the international literature and adopted it.

The discovery, which took place in 1875 a few kilometers from São Francisco do Sul (Ornellas et al., 2021), is attributed to Manoel Gonçalves da Rosa. The mass was initially interpreted as a possible iron deposit, which led to the concession of exploration and the subsequent systematic extraction of the material as iron and nickel ores, until its exhaustion. It is estimated that at least 25 tons of the metal were exported to England. This would have been, therefore, the largest volume of meteoritic material in Brazilian territory, although not in a single mass, but rather adding the various fragments. The largest fragment found weighed 2,250 kg.

Samples sent to the Polytechnic School of Rio de Janeiro were analyzed by Guignet and Almeida (1876), accompanied by a note by Damour (1877). This note was presented by Emperor Dom Pedro II at the Académie des Sciences in Paris, which highlights the international repercussion of the case.

Much of the material was fragmented for ease of transport and later melted before its scientific value was fully recognized – a circumstance regretted by Derby. Still, representative specimens have remained preserved in the major meteoritic collections of Europe and the Americas (Figure 5).

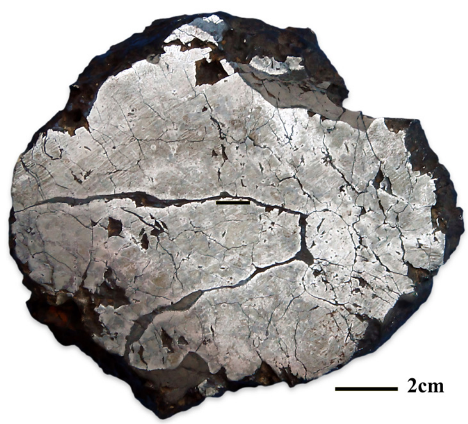

FIGURE 5 – Santa Catharina meteorite showing the brechiform structure mentioned by Derby. Specimen belonging to the collection of the National Museum (credit: E. M. Zucolotto).

Santa Catharina is distinguished by its exceptional composition, with about 34% nickel, a very high value among metallic meteorites. Its structure was also unusual: it had a brechiform texture, with rounded metallic masses coated with magnetite and separated by sulfides, as described in detail by Daubrée (1878). The absence of Widmanstätten figures, which baffled researchers, is compatible with its modern classification as a taenite-dominated ataxite.

These compositional and textural singularities raised, at the time, doubts as to their meteoric nature, especially due to the analogy with the native iron of Ovifak, in Greenland. However, the geological observations of Charles Frederick Hartt and, later, Luiz Gonzaga de Campos, did not identify associated basic rocks that supported a terrestrial origin (Derby, 1885). Derby considered this possibility but did not favor it due to the lack of convincing geological evidence.

The structure of the Santa Catharina was examined by Daubrée (1887), who interpreted the crust as a secondary product of terrestrial alteration, composed essentially of limonite derived from the oxidation of iron, as well as fragments of disaggregated granite on which the mass would have rested. Derby, however, when analyzing better-preserved specimens, argued that this crust was part of the meteorite's own organization. In addition, he distinguished a facies with a granitoid aspect, formed by intensely fractured fragments of olivine and plagioclase, and another of porphyritic character, with rounded metallic masses immersed in the matrix, which is not observed in current specimens.

In his article in the *American Journal of Science* (Derby, 1885), the author championed the meteoritic origin of the material based on textural and experimental observations. He also proposed a structural association between metal and silicates, suggesting that Santa Catharina would occupy an intermediate position between holosiderites and asiderites in the Daubrée classification. His interpretation brought him closer to the group that would later be recognized as the siderolites. Derby also suggested that other large meteoritic irons could have a similar internal organization, including the Bendegó.

Also noteworthy was the variable magnetic behavior of the material, relatively weak at room temperature, but more intense when heated. Studies conducted by Lawrence Smith and Edmond Becquerel indicated that the mass had not been subjected to sufficiently high temperatures to profoundly modify its original magnetic structure Derby (1895b).

The Santa Catharina has thus established itself as one of the most unique metallic meteorites known, still with few comparable specimens in the world´s collections, both for the volume extracted and for its unusual composition and complexity of its internal structure.

6 THE MACAO METEORITE

The Macau meteorite is mentioned by Derby as the only Brazilian stony meteorite cited in specialized works of the nineteenth century. Its fall occurred at 5 a.m. on November 11, 1836, near the village of Macau, in the province of Rio Grande do Norte. It is the oldest meteoritic fall recorded in Brazil.

Contemporary reports published in European scientific journals describe the event as a veritable "rain of stones", with masses ranging from a few grams to about 40 kg, with a predominance of fragments of a few centimeters in size. The main area of dispersion was concentrated in the region of the mouth of the Assú River, although smaller fragments were recorded along a range estimated to be approximately 50 km long. Witnesses reported the passage of a meteor of extraordinary brightness, compared to a large luminous balloon, followed by an audible detonation 200 km away.

A description of the phenomenon was made by Berthou (1837), indicating that numerous fragments reached dwellings and penetrated the ground of the site. There were no human victims, but some animals (cattle) would have been injured or killed by the fragments. This episode had international repercussions, which confirms its exceptional magnitude.

Despite this, few samples have been preserved. In addition to one copy in the National Museum (Figure 6), some others were incorporated into European collections, such as those of the museums of Vienna, Berlin, Göttingen, Paris, St. Petersburg, Madrid and Utrecht (Figure 7). The whereabouts of the main mass of almost 40 kg remain unknown.

At the National Museum, the fragments attributed to the fall of the Macau meteorite were later identified, without detailed documentation of origin, other than the indication that they had been sent to the Historical Institute by the president of the province of Rio Grande do Norte. Despite the

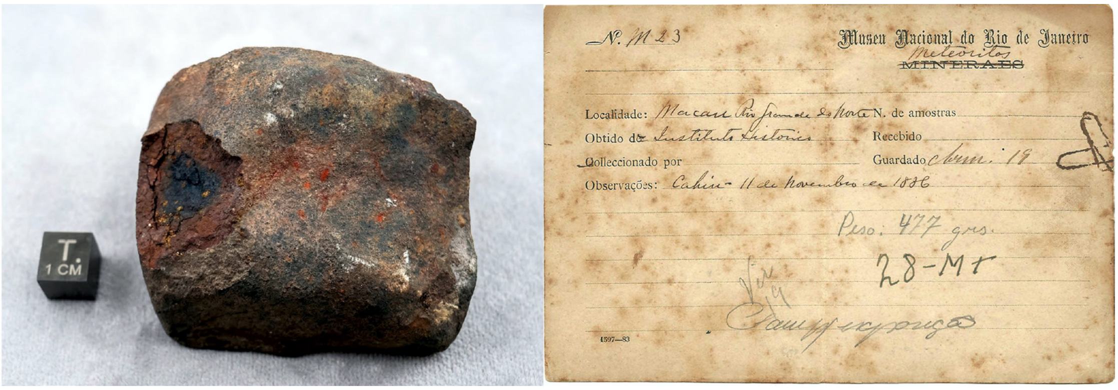

FIGURE 6 – On the left, a specimen of the Macao meteorite from the National Museum. Even though it suffered some damage due to the fire at the National Museum in 2018, the specimen is degrading due to oxidation (credit: E. M. Zucolotto). On the right, handwritten file by O. Derby referring to the record of this meteorite in the collection of the National Museum.

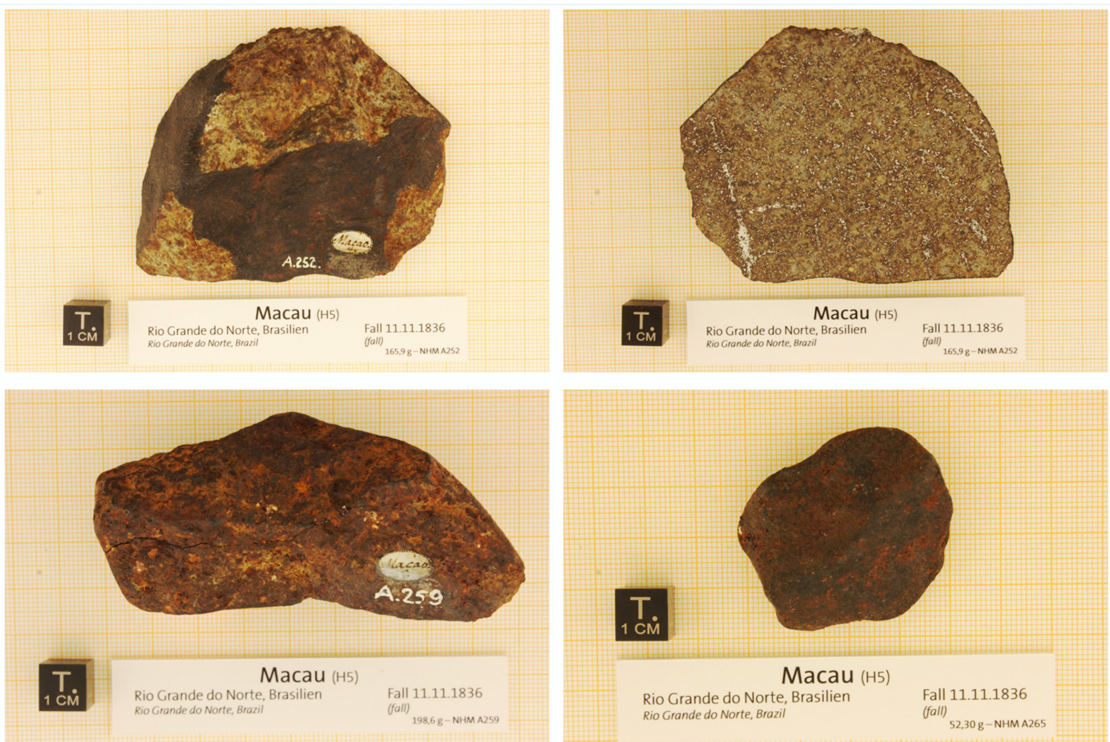

FIGURE 7 – Specimens of the Macao meteorite belonging to the collection of the Natural History Museum in Vienna (Naturhistorisches Museum Wien), Austria (credit: Julia Roszjar, NHMW).

absence of complete administrative records, Derby considered it safe to attribute these samples to the fall of 1836.

The preserved specimens totaled about 2 kg, with the largest fragment weighing approximately 800 grams (Figure 6). There is no record of systematic chemical analysis of the material. The specific weight is 3.74 g/cm3, which suggests significant metallic iron content, compatible with the microscopic observations carried out at the Museum. In thin sections, relatively abundant metallic grains are observed dispersed in the silicate matrix. Chondrules are frequent, some composed exclusively of enstatite in radial texture and others of olivine, in addition to specimens with a granular mixture of both minerals. The overall mass consists of irregular fragments of these silicates, interspersed with grains of metallic iron. The description confirms that it is a chondrite, inserted in the most common group of rocky meteorites, that of the ordinary chondrites H5.

7 THE ITAPICURU-MIRIM METEORITE

According to Derby (1888), the Itapicuru-Mirim meteorite does not present, in general, marked differences in relation to the larger masses of Macau. He reports that the copy was sent to the National Museum in April 1879 by Dr. Themístocles Aranha, editor of the newspaper "Paiz do Maranhão", a prominent figure in the intellectual scene of Maranhão at the time.

The original note that accompanied the shipment was lost, which led Derby to seek to reconstruct the history of the fall. When he later met with Dr. Aranha himself, he obtained from him a handwritten report that he transcribes in his publication. According to this information, the meteorite would have fallen in March 1879, near the village of Itapicuru-Mirim, in the province of Maranhão, at 11 am, under a clear sky, and the phenomenon was accompanied by a small stampede and a "buzz", as described by an eyewitness. Derby also sought more detailed news about the event in the Maranhão press. However, all attempts to locate such records proved fruitless, revealing the difficulties of documentary consolidation of the Brazilian meteoritics.

The specimen preserved in the National Museum has a thin black crust and exhibits on the surface several relatively deep round-shaped depressions, typical of meteorites from recent falls (Figure 8). The specific weight was calculated at 3.638 g/cm3. On microscopic examination, the material reveals an appearance practically identical to that of the Macau meteorite, suggesting a close petrographic affinity between the two.

8 O SANTA BARBARA METEORITE

The story of this meteorite was rescued by Derby (1888). The fall occurred in 1873 in the then Province of Rio Grande do Sul. The reconstruction of the events was due to the diligence of the president of the province himself, Dr. João Pedro Carvalho de Moraes, and the collaboration of the journalist Carlos von Koseritz, whose information allowed the establishment of one of the most complete reports of meteoritic falls in Brazil in the 19th century.

According to the regional press at the time, the president of Rio Grande do Sul ordered an official investigation of the phenomenon through the police of the parish of Santa Christina do Pinhal. In a letter dated December 16, 1873, sub-delegate João Paes de Oliveira reported that Carlos Pohlman was in possession of a stone of unknown origin. According to witnesses, rural workers would have observed several stones falling on a nearby bush, breaking tree branches. Subsequent rain erased the traces, leaving

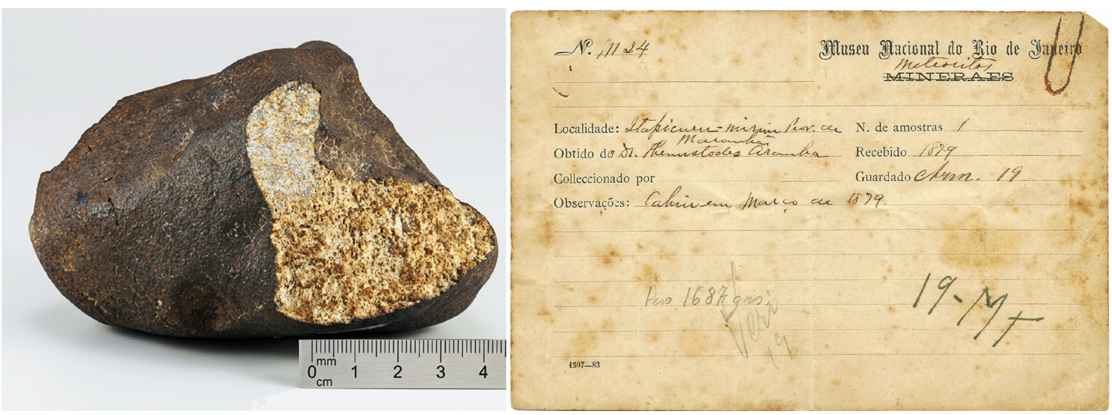

FIGURE 8 – Itapicuru meteorite. On the left, specimen with a mass of 1.2 kg belonging to the collection of the National Museum; current weight: 1.2 kg (credit: Elizabeth M. Zucolotto). On the right, handwritten file by O. Derby referring to the record of this meteorite in the collection of the National Museum.

only a fragment found buried at the foot of a tree, about two palms deep, held by a root that apparently prevented it from penetrating deeper. This fragment, about the size of an orange, was acquired by Pohlman for 5$000 réis. Divided into parts, one of them was handed over to the authorities and, by determination of the provincial president, sent to the National Museum through the Ministry of Agriculture.

Later, new information indicated that the phenomenon had probably occurred on September 26, 1873, and not in December, as initially supposed. This correction was based on the transcription of a news article published in the Zeitung von Porto Alegre, which described booms, detonations like artillery discharges and a prolonged noise moving from north to south under clear skies.

The full report is very relevant because it places the phenomenon in the colony of Leonerhof, 2.5 km from the city of São Leopoldo and about 27 km southwest of Santa Christina. This data displaces the geographic interpretation associated with the meteorite. The explicit reference to the localities of Santa Bárbara (Picada Santa Bárbara) and Leonerhof, in the vicinity of the former German Colony of São Leopoldo, clearly indicate that the event occurred in the metropolitan region of Porto Alegre, and not in the current municipality of Santa Bárbara, as cited by Gomes and Keil (1980).

Derby's analysis demonstrates not only rigor in the physical characterization of the material, but also critical attention to administrative, journalistic and testimonial documentation, articulating scientific data and historical sources. Furthermore, this case serves as testimony of perfect political and journalistic engagement for the Brazilian context of the 19th century.

According to Derby (1888), the National Museum had two fragments of this meteorite, one weighing 43.896 g and having a specific weight of 3.478 g/cm^3 (Figure 9) and the other, weighing 49.415 g and with a specific weight of 3.493 g/cm^3, offered to Princess Isabel and later incorporated into the collection of the Prince of Grão-Pará. Both fit together and are estimated to account for about a quarter of the original mass.

In addition to these two fragments, the National Museum had another mass, weighing 41.265 g, which appeared in the collections as coming from a fall on Ajuda Street in the city of Rio de Janeiro. However, according to Derby, it was probably a fragment of the Santa Barbara meteorite, since all efforts to obtain information about a meteorite from Rio de Janeiro would have been in vain and some of the Museum's employees had a vague memory that this fragment had been found stored in a house on Rua da Ajuda. As it had physical characteristics and density compatible with the specimens from Rio Grande do Sul, Derby inferred that it was Santa Bárbara itself.

Of all the specimens of the Santa Barbara meteorite, the National Museum did not keep any. One of the masses, weighing 41 g, was exchanged with the Field Museum of Natural History in

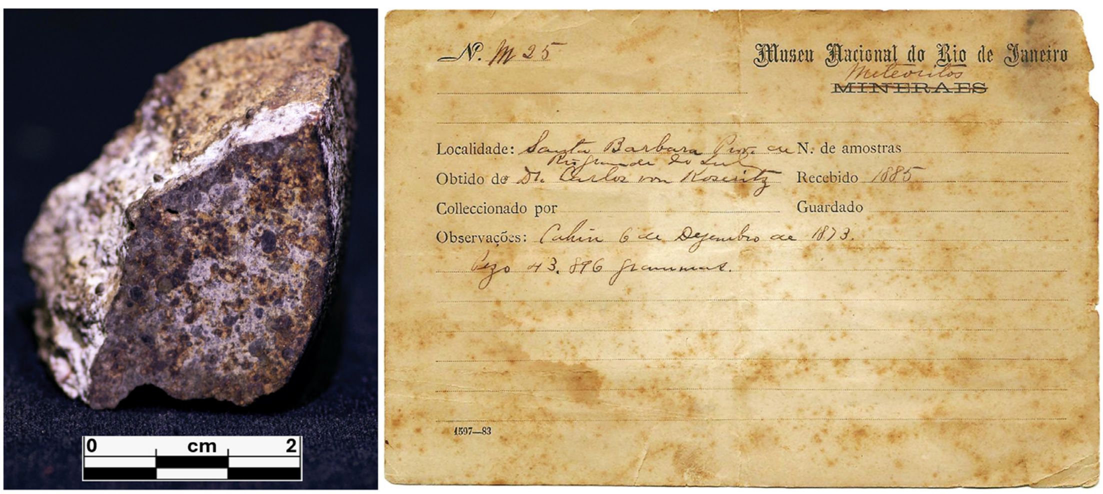

FIGURE 9 – On the left, the Santa Bárbara meteorite with a mass of 34.08 g exhibited at the Museum of Geosciences of the University of São Paulo (photo credit: Priscila de Cássia Silva). On the right, handwritten file by O. Derby referring to the record of this meteorite in the collection of the National Museum.

Chicago. A second, weighing 33g, was exchanged with the Monnig Meteorite Collection at Texas Christian University, Dallas, USA. The third mass was given to studies that led to the publication of the book "Brazilian Stone Meteorites" (Gomes and Keil, 1980) and, like the Minas Gerais meteorite, it did not return to the collection of the National Museum. This specimen is currently in the Museum of Geosciences of USP, in São Paulo. There are individual specimens in private collections, but historical data do not allow us to reliably associate them with the fall of the Santa Barbara meteorite.

9 THE ANGRA DOS REIS METEORITE

The Angra dos Reis meteorite occupies a prominent place in meteoritic science due to its unique mineralogical composition and unusual petrographic characteristics, which gave rise to the *angrite* class.

The news of his fall was communicated to Orville A. Derby by Dr. Joaquim Carlos Travassos, a physician residing in Rio de Janeiro and a native of Angra dos Reis. According to the report, in the last days of January 1869, at five o'clock in the morning, Travassos was in a boat, in front of Praia Grande de Angra, near the Church of Bonfim, when he observed the fall of a stone coming from the sky near the beach, in a place about two meters deep. The mass seemed to move from north to south, accompanied by some kind of smoke, without intense light or audible detonation. The exact date of the fall was not noted, but the doctor placed it between January 15 and 31, 1869, based on the memory of the recent birth of a daughter.

Dr. Travassos managed to recover two fragments with the help of slaves, who dived to look for them. The fracture surfaces suggested the existence of a third, unrecovered piece. One of the fragments was delivered to the judge of law of Angra, who passed it on to Dr. Ermilino Leão, responsible for forwarding it to the National Museum. The second fragment would have remained in Angra dos Reis, in the possession of Dr. Travassos' father-in-law. Derby reports: *"The other piece, as Dr. Travassos supposed, is still in Angra dos Reis in the possession of his father-in-law and, if this assumption is accurate, it is to be hoped that it will come to the museum someday"*. However, this other fragment has its whereabouts unknown to this day. At the same time, a meteorite with the name of Angra dos Reis was offered as a gift to Pope Leo XIII; however, it is a metallic meteorite that is thought to be the Pirapora meteorite.

The fragment incorporated into the National Museum originally weighed 446.5 g, later reduced to 344.5 g due to the collection of samples for study and exchange with institutions such as the Natural History Museum in Paris, the Natural History Museum in Vienna, the Field Museum of Natural History, the American Museum of Natural History, the Vatican Collection, among others (Zucolotto, 2006). The mass that was 270 g in the 1950s and 101 g at the end of the 1970s is now reduced to 66 g (Figure 10).

According to Derby's description, from a macroscopic point of view the outer surface has a black, glassy, glossy fusion crust. This crust exhibits delicate wrinkles that form a continuous network of small elevations, delimiting irregular cupuliform areas of a few square millimeters. Inside it, small circular perforations can be observed, interpreted as evidence of gaseous escape during the formation of the crust. Under adequate lighting, the glassy and slightly translucent nature of the crust, with a dark violet hue, can be perceived.

On the fracture surfaces, the rock reveals a friable grainy texture, with no visible free metal and dark brown color, punctuated by yellowish grains. Some fractures exhibit partially vitrified zones that extend 1 to 2 cm below the surface, indicating that the heat responsible for crustal formation has penetrated through natural cracks,

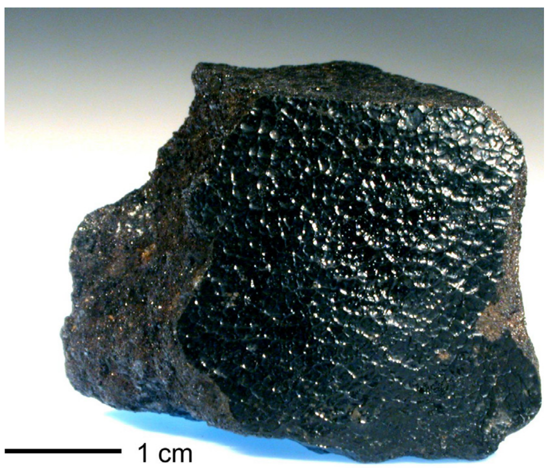

FIGURE 10 – Angra dos Reis meteorite. 66 g fragment from the collection of the National Museum (credit: E. M. Zucolotto).

initiating local melting processes in the most prominent portions.

Upon examining the material, Derby recognized that this meteorite was considerably different from all types of meteorites hitherto known. Because of this uniqueness, he consulted Professor Gustav Tschermak, from Vienna, who was willing to carry out a detailed mineralogical study. Ludwig and Tschermak (1887) established the then unique specimen from Angra as representative of a rare new type of meteorite, which was given the name *angrite*. According to this research, the specific weight of this rock varies between 3.43 and 3.47 g/cm3. The mineralogical composition is dominated by augite (93.28%), followed by olivine (5.45%) and magnetic pyrite (1.27%) (Figure 11). Both augite and olivine have vitreous inclusions. Associated with olivine, grains of a type of feldspar described by Tschermak in other meteorites and called *monticelite* ($CaMg(SiO_4)$) have been identified.

The global chemical analysis revealed high values of calcium and aluminum in the augitic fraction, proportions that the authors highlighted as the highest so far recognized in augite of meteoritic origin.

Such characteristics consolidated the Angra dos Reis meteorite as an example of remarkable singularity, defining a new and rare class within the meteoritic, of which only 67 specimens found on Earth are known. The angrite group currently occupies an important position for the understanding of primitive planetary differentiation.

10 THE MINAS GERAIS METEORITE

Derby (1888) records the existence of an unlabeled meteorite, found among the old collections of the National Museum, whose provenance would have been attributed to the province of Minas Geraes. About this copy, the author writes:

> *"An unlabeled meteorite of the same type as those of Macau, Itapicuru-mirim and Santa Bárbara was found unlabeled among the Museum's old collections, which, according to the vague memories of former employees of the house, is presumed to have come from the province of Minas Geraes (?).*
>
> *It weighs 1,224 grams and seems to have lost some 200 to 500 grams. The specific weight is 3.48 to 3.51. It is more coherent and lighter in color than the meteorites of Macao and Itapicuru-mirim, but it does not present another notable difference on superficial examination. These differences and that of the specific weight exclude the hypothesis that it is one of the stones of Macao."*

The case illustrates the documentary fragility of the Museum's historical collections: the attribution of the origin to Minas Gerais was based only on vague memories of former employees, with no record of collection, date of entry or context of finding. Unfortunately, this documentary fragility in museum collections persists to the present day.

Subsequently, a 370 g sample was exchanged with the Field Museum of Natural History, in Chicago, and other smaller fractions went to

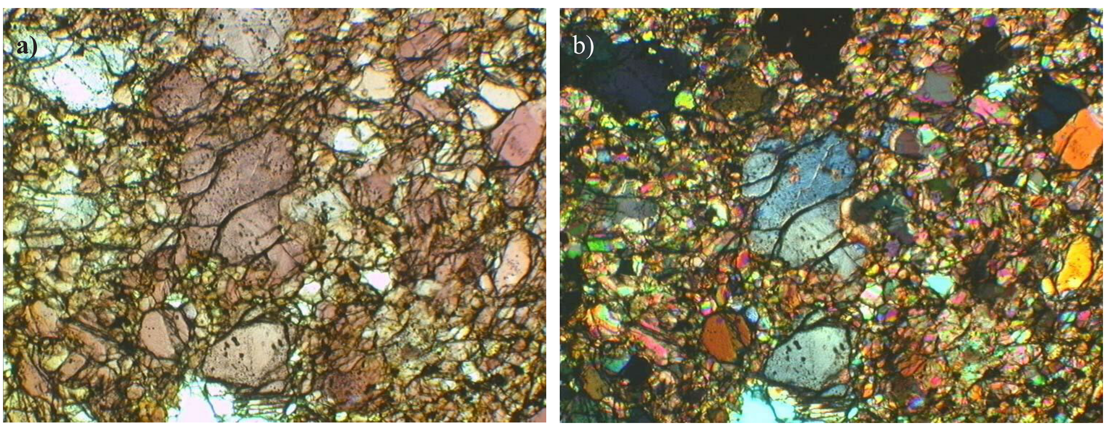

FIGURE 11 – Photomicrograph of a slide of Angra dos Reis under transmitted light (left) and cross-polarized (right). Large grains of phassaite are observed, which cover about 90% of the blade. Field width: 5 mm. (credit: E. M. Zucolotto).

different institutions. In the 1970s, the specimen then remaining in the National Museum, weighing 628 g, was loaned for the studies that resulted in the book "Brazilian Stone Meteorites" (Gomes and Keil, 1980). This specimen, however, did not return to the National Museum and is currently in the Museum of Geosciences of USP, in São Paulo (Figure 12).

11 "DOUBTFUL" METEORITES

Under the title of "doubtful meteorites", Derby (1888) gathered information about possible meteorites whose existence had been mentioned in documents, newspapers or official correspondence, but which had disappeared, or which could not be found again so that their origins could be established.

11.1 Ponta Grossa (PR)

Documents in the archive of the National Museum and in the library of Emperor Dom Pedro II mention an alleged meteorite from Campos Gerais, in the then province of Paraná.

In a letter dated December 4, 1867, Dr. Carlos Rath offered the Emperor a stone that he claimed had been colected in Ponta Grossa, in Mr. Ferreira's yard, in April 1846. The sample, with a declared weight of 11/4 pounds (~567 g), was sent to the National Museum accompanied by an opinion from Friar Camillo de Monserrate, who attested that the stone presented *"with evidence and in an incontestable way all the characteristics of the so-called meteorites or aerolithos"*.

The sample, unfortunately, was no longer in the Museum's collections. Derby ponders, however, that the evidence pointed to a real meteorite. The combination of varnished crust, brown hue, and feldspar appearance suggested affinity with the howardite or eucrite groups.

11.2 Curvello (MG)

More complex is the episode of Curvello, Minas Gerais. The news dates to April 11, 1833, when, according to an account published by the Danish naturalist Pedro Claussen (Claussen, 1841), a fireball with a long tail crossed the sky from SSW to NNE, splitting at the zenith and producing three detonations after 123 "pulsations".

A 3-ounce (28 g) fragment was reportedly collected and sent to the Museum of Rio de Janeiro, described in the catalog as "native iron." However, when asked by Professor Brezina of Vienna to provide additional information, Derby carefully examined the Minas Gerais collection incorporated into the collection, without being able to identify with certainty the piece in question.

The only existing iron sample weighed 218 g, diverging substantially from the three ounces mentioned by Claussen. In addition, when dissolved

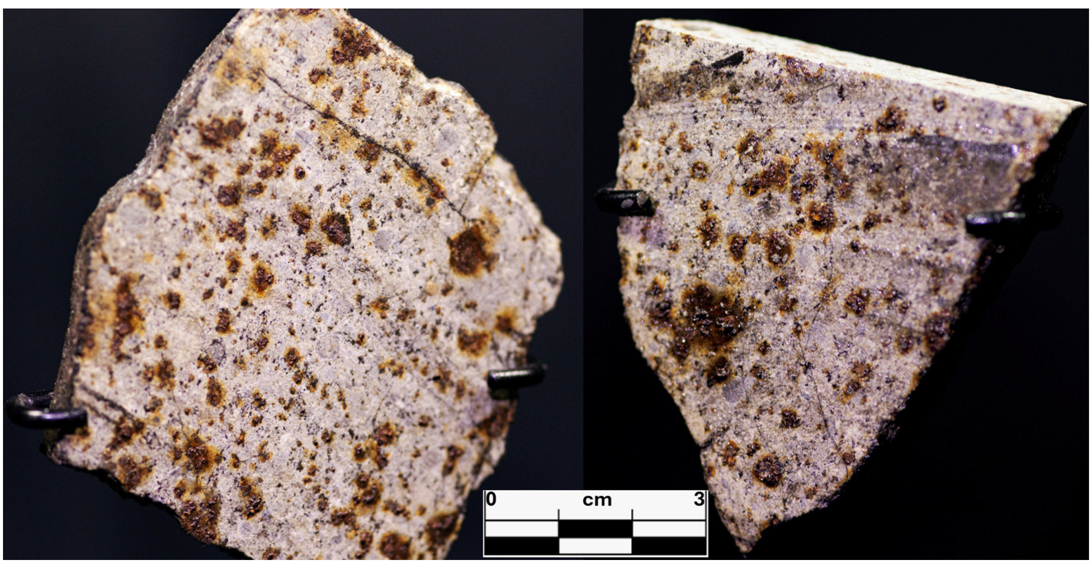

FIGURE 12 – Fragments of the Minas Gerais meteorite with masses of 19.42 and 2.44 g exhibited at the Museum of Geosciences of the University of São Paulo (photo credit: Priscila de Cássia Silva).

in acid, it left charcoal residues – unequivocal evidence of artificial origin. The discrepancy of weights in the later citations by Buchner and Brezina only amplified the uncertainty. For Derby, if Claussen had really obtained a fragment of the meteorite, it could no longer be located.

11.3 Córrego do Areado/Patos de Minas (MG)

Having learned of the existence of a supposed meteorite found near the village of Areado in the province of Minas, Derby took advantage of a trip in 1880 and found it in the house of Father José de Moraes, near the village of Carmo do Paranaíba. *"It was a mass of raw iron of roughly rectangular shape, weighing about 36 kilograms, having the appearance of a magnifying glass taken from the small forges of the common law process in the province of Minas".* The mass had been found 15 years before Derby's visit, in the slave quarters of a farm near the iron deposits of Areado. The assumption of being of meteoric origin was based on the absence of forgery in the region.

However, the fragment shown to Derby did not have nickel or Widmanstätten figures, typical characteristics of meteoritic irons. Because he was not convinced that it was a meteorite and was unable to transport the mass offered by the priest, Derby did not take it to the National Museum. This episode highlights Derby's cautious stance: not every isolated iron mass, no matter how suggestive it may seem, is a meteorite.

Many years later, a 32 kg metallic meteorite of semi-prismatic shape arrived at the Technological Institute of Belo Horizonte, reported to have supposedly come from a fall that occurred in 1925 on the banks of the Areado Stream in Patos de Minas, Minas Gerais (Figure 13). This meteorite was then described by Guimarães (1958) under the name Córrego do Areado. However, the meteorite showed signs that it had fallen long ago. There is, therefore, some coincidence in relation to the region, as well as references to masses with similar values. As it is a hexahedrite, a meteorite that is poorer in nickel and does not have Widmanstätten structures, it leads to believe that both Derby and Guimarães referred to the same meteorite.

Buchwald (1975), when dealing with this meteorite, considered that the find was not adequately characterized, including the fact that there were other watercourses with the same name as Areado. He then changed the name from Córrego do Areado to Patos de Minas, by which he is known today.

11.4 Curitiba (PR)

A piece arrived at the National Museum with a label in French describing it as a meteorite that fell on June 14, 1861, near Curitiba and was stored in a store. The morphology – one flat face with vacuoles and the other with lamellar crystals – clearly indicated a crucible melting product.

After verifying the absence of nickel, Derby considered the material to be of artificial origin, and further analysis was unnecessary. He recognized that, although it had remote meteoric origins, it had lost any scientific value after the fusion.

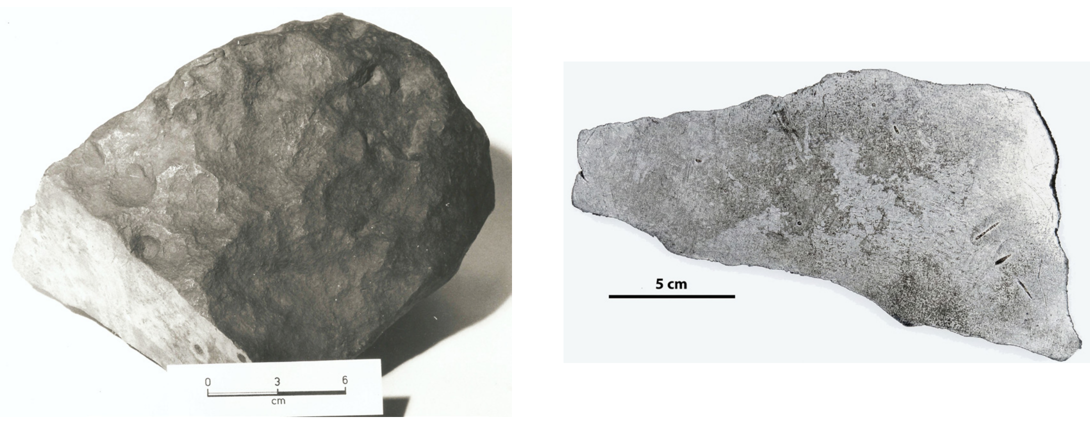

FIGURE 13 – Patos de Minas Meteorite (Areado Stream). On the left, part of the main mass, with a sub--rounded and flattened appearance, in accordance with Derby's description. On the right, a slice of the meteorite polished and attacked with nital, exhibiting spots characteristic of hexahedrite-type meteorites. Because they have a lower nickel content, hexahedrites do not develop the Widmanstätten structure typical of octahedrites, which is also in agreement with Derby's account. (credit: E. M. Zucolotto).

Derby concluded his report by saying *"Through people residing in Curitiba, it is being sought to ascertain if there really is reliable news of a meteorite on the mentioned date"* but does not provide additional information about the outcome of this case.

11.5 Pernambuco (PE)

About this supposed meteorite, Derby (1888) reports that *"The caricature newspaper "A América Illustrada" of Pernambuco published a table years ago with the couplet "On the subject of aerolite" which makes it presume that a meteorite had fallen around that time. Recently and casually finding the said newspaper, I had in vain searched through friends in that city, for news of the circumstance that inspired this picture that I mention here in the hope that some Pernambuco can still provide some information about it. The fragment of the newspaper that I found casually lining the wall of a house in Cabo-Frio, had no date, but it seems that it was from October 1882.*

11.6 Morro do Chapéu (BA)

Derby (1888) reports that *"In the catalogue of the Bahian exhibition of 1875, page 129, there is the following inscription: «Nº 49 – five meteorites found in Morro do Chapéo; exhibitor, the commission of Morro do Chapéo. No. 95 – Native iron from the same locality, the same exhibitor."* He concludes by saying that *"Nothing is known about the end of these samples, nor whether they are truly meteorites."*

11.7 Monte Alto (BA)

About this supposed meteorite, Derby (1888) reports: *"In a letter addressed to the director of the National Museum, dated October 1887, Rev. Father José Dorne, resident in the city of Bahia, communicated the existence of an alleged aerolite in the Serra de Monte Alto, located about three leagues from the homonymous locality. According to him, "many serious people" had assured him of the presence of a mass much greater than the Bendegó meteorite, claiming to be of the same nature.*

The correspondent himself, however, declares that he has not seen the object, limiting himself to transmitting information from third parties. As in so many other episodes of the Brazilian meteoritics, the news lacks material confirmation and technical description that allows any conclusive judgment.

The case remained doubtful for decades until, in 2007, paleontologist Douglas Riff recognized as a meteorite a piece that for many years served as a support for a gate of the Marcelino Neves Municipal School, in Palmas de Monte Alto (Carvalho et al., 2018; Zucolotto & Riff, 2009). Found around the 1950s, the specimen weighing about 98 kg is significantly smaller than the mass mentioned in nineteenth-century accounts. Even so, because it was located in the same mountain range indicated by Father José Dorme and recorded by Derby, it is plausible to suppose that it corresponds to the same find, leaving the possibility that the larger mass never existed or that it remains unknown.

12 THE CANYON DIABLO METEORITE

The Canyon Diablo meteorite was found in 1891 in Coconino County, Arizona, and named after the nearest post office then in existence. It is, in fact, a numerous set of fragments found in this region, which are attributed to a single body that originally would have been about 50 m in diameter and at least 100 thousand tons in mass. The fall of this meteorite has been dated to 49,000 years.

Despite the coexistence in the same region of the fragments of this meteorite and a crater with a diameter of 1.2 km and a maximum depth of 170 m (Figure 14), it was not believed at that time that the two were related. The crater had been interpreted as being of volcanic origin, the result of the explosion of gases and water vapor, but without the outflow of lava. This interpretation was due to studies carried out in 1891 by the then Chief Geologist of the United States Geological Survey, Grove Karl

FIGURE 14 – Meteor/Barringer Crater, Arizona (diameter: 1.2 km; depth: 170 m) (credit: Shane Torgerson, https://commons.wikimedia.org/wiki/File:Meteorcrater.jpg).

Gilbert. At that time, craters on the surface of the Moon were thought to be of volcanic origin and the existence of meteoritic impact craters on Earth had not yet been proven.

However, mining engineer Daniel M. Barringer offered a different interpretation of the crater's formation, attributing it to excavation resulting from the impact of a large metallic meteorite that would result in the fragments of the Canyon Diablo (Barringer, 1964). Using his own financial resources, obtained from the exploration of silver and gold in Arizona, and based on the assumption that the huge meteorite, which he estimated to be about 10 million tons, would have penetrated the Earth's surface and was buried below the floor of the Meteor Crater, Barringer began exploratory drilling activities in 1903 to find the meteorite and extract the metal for commercial purposes. Because he did not know the physical conditions of a large impact, he could not have known that most of the meteorite would have fragmented and vaporized on impact, leaving only smaller fragments. Some of these smaller fragments were found inside the crater (Figure 15), but most were thrown out of it and scattered around the surrounding region. Barringer's drillings reached 419 m deep below the crater floor and cost millions of dollars, without ever finding the great mass of the meteorite. After 27 years of fruitless efforts and having exhausted financial resources, Barringer gave up, but eventually obtained the concession for the area where the crater is located, currently known by the names of Meteor Crater and Barringer Crater. Today it is a tourist attraction open to the public upon admission payment, with a Visitor Center and a Space Museum. It exhibits samples of the Canyon Diablo meteorite, including the largest known fragment weighing 639 kg (Figure 16), nicknamed the "Holsinger meteorite". The crater is also used as a training site for astronaut classes from NASA and other space agencies.

At the time Derby developed his studies of this meteorite, the hypothesis of the meteoritic origin of the Meteor Crater and its relationship to the Canyon Diablo had not yet been established. However, over the years and with the evolution of scientific knowledge, both were proven, including the subsequent discovery of other meteoritic craters, such as the Odessa crater in Texas (Barringer, 1928; Spencer, 1933).

Derby's interest in the Canyon Diablo meteorite, a coarse IAB octahedrite-type siderite, was aroused by the fact that it contained "high-hardness particles", described by Foote (1891), which were suspected to be micro-diamonds. These were in fact later proven by Ksanda and Henderson (1939) using X-ray diffraction (XRD). In the article in which he analyzes, in detail, the physical,

FIGURE 15 – Oxidized fragment of the Cañon Diablo meteorite embedded in the wall of the inner rim of the Meteor Crater (in the photo, Dr. David A. Kring indicates the exact location of the fragment). There are reports that such fragments were relatively common, but that, over the years, they were illegally removed from the site by meteorite hunters. The crater is a private property in which the collection of specimens is expressly prohibited. (photo credit: Alvaro P. Crósta).

FIGURE 16 – Holsinger fragment of the Cañon Diablo meteorite, weighing 639 kg, on display at the Meteor Crater Visitor Center and Museum (photo credit: Alvaro P. Crósta).

mineralogical and chemical characteristics of the Canyon Diablo meteorite and compares them with those of the Bendegó (Derby 1895a, b), he states *"... this investigation was conducted primarily with the aim of verifying the existence of diamonds in the Cañon Diablo meteorite."* However, he found nothing to indicate the presence of diamonds, or any other forms of free carbon, attributing the failure to the possibility that Foote had made a mistake in analyzing the residue of the meteorite's dissolution. However, later analyses, mainly using XRD, proved not only the existence of micro-diamonds, but also of other forms of free carbon, such as graphite and lonsdaleite (Ksanda and Henderson, 1939).

It is important to highlight that the results mentioned by Derby for the Canyon Diablo, using analytical techniques available at the time, are relatively close to the results published in the current literature. An example is the sum value of Ni and Co obtained by him, of 8.252%, compared to the current indicated value of 7.56%. The chemical analyses used by Derby were carried out by Guilherme Florence, one of his most frequent collaborators (Derby, 1895a).

13 THE LEGACY

More than a century later, Derby remains a key figure in the Brazilian geological history. His work with meteorites laid the foundations of Brazilian meteorite science. His collections, methods, and descriptions have survived time as well as tragedies, including the 2018 fire at the National Museum. Whenever a Brazilian meteorite is cataloged, studied or exhibited, there is a direct trace of the pioneering work that it developed almost a century and a half ago.

Derby played a decisive role in the founding of geological mapping services and in the formation of scientific collections, including meteorites. Upon arriving at the National Museum, he noticed that there were some meteorites among the specimens that made up the Werner Collection, a set of minerals and rocks originally organized by scientist Abraham Gottlob Werner, from the Freiberg School of Mines, in Germany, which later passed into the hands of the Portuguese royal family. It is noted that this occurred even before the extraterrestrial origin of meteorites was established. The collection came to Brazil in 1808 along with the Portuguese royal family and, in 1819, it was the first collection to be part of the collection of the National Museum.

In the searches for the history of the National Museum's meteorite collection, the first author of this article (M.E. Zucolotto) found some original cards from the Werner collection. She photographed them before they were lost during the National Museum fire in September 2018. Although the card set was not complete, it is known that there were at least 26 meteorite samples in the collection. In addition to the 7 Brazilian meteorites mentioned by Derby, the collection included several foreign meteorites that came even before the exchanges for the slices of the Bendegó. Figure 17 shows some cards made by Derby for one of these meteorites, the Pallas Iron (Krasnojarsk) with his own handwriting. In the Appendix to this article, the images of some of the files handwritten by Derby are presented. Unfortunately, ehe originals of these cards were destroyed in the 2018 fire, some of them along with the respective copies.

Orville Derby's work inspired generations of Brazilian geologists and shaped the early development of planetary geology, even though that term did not exist at the time. Thanks, in part, to his efforts, Brazil entered the international map of geology, paleontology, and also meteoritics.

Regarding the study of meteorites, especially those found in Brazil, Derby pointed out, in the conclusion of his "Note on Brazilian Meteorites", of 1888, that: *"In addition to some positive information, it contains a lot of vagueness, due to the regrettable negligence that has occurred in Brazil, in relation to the very interesting subject of meteorites, I dare to make an appeal to everyone who can give news or samples of meteorites to direct their information to the director of the 3rd section of the National Museum. Journalists and especially those from the interior can provide a very relevant service to science, seeking to give the most detailed and accurate information possible about any phenomena of the discovery or fall of meteorites that happened in their vicinity, certain that they will thus enrich their columns with news of real importance."*

This passage, apparently administrative, is a true call to the development of the embryonic Brazilian meteoritic science and remains valid today. It transforms the public into potential collaborators and, in a modern way, establishes a network of evidence that goes beyond the cabinet: provincial archives, local newspapers, memories of residents, shipping labels, reports of expeditions

FIGURE 17 – On the left, the identification card of the Pallas Iron meteorite (Krasnojarsk) written by Derby and, on the right, the historical description in the record book of the Werner collection. In the lower left, photographs of three of the four original samples that were part of the collection brought by the Portuguese Court. This specimen is historically relevant for being the first meteorite officially recognized by science. (credit: E. M. Zucolotto).

and inventories. By making this appeal, Derby initiated a way of working that combines the three pillars of the University (teaching, research and extension). These factors constitute the backbone of meteoritics in Brazil to this day: collection survey, documentary reconstruction, and public engagement to recover new meteorites and fill gaps in knowledge.

His legacy is, in every sense, that of an extraordinary pioneer and a talented scientist, who dedicated his life to a country he chose and which, in many ways, he helped to build scientifically.

14 FINAL REMARKS

The trajectory of Orville Adelbert Derby reveals the importance of the individual performance of a visionary scientist in the construction of scientific institutions. More than a field researcher, Derby was an articulator between science, the State and society, playing a fundamental role in the organization of geological knowledge and in the formation of the scientific bases of Brazilian geology.

Derby was the first to carry out detailed studies of the Bendegó, the largest meteorite found in Brazil. His research was systematic and meticulous, standing out for its structural, mineralogical and chemical description. Published in 1895, the article represents one of the first studies to follow a rigorous scientific approach to meteoritics, using advanced methods for the time. Derby classified the meteorite and presented analyses that contributed to the understanding of its composition and characteristics. The study of Bendegó not only enriched science but also influenced culture and science education in Brazil, inspiring future generations of geologists and scientists to explore and value the country's natural heritage.

The method of cataloguing and conserving meteorites developed by Derby is still used to this day. In addition, he emphasized the importance of recording new falls and findings, mobilizing the scientific community and the public to participate in this effort, pioneering the introduction of what is known today as "citizen science."

The pioneering studies on meteorites allow Orville A. Derby, in addition to being considered

"The Father of Geology in Brazil", to also be called "The Pioneer of Meteoritics in Brazil", as suggested by Walter da Silva Curvello (1915-1999), a researcher at the National Museum, and a expert in meteorites.

Perhaps this is the most appropriate way to celebrate the memory and legacy of Orville A. Derby: a man who, by studying rocks from space, became part of the constellation of Brazilian science. His legacy remains central to understanding the history of geosciences in the country.

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