



Citation: J.H. Maar (2018) Almost a Discovery – Henri Gorceix, the Mining School of Ouro Preto, the Monazite Sand of Bahia and the Chemistry of Didymium. *Substantia* 2(2): 27-41. doi: 10.13128/substantia-59

Copyright: © 2018 J.H. Maar. This is an open access, peer-reviewed article published by Firenze University Press (<http://www.fupress.com/substantia>) and distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

Feature Article

Almost a Discovery – Henri Gorceix, the Mining School of Ouro Preto, the Monazite Sand of Bahia and the Chemistry of Didymium

JUERGEN HEINRICH MAAR

Retired, Chemistry Department, Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil

E-mail: jhmaar@yahoo.com.br

Abstract. The chemical history of the supposed element didymium may well be characterised as a case of collecting empirical data in a period of “normal” science. But this element’s history also reveals little known facts of the history of chemistry in South America, such as the exploration and smuggling of monazite sands, and the difficult beginnings of scientific research and higher education in Brazil. Didymium is also a curious case: even after it was shown to be a mixture, it continued to be regarded as an element. This fact alone raises questions about the adequacy of scientific methodology at the time. In this paper, we consider the history of didymium, and determine how this history’s different facts and stories, set in Brazil’s rather unique historical and scientific context, intertwine thanks to the work of Claude Henri Gorceix.

Keywords. History of didymium, Claude Henri Gorceix, Ouro Preto Mining School, monazite sands.

It is absolutely necessary to study the facts, to observe phenomena.

Henri Gorceix

Whatever the aim Man establishes for himself to reach, whatever the idea he chooses to develop, they cause a great feeling of pleasure when he succeeds, a great happiness when turned reality.¹

Henri Gorceix

TO DISCOVER AN ELEMENT

For the layman, more than for the scientist, the discovery of a new element marks a great event in the history of chemistry. Indeed, discoveries or isolations of elements signify a great scientific advance, even from a theoretical point of view: the discovery of oxygen, of the first noble gas, of the elements foreseen by Mendeleev in his Periodic System. The discovery of an

element is also one of the most “democratic” aspects of the history of chemistry. While some elements were discovered by the most respected scientific authorities – Scheele, Berzelius, Klaproth, Vauquelin, Wollaston, Davy – others were found by diligent and industrious practitioners of a “normal” science (in *Kuhnian* terminology) – Mosander or Marignac. Some of these elements perpetuate the names of their discoverers: Gregor and titanium (1791), Courtois and iodine (1811), Balard and bromine (1826).²

The discovery, isolation and physical and chemical characterisations of rare earth elements constitute an apparently unbounded harvest for historians of chemistry. In this endeavor, the marvels of science and the aesthetic pleasure of discovery are painted in the best possible light. Isolation and perfect characterization are necessary requirements for defining a “discovery” of a new element. In the case of the elements of the rare earths, all were derived from two pioneering discoveries: Gadolin’s yttria (1794) and Berzelius’ and Klaproth’s ceria (1803). Experimental problems were, however, particularly difficult: their physical and chemical properties are so similar that chemical separations proved extremely burdensome and laborious (thousands of recrystallizations are often required). Such difficulties led chemical annals to occasionally record the same discovery twice or announce discoveries of nonexistent ‘elements’ that were, in reality, mixtures or already known elements. Many such situations are discussed in Karpenko’s paper on ‘spurious elements’.³

For most of the 19th century, chemistry lacked a theoretical framework that could guide a targeted or systematic search for new elements. Experimental complexity was later reduced by the introduction of a new analytical tool – spectroscopy (Bunsen, Kirchhoff, 1859). But the spectra of alleged newly discovered elements can easily be mistaken for either combinations of the spectra of already known elements or an impure element. For this reason, many ‘discoveries’ of new elements in the realm of rare earths were made, much to the perplexity of the scientific community. In 1880, the anonymous editor of the *Manufacturer and Builder* observed that the chemists of recent decades had discovered an enormous number of new ‘elements’. But, even if one only considers the last few years, the number of ‘discoveries’ and accumulation of unconfirmed empirical facts was simply beyond belief.⁴ The editor correctly identified why: chemists considered evidence from spectroscopic analyses sufficient to warrant the report of a new discovery, ignoring that such evidence could well be a mixture of rare earth elements, or a re-discovery. The desire and haste to claim priority over a new discovery sometimes

prevented the discoverer from carefully isolating the new element from mixtures of elements or already known elements.

The discoveries of only three elements have been associated with scientific practice in Latin America: platinum – discovered in gold deposits in Colombia by the Spaniard Antonio de Ulloa (1716-1795); vanadium – discovered as “eritrônio” in a lead mineral from Zimapán (Mexico) by the Spanish mineralogist Andrés Manuel del Río (1764-1849), professor at the *Real Seminario de Minería* in Mexico; and tungsten, whose Spanish discoverers Fausto de Elhuyar (1755-1833) and Juan José de Elhuyar (1754-1796) were later key personalities in the scientific communities of Mexico and Colombia, respectively.

In this paper, we will shed light on the little-known aspects of two stories that are intertwined by the works of an important figure within the history of chemistry in South America: the French mineralogist and chemist Henri Gorceix (1842-1919). The first of these stories is the foundation of the Mining School of Ouro Preto, where Gorceix acted as director for several years. The second is the curious case of the didymium (Mosander, 1841), a supposed rare earth element that continued to be the subject of much research – especially at the chemical laboratory of the Mining School of Ouro Preto – even after it had been shown to be a mixture of neodymium and praseodymium, and not an element after all.⁵

THE MINING SCHOOL OF OURO PRETO

In contrast to Hispanic America, where the first universities were founded in the 16th century, Portuguese America was only granted access to higher education beginning in the 19th century – unless we consider the Hispanic universities as mere colleges and some of the Luso American institutions, such as the Jesuit College in Salvador (1557), the *Seminario* in Olinda (1800)⁶, and the military School of Fortifications in Rio de Janeiro (1792) as institutions of higher learning.⁷

The transfer of the Portuguese royal family from the capital Lisbon to Rio de Janeiro (1808) brought freedom and favoured the growth of Brazil’s practical and applied sciences, which evolved in line with the pragmatism established by the Marquis de Pombal (1699-1782) at the University of Coimbra. But it was only Brazil’s political Independence (1822) which enabled the foundation of the first faculties *stricto sensu*: the law schools in São Paulo and in Olinda (1827), the medical schools in Rio de Janeiro and Bahia (1832), pharmacy courses in Rio de Janeiro (1832), Bahia (1832) and Ouro Preto (1835), and



Figure 1. Emeric Marcier (1916-1990), “Ouro Preto”, 1952. Oil on canvas, 64 x 90 cm. Museu de Arte de Santa Catarina/MASC, Florianópolis, Brazil.

the polytechnical school in Rio de Janeiro (1874), which was separated as institution from the *Escola Central* (1848), successor of the military school and a cradle of positivist thinking in Brazil.

These institutions created an intellectual elite in Brazil and provided higher level education – but only in a practical and pragmatic sense. Proper scientific research in Brazil was the odd exception, not the rule, and Brazilian universities were created as predominantly anachronistic institutions.⁸ In this context, the Mining School of Ouro Preto occupies a position entirely *sui generis*. Since its conception and foundation, the school’s day-to-day life involved not only teaching, but also much international-level research in its first decades of existence.

According to S. Figueirôa, the first proposal for the creation of a mining school in Brazil was made in 1804 by Manuel Ferreira da Câmara (1764-1835), who took his *Alma Mater*, the Mining School of Freiberg as a model.⁹ The first attempt to create a mining school in Ouro Preto, Minas Gerais, dates back to 1832, during the period of the *Regência* – which governed Brazil from the abdication of Pedro I (1831) until the majority of Pedro II (1840). But why Ouro Preto?

Ouro Preto was chosen to host a new mining school thanks in great part to the efforts of Bernardo Pereira de Vasconcelos (1795-1850), who argued before the Brazilian Parliament for a law able to facilitate the economic recovery of Minas Gerais, which had been stagnant since 1780. This law was also meant to compensate for the fact that the province had received none of the schools created after Brazilian independence. But the law would only be made a reality 43 years later. Located at the center of

a region rich in ores and geological interest, Ouro Preto proved an obvious choice for a mining school. Potosi, in Bolivia, centralizing immense silver ore extraction, hosted since 1756 the first Mining School of the Americas, perhaps the first worldwide.¹⁰

After 1699, when the adventurer Antonio Dias discovered the first gold deposits around what is now Ouro Preto, the original village grew very quickly. It became a municipality in 1711 and was suggestively named Vila Rica (Rich Village); in 1720 the village became the capital of the new captaincy of Minas Gerais. During the 18th century, Vila Rica was responsible for most of the Americas’ gold production, which is reflected in the rich religious and profane architecture preserved to our days (included by UNESCO in the World Heritage in 1980), as well as a rich literary and artistic activity. A timid reflex of the Enlightenment can also be detected in a movement for political emancipation in 1789 in Ouro Preto, which was the capital city of the Province and State of Minas Gerais until 1897.

The Mining School of Ouro Preto was finally founded in 1875, during Alfredo Correia de Oliveira’s (1835-1919) tenure as minister of the empire. A personal decision, almost an imposition, of Emperor Pedro II, in the words of the historian José Murilo de Carvalho, “*the creation of the School was, after all, an act of political will, directed in great part by ideological rather than economic reasons*”¹¹. In a nation with a slave-based society and an economy based on agriculture and export with “*a very incipient industrial activity*”, there was no real need to train geologists or mining engineers. The country had no tradition of geological or mineralogical research. It is therefore difficult to imagine the creation of the Mining School as a requirement mandated by society, the lower classes, or even as a necessary step for the country’s economic, social and scientific development. Pedro II (1825-1891), constitutional monarch at the tender age of 15, was educated by his tutors, José Bonifácio de Andrada e Silva (1763-1838), the “patriarch of independence”, and the Marquis de Itanhaém, Manuel Inácio de Andrade (1782-1867), mentors responsible for awakening, besides his ever mentioned interests in literature and arts, a strong interest in science, particularly chemistry.¹² There are well preserved notes from Pedro II on Mendeleev’s periodic system (the evolution of which he documented through scientific journals), and on scientific subjects he personally taught his daughters. During his trips to Europe, the emperor visited many chemists: Chevreul, Liebig, Berthelot, Pasteur, Kelvin, van’t Hoff. The emperor was also a member of the Royal Society and of the Academies of Paris, Berlin, St. Petersburg and Munich.¹³ We shall not occupy ourselves with well-known contro-



Figure 2. Claude Henri Gorceix (1842-1919). Lithography by unknown artist. (courtesy Oesper Collection for the History of Chemistry, University of Cincinnati).

versies surrounding his lack of commitment to matters of State in favour of his pursuit of personal interests¹⁴ – matters possibly made worse by the longevity of his reign. We will, however, focus on his interest in science.

On his second voyage to Europe (1870/1871), Pedro II visited the Paris Academy (he would be elected a member in 1875), and upon his return, he invited Gabriel Auguste Daubr e (1814-1896), a former student of the  cole Polytechnique and then director of the Mining School in Paris, to visit Brazil – not only to research our mineral kingdom, but to help with the foundation of a mining school. Daubr e had no interest in leaving Europe, and suggested Claude Henri Gorceix for this task. As we will see, Gorceix was the perfect man, in all respects, for this work. A sincere friendship linked Gorceix and the emperor, as demonstrated by the surviving, prolific correspondence between them. The emperor and Empress Teresa Cristina (1822-1889) became godparents to Gorceix’s daughter, C cile Pierrere Th r se Gorceix (Professor Christiano Barbosa da Silva would later say that Gorceix’s “first daughter was the School of Mines”).

CLAUDE HENRI GORCEIX (1842-1919)

Several foreign scientists exerted a long-lasting influence on the evolution of chemistry in Brazil. We may begin by remembering the Italian general Carlos Ant nio Napion (1757-1814), professor of chemistry at the Military Academy, or the Frenchman F lix d’Arcet (1814-1847), who attempted to produce sulfuric acid in Rio de Janeiro but died in a laboratory fire. Those who had the most enduring influence on Brazilian chemistry were the German phytochemist Theodor Peckoldt (1822-1912), pharmacist of the emperor, and analyst Henri Gorceix, a pioneer of geochemistry in Brazil.

Claude Henri Gorceix was born on October 19th, 1842, in the small village of Saint-Denis-des-Murs, district of St. L onard, Department of Haute-Vienne (which is also the native region of Gay-Lussac, a distant relative of Gorceix) and fathered by Antoine Gorceix and C cile-Val rie Beure la Mareille.¹⁵ Gorceix concluded his studies at the *Lyc es* in Limoges and Douai, graduated in 1866 at the  cole Normale, and obtained a diploma of a “Generalist in Physical Sciences and Mathematics”. Gorceix lectured at the French School in Athens while exploring the geology and mineralogy of Greece. Daubr e found him in Athens after Pedro II’s invitation, and in March 1874, Gorceix signed a contract with the Brazilian government at the Brazilian embassy in Paris. The contract mandated he “to organize teaching of mineralogy and geology in Brazil”. Article 12 of the contract states, *ipsis litteris*: “Mr. Gorceix promises to go to Rio de Janeiro, at the services of the Imperial Government to organize the teaching of Mineralogy and Geology”. Resolute, severe and ill-tempered, rough and rude according to contemporaries, and arrogant in the opinion of S. Figueir a¹⁶, Gorceix was a man tailored to his new functions: teaching and research in mineralogy and geology. Multiple administrative and bureaucratic difficulties also awaited him – not to mention envy, enmity, unfair sponsorship and competition, lack of recognition and understanding.

While still in Europe, Gorceix organized equipment and materials for teaching and laboratory activities. After the School was installed, he had to hire and engage teachers, assistants and other staff members, as well as ascertain financial assistance for poor students arriving from other provinces. About the installation of the laboratory, Dutra comments:

For us today it is practically impossible to evaluate the immense difficulties associated with the installation and maintenance of a chemical laboratory in the tropics at the end of the 19th century. How was it possible to find in Europe and take to Ouro Preto the necessary chemicals,

glassware, stoves, distillation apparatus, equipment for preparing samples, and all kinds of paraphernalia? How to hire skilled labour necessary for scientific and technical activities? [...]. We can affirm with certainty that during many and many years the laboratory supplied the incipient demand for analyses, in a country just beginning to know its immense mineral possibilities, and also that the laboratory created a basis for future development of geochemistry in our country.¹⁷

With respect to equipment, the laboratory owned a small spectroscope (a detail important for our discussion) that may have been considered a novelty in laboratories and was certainly a rarity in Latin America.

In July 1874, Gorceix arrived in Rio de Janeiro to a country that lacked any tradition in mineralogy and geology. Once there, he was tasked with organizing teaching and research *ex nihilo*. Brazil's supposed and often hailed mineral richness is in great part a myth.¹⁸ Geologist Daniel Atêncio of São Paulo University notes that of more than 5000 mineral species known today, only 65 are native to Brazil (23 of them discovered by Atêncio himself). The first to be discovered was chrysoberyl (BeAl_2O_4), described in 1789 by Christian August S. Hoffmann (1760-1814) and Dietrich Ludwig Karsten (1768-1810), both students of Abraham Werner in Freiberg. Chrysoberyl was analyzed by Martin H. Klaproth (1795, before characterization of beryllium as an element). José Bonifácio de Andrada e Silva (1763-1838), also a former student at Freiberg and discoverer of several new mineral species in Scandinavia (1799/1801), could have contributed to the creation of a Brazilian mineralogical tradition, but he instead devoted himself exclusively to the cause of Brazilian political independence.

Gorceix's first assignment in Brazil was a visit to the Province of Rio Grande Sul with the botanist Ladislau Neto (1838-1894), director of the National Museum. Near the end of the same year, Gorceix travelled to Minas Gerais to determine the location of the Mining School. He opted for Ouro Preto. In the midst of 1875, he presented his proposals for the School, which included his "teaching philosophy", to the governor. Finally, on October 12th, 1876, the Mining School of Ouro Preto was formally established. Gorceix was named the director (until 1891) and was responsible for various disciplines.

With the fall of the monarchy and the proclamation of a Republic in 1889, Gorceix and the school lost their great protector, Pedro II. In the face of this new political context, Gorceix departed as director of the school in 1891 and named Professor Archias Medrado (1851-1906) as *interim* director. Gorceix returned to France, but his long absence made it difficult for him to return to aca-

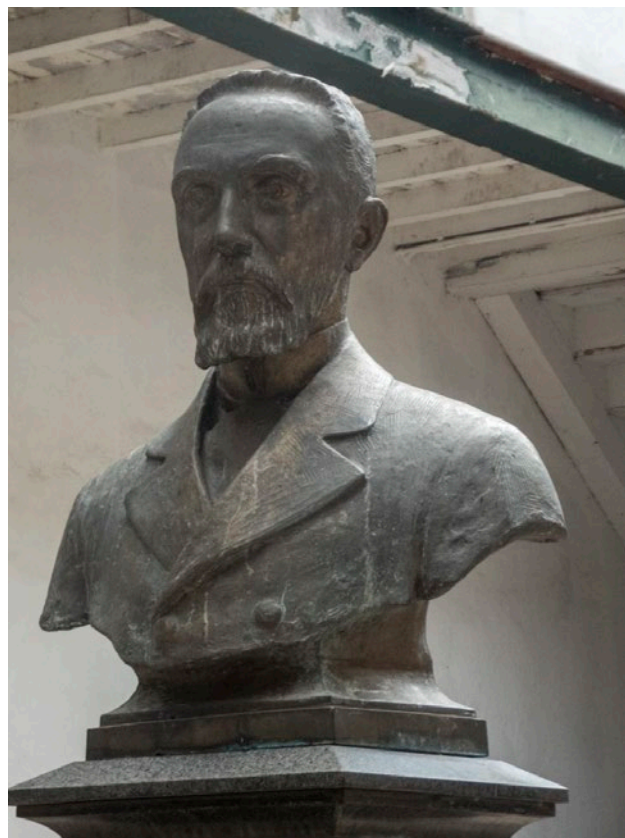


Figure 3. Bust of Henri Gorceix by an unknown sculptor in the inner yard of the former *Escola de Minas*, erected 1926 at the 50th anniversary of the Mining School, copyright and photograph by René & Peter van der Krogt, Delft, Netherlands. (courtesy René & Peter van der Krogt, Delft).

demical and scientific activities. So, instead, he decided to finish his research career and engage in politics. He became mayor of Le Mont par Bujaleuf. Gorceix only returned once to Brazil, in 1896, when he was invited as a teaching consultant. He died in Limoges at September 6th, 1919. In 1926, on the 50th anniversary of the School, a bronze bust was erected in the internal yard of the building. In 1970, his remains were transferred to the *Mausoléu Gorceix* in Ouro Preto.

Besides his continuous efforts to ensure the survival and quality of the School, several examples of his own scientific research were published during his time in Ouro Preto, including analyses of minerals and the discovery of xenotime-Y (YPO_4). These research papers were published in part in the journal he founded in 1881, *Anais da Escola de Minas* (since 1936 *Revista da Escola de Minas*, and since 2016 *International Journal of Engineering*), and also in part in the *Comptes Rendus* of the French Academy and in the *Bulletin de la Société*

Minéralogique de France. Gorceix was responsible for the section “Geology in Brazil” at universal expositions such as the *Exposition Universelle de Paris* (1889) and the South American Exposition in Berlin (1886).¹⁹

THE MINING SCHOOL OF OURO PRETO. CUM
MENTE ET MALLEO

Once the location of Ouro Preto had been selected, the Mining School was installed in the old Governor’s Palace, a partially fortified building erected in 1741 under the orders of Governor Gomes Freire de Andrade (1685-1763). The building shares a location with the former *Casa de Fundação*, designed by Portuguese architect Manuel Francisco Lisboa (17...-1767) on the basis of a project by general and military engineer José Fernandes Pinto Alpoim (1700-1765), an important figure in the development of Brazilian mathematics.²⁰

In Ouro Preto, Gorceix had to choose between two models: the Paris Mining School and the Saint Etienne Mining School. He was also, of course, influenced by his own course at the *École Normale*.²¹ Practical reasons led him to choose the St. Etienne model, which proved easier to adapt to local conditions. Gorceix’s project differed substantially from all other higher education courses in Imperial Brazil. Murilo de Carvalho lists the proposed facets of Gorceix’s institution: free-of-charge education, full time classes (including Saturdays and Sundays) for students and teachers, a ten-month long school term (seven months was the norm in Brazil) followed by two months of fieldwork, valuation of creativity and laboratory work, entrance examinations and frequent tests throughout the year, limited enrollments, grants for qualified students (for further studies in Europe), and financial assistance to students in need.²²

In Gorceix’s own words:

*Time for frivolous discussions about concepts and theories, simple speculations of the mind, a legacy from the Middle Ages and abandoned by the Old World since a long time, are over [...] mines and metallurgical plants will be the best books in our libraries.*²³

Gorceix’s project was not only innovative, but also almost an affront to Brazilian academic traditions. The project was submitted to the appreciation of a commission of the Rio de Janeiro Polytechnic School, and although approval was granted in the end, many sharp criticisms arose, marking the beginning of a famous rivalry between the two schools.

The approval of his plans confirms Gorceix’s political strength during the imperial period. Gorceix

defeated the arguments of influential people, including the Viscount of Rio Branco, José Maria da Silva Paranhos (1819-1880), who was a former Prime-Minister (1871/1875) and very close to the Polytechnic, where he served as dean and professor. Gorceix’s plan remained in effect, with minor adjustments, until 1893 – substantial revisions occurred only in 1936, when the School became part of the *Universidade do Brasil*. Since 1969, the School has been part of the Federal University of Ouro Preto.

It proved difficult to attract teachers and students to Ouro Preto. Although a provincial capital, the town was still relatively small (circa 12.500 inhabitants in 1872). Ouro Preto was also far from Rio de Janeiro, and the school’s admission examinations and coursework itself were rigorous (at least compared to the country’s poor secondary schooling). Graduates also faced poor prospects when searching for work in Brazil.²⁴

For the disciplines of physics, chemistry, mathematics, geology, mineralogy, foreign teachers were hired: Armand de Paul Bovet, Arthur Charles Thiré (1853-1924), Paul Ferrand (1855-1895); Brazilian instructors included Archias Medrado (1851-1906), Leônidas Botelho Damásio, and Francisco van Erven (1851-1936).²⁵ S. Figueirôa highlights that Gorceix’s letters expose his contempt for Brazilian teachers, who in his judgement were bad teachers teaching bad students.

Brazil’s general political and intellectual context must be considered when discussing the importance of the Mining School. Unlike what occurred at the Polytechnical and Medical schools in Rio de Janeiro, Positivism had no influence in Ouro Preto. Murilo de Carvalho describes Gorceix as a Catholic, and his fellows as materialists or evolutionists.²⁶ Provincial and isolated, Ouro Preto was the right place for study and research: students and teachers interacted more than in other schools, and both remained longer at the school, the principal point of social life in the city. Student life was much different from other schools, and interest in the nation’s economic and political future led to strong nationalist thought. Many former students ascended to high posts in science, technology and government.

Carvalho observes that “*it was essential for the ‘Gorceix spirit’ the concern in translating scientific knowledge in developmental policies*”. Similarly, in 1970, Djalma Guimarães (1894-1973), pioneer of Geochemistry and former Ouro Preto student, said:

Probably former students of the School of Mines exercised a great influence during the first two decades of this century, when political context was not yet prepared to discuss issues related to scientific and technological knowledge. Calógeras,²⁷ Pires do Rio,²⁸ Francisco de Sá,²⁹ and other

*eminent former students of the Ouro Preto Mining School entered the political scenario armed with objective knowledge of our natural resources [...].*³⁰

However, the State government assigned the planning and supervision of construction of the new capital Belo Horizonte (1897) to engineer Aarão Reis (1853-1936), a Rio de Janeiro Polytechnic graduate. Orville Adalbert Derby (1851-1915), an American geologist active in Brazil, highlighted the quality of research done in Ouro Preto and its international recognition in an 1883 paper published in *Science*:

*At present, the national museum and observatory in Rio, and the school of mines in Ouro Preto, are the principal centres of scientific activity. The latter, being a comparatively new establishment, remote from the centralizing tendencies of the capital, organized on European models, and controlled by an able corps of French specialists, has escaped many of the vices of the older institutions.*³¹

MONAZITE SANDS FROM BAHIA

On the southern coast of the Province/State of Bahia, in the municipalities of Caravelas and Prado, dark and heavy sand extends in long strips. Known today as monazite sand, these strips are rich in rare earth minerals, and, in the case of sands from Bahia, thorium minerals. Ludwig Camillo Haitinger (1860-1945) and K. Peters discovered the presence of radium in these sands in 1904.³² Later, other deposits of monazite sands were discovered in Espírito Santo (1896) and Rio de Janeiro. Orville Derby, director of the geology section of the National Museum in Rio de Janeiro, sent samples of sand from the beach of Cumuruxatiba (municipality of Prado) to Gorceix in Ouro Preto (1883). This heavy brown sand he received from John Gordon, an Englishman (or American?), a manager of the North-American coffee exporting company *E. Johnstone & Co.* Gorceix analyzed the samples from 1883 to 1885 and realized they contained phosphates and oxides of cerium, lanthanum and didymium (then still believed to be an element). At the same time, Gordon, in partnership with English and German merchants, had exported 3000 tons of monazite sand by 1888. By 1890, the endeavor had “exported” a total of 15.000 tons to Hamburg and was supplying rare earth processing industries in Vienna and Berlin.³³ Although there is no confirming evidence, it is believed Gordon personally negotiated with Carl Auer von Welsbach (1858-1929) and collected a fortune with this not entirely legal “trade”.

The remnants of the wooden pier built on Cumuruxatiba beach can still be seen today. The ruin advances hundreds of meters into the sea and facilitated the transfer of the “ballast of Brazilian ships” into ship holds. Inhabitants and tourists in Cumuruxatiba, today a summer resort, remain predominantly unaware of the history and purpose of this derelict construction project, which has withstood the forces of the ocean, the mercilessness of time and decay, and even vandalism. After the pier was intentionally set on fire in 2005, only its row of pillars survives.

In 1890, the government of Bahia forbade “export” of the sands. But the trade was liberated again in 1895, though this time it was at least nominally under the control of state authorities. In 1900, a record-breaking 7120 tons were exported. Afterward, the Brazilian government finally forbade any export of this valuable raw material. International interest in the illegal extraction and smuggling of rare earth can be seen in Alfred Hitchcock’s 1946’s production “*Notorious*” (launched in Brazil as “*Interlúdio*”).³⁴

DIDYMIUM AND THE CHEMICAL ANALYSES OF GORCEIX

The supposed element didymium was first espoused to exist in 1841, when Carl Gustaf Mosander (1797-1858) isolated it as an impurity of lanthanum, an element he had discovered as a contamination of cerium in 1839. Didymium remained an element (symbol Di) until 1879, when Paul Émile Lecoq de Boisbaudran (1838-1912) discovered a fraction of samarium in didymium, and as such didymium was included in periodic tables (Gme-

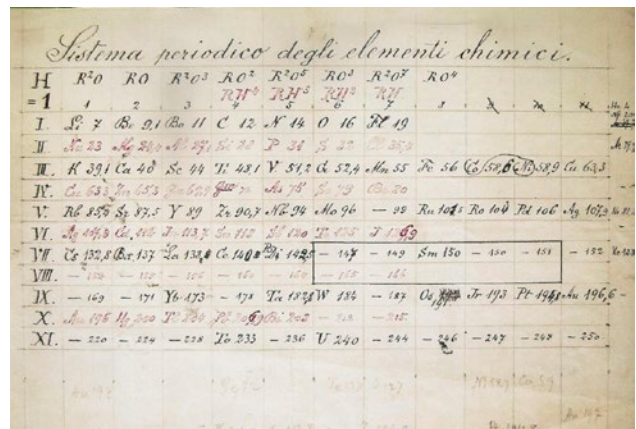
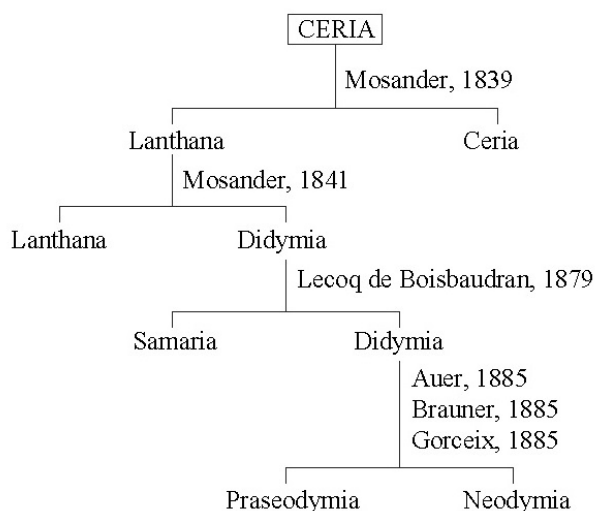


Figure 4. Didymium was incorporated in many periodic classifications, like this draft by Hugo Schiff (1834-1915) (courtesy Museo di Storia della Scienza, Florence, reproduced with permission).

lin, 1843, Newlands, 1865, Kremers, 1869, Mendeleev, 1869). Didymium possessed elemental status from 1841 to 1885, when Carl Auer von Welsbach (1858-1929) split the mixture into two elements: neodymium and praseodymium. Didymium's story is not a simple one, and other researchers, like Georges Urbain and Henri Gorceix, came to the same conclusion; in his work on the subject, Gorceix made no claim for a priority, and his effort was virtually ignored in the "central" scientific scenario as well as in the country where he lived and worked. To the best of our knowledge, Dutra (2002) was the first to draw attention to Gorceix's 'decomposition' of didymium. We brought this information to the attention of colleagues abroad, who mentioned it in recent publications. Didymium, as well as six 'authentic' elements (lanthanum, neodymium, praseodymium, gadolinium, samarium, europium) were obtained from cerium, discovered in 1803 by Berzelius, and independently by Klaproth in bastnaesite, a mineral found in the mines of Bastnaes in Sweden (Bastnaesite was described for the first time by Vilhelm Hisinger [1766-1852]).

Rare Earths obtained from Ceria



With reference to the great amount of data on the chemistry of didymium, Arthur Comings Langmuir (1872-1941) wrote in 1903: "*The voluminous literature of didymium affords a striking illustration of the pursuit of science for its own sake, and with no reward beyond the satisfaction of having advanced the cause of truth*".³⁵ Moreover, adding to this "science for science", to paraphrase parnassians' "*l'art pour l'art*", the enormous quantity of publications on didymium can now be found in A. C. Langmuir's "Index to the Literature of Didym-

ium (1842-1893)", which was published in 1903 by the *Smithsonian Institution* after the initiative of Henry Carington Bolton (1843-1903). We may suggest a thought provoking question: to what extent is chemical practice an exact science, considering the many publications on the extraction, isolation, purification, chemical and physical properties of compounds of an element which does not exist? Should we not consider the scientific methodology in place to be questionable or inappropriate? Has the data been intersubjectively verified? Should we accept the sometimes incoherent and inconsistent data, and the buildup of information, which would later be rejected, as a 'normal' step for any scientific investigation? Or should we explain away such anomalies by appealing to "anthropogenic factors" centered on the shortcomings of our instruments and research techniques?

In fact, until 1885, didymium was widely accepted to be a real element. However, many experiments showed contradictory results, which sometimes differed in samples with different origins, were sometimes impossible to replicate, or offered inconclusive results (such problems are not exclusive to didymium). Since the discovery of didymium, there have been doubts about its elementary nature – this is clear in publications by Hans Rudolph Hermann (1805-1875) as early as 1845, O. Popp in 1864 (erbium and terbium as mixtures of didymium and yttrium), Per Theodor Cleve (1840-1905) in 1885 after a series of experiments done since 1874, Marc Delafontaine (1838-1911) in 1878, and Bohuslav Brauner (1855-1935) in 1885.

When, in 1879, Lecoq de Boisbaudran discovered samarium as an impurity in didymium, these doubts seemed to be clarified in part. Among the chemists that systematically completed research on didymium, we cite Jean Charles Galissard de Marignac (1817-1894), H. R. Hermann, F. Frerichs, Per T. Cleve, Karl Friedrich A. Rammelsberg (1813-1899), and many others. None of these chemists used unorthodox research strategies. No less than nine methods were proposed (and published) to separate lanthanum from didymium, by Hermann, Robert Bunsen (1811-1899) and Zschiesche, Augustin Damour (1808-1902) and Deville, F. Frerichs, Auer von Welsbach, Auguste Victor Verneuil (1856-1913) and Grigory Wyruboff (1843-1913), P. Mengel, Witt, Paul Gerard Drossbach (1866-1903). At the same time, William Crookes (1832-1919), Octave Leopold Boudouard (1872-1923), Eugène Demarçay (1852-1903), Georges Urbain (1872-1938) and G. Dimmer expressed views on the probable decomposition of didymium, retaining this opinion even after failing to prove it experimentally (not confirming Brauner's publication from 1885).³⁶ Adding

to the uncertainties about rare earths, Boudouard, from the *Conservatoire National des Arts et Métiers*, suggested that even Mosander's cerium from 1839 could be a mixture of two elements (1895).³⁷

Our purpose here is to provide detail on Gorceix's chemical experiments with monazite sand and the didymium it supposedly contained. These experiments were performed in Ouro Preto from 1883 to 1886, a place distant from "central" scientific research institutions. Although the findings were presented at the Paris Academy and published in French journals known worldwide, they did not attract the deserved attention, perhaps because Gorceix lived and worked at the fringe of international academic life and at the "periphery" of the academic world. It is interesting to observe that, among the hundreds of scientific communications and papers published by Langmuir in 1903, there is not a single reference to Gorceix. The so-called "official" science solemnly ignored scientific productions from outside its geographic limits. The exhaustive two volume texts of Richard Böhm, "Die Darstellung der Seltenen Erden" (1905) make no reference to Gorceix's work on monazite sand.³⁸

Before coming to Gorceix, it is interesting to see past research on the rare earth "didymia" since its "discovery" by Mosander in 1841. Marignac (1848, 1854), Hermann (1853), Cleve (1875, 1883), Delafontaine (1878), Kopp (1879), and Clarke (1881) determined the "atomic weight" of didymium. Mendeleev admitted the value 138 in his Table. Rammelsberg (1861) found the isomorphisms of didymium sulfate and other sulfates ("the isomorphism of the three cerite metals is beyond question"), Marignac (1856) determined the theoretical crystalline form of didymium sulfate, and Nordenskiöld (1861) determined the crystalline structure of didymium oxide, DiO (Rammelsberg proposed DiO_2).

American chemists Francis William Hillebrand (1853-1925) and Thomas Norton (1851-1941) believed to have isolated metallic didymium in 1875 via electrolytic reduction of DiCl_2 , thus obtaining cerium and lanthanum in accordance with a method developed by Bunsen shortly after the development of the Bunsen cell.³⁹ Using electrolysis, Bunsen obtained yttrium, cerium, lanthanum, didymium, thorium, zirconium, calcium and strontium in a "free state". Bunsen's process converts oxides into sulfates, sulfates in chlorides (via oxalates), which were finally submitted to electrolysis. The authors remark that, of the three metals, didymium is the most difficult to obtain: didymium reacts with oxygen from the air to regenerate as an oxide. They further mention that the physical properties of didymium are more similar to those of lanthanum, rather than cerium. Hille-

brand and Norton were looking for a very pure sample of didymium, like 'pure didymium chloride', which is necessary for electrolysis, and supposedly used the entire supply of lanthanum sulfate and didymium sulfate available at the laboratories of Heidelberg University (Hillebrand was a student and later an assistant of Bunsen; Norton was also a graduate student of Bunsen). In the electrochemical series, didymium is located between cerium and magnesium.

Numerous contemporary papers discuss the separation of didymium from lanthanum and cerium (Marignac, 1849; Bunsen, 1875) or independently from cerium (Popp, 1864) or lanthanum (Frerichs, 1874), or from still other species, such as gallium (Lecoq de Boisbaudran, 1882), thorium (Hermann, 1864), and zirconium (Hermann, 1864). The separation of 'didymium' from cerium or lanthanum is not an absurdity; it could be a separation of a 'mixture (neodymium + praseodymium)' from its neighbours. Didymium's place in the Periodic Table was also a contentious matter (Schiff, 1879; Piccini, 1885). The paradox of an experimental investigation of a non-existent element will be discussed later. The figure shows a drawing of the Periodic System by Ugo Schiff (1834-1915), which included didymium as an element.⁴⁰

By way of example, let us discuss the procedure developed by F. Frerichs for separating lanthanum from didymium (1874).⁴¹ A mixture of lanthanum and didymium oxides is heated in a flow of chlorine, then water is added to the resultant mixture of the oxichlorides, and the solution is allowed to stand for a while – La and Di proportions in the solution are 3:6. Lanthanum chloride remains dissolved, and didymium chloride precipitates. With higher concentrations of lanthanum, the procedure must be repeated. Other methods suggested by Frerichs consist of dissolving the oxides in nitric acid, adding sulfuric acid, and allowing the solution to stand for several days. The sulfuric acid combines with lanthanum, creating lanthanum sulfate. In order to obtain pure didymium compounds, sulfuric acid is added to the oxides until all the lanthanum and some of the didymium is converted in sulfates. After evaporation and ignition, a white mass is obtained, from which water extracts the lanthanum and part of the didymium. Pure didymium oxide is obtained by dissolving the residue in sulfuric acid. This example illustrates how the lack of appropriate experimental (in this case, analytical) methods may result in false conclusions in chemical practices.

In the case of Gorceix, our interests lie in one aspect of didymium's chemistry: its occurrence in monazite and monazite sand. Gorceix had already completed some research on monazite before receiving the samples of Caravelas from Orville Derby in 1883.⁴² The first men-

tions of monazite in Brazil came from Gorceix himself (1883), when he “tentatively” considered the yellow sand grains from Fazenda Quebra-Galho (São Paulo) to be monazite. He was later informed that the sand was actually from Caravelas (1884). Gorceix mentions the occurrence of monazite in other places in Minas Gerais: the diamond-containing depositions in Diamantina⁴³ (1884, 1885⁴⁴), gold places in Casca on the Rio Doce (1885),⁴⁵ and finally in Salobro, Bahia (1884).⁴⁶ In possession of the sands remitted by Derby, Gorceix worked on separations. In 1885, in the *Bulletin de la Société Minéralogique de France*, he writes the following: “the samples [from Caravelas sands] are found in form of yellow bright grains, mixed with some ferro-titanium”.⁴⁷ Once the iron is completely removed, microscopic examination of the sands reveals a homogeneous aspect containing crystals. Some of these crystals resemble monazite and others suggest the presence of another species of mineral. The density of the mixture is 5.1. The sand is then ground into a fine powder, heated with sulfuric acid, dried and dissolved again in a weak acid solution. The insoluble fraction in the resultant sulfuric acid contains silica and zirconia, and the soluble fraction contains cerium and didymium oxides, which are precipitated with oxalic acid. Oxalates are heated and converted into nitrates. Fusion with potassium nitrate at 360°C separates cerium from didymium. Gorceix’s analysis suggests the following composition for the monazite sand from Caravelas:

	(a)	(b)	
SiO ₂	3.4%		
ZrO ₂	6.3	9.7%	
CaO		1.1	
Phosphate		25.7	
CeO		28.0	
DiO + LaO (?)		35.8	Total: 100.3

(a) Insoluble fraction; (b) Soluble fraction.

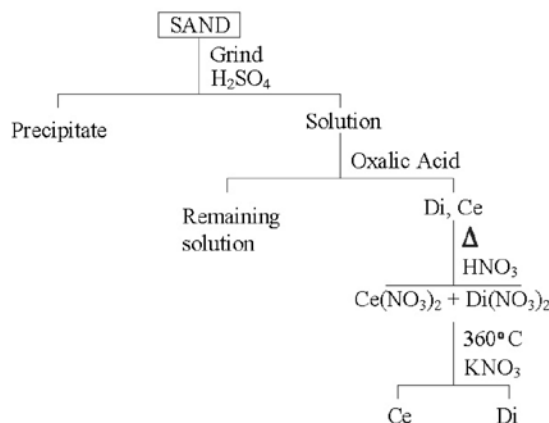
Fraction solubilised by sulfuric acid contains:

Phosphate	28.7 %	
CeO	31.3	
DiO + LaO (?)	39.9	Total: 99.9

Hence, the formula is $\text{PO}_3 \cdot 3[\text{CeO}, \text{DiO}, \text{LaO}]$, where 30% is phosphate and 70% are oxides of the three rare earths. Gorceix emphasizes that his analysis revealed greater didymium content in the Caravelas sands when compared with similar sands found in Slatoust (Russia) and Arendal (Norway). Sands from Slatoust were analysed by Debray at the *École Normale*. Gorceix’s paper was also published in the *Comptes Rendus* of the Paris Academy,⁴⁸ where it was presented by Jules Henri Debray (1827-1888), which should have given it a greater

visibility among scientists. However, its relative obscurity may be due to its provenance from the distant and unfamiliar Ouro Preto.

Gorceix's Analytical Scheme



In 1913, Richard Böhm published a more detailed analysis of monazite sand from Bahia, showing the elements neodymium and praseodymium to be decomposition products of didymium⁴⁹:

Cerium dioxide	31.5 %
Phosphoric acid	26.0
Lanthanum oxide	17.52
Neodymium oxide	10.52
Praseodymium oxide	4.9
Thorium oxide	1.0
Other rare earths	9.6

In the same year, 1885, as Gorceix’s publication, Bohuslav Brauner (1885-1935) in Prague and Carl Auer von Welsbach (1858-1929) in Vienna analyzed didymium due to the well-founded suspicion about the possible divisibility of didymium. Brauner was initially interested in finding new evidence for the Periodic System of his friend Mendeleev, as well as confirming P. Cleve’s work signaling the decomposition of didymium into three elements (including Lecoq’s samarium there where indeed three elements).⁵⁰ Auer decomposed didymium into two elements, neodymium and praseodymium, and after many recrystallizations, finally obtained the elements as double nitrates of ammonium – with slight differences in solubility and with different colours.⁵¹ Former attempts were unsuccessful, lacking fractional recrystallizations of other salts, like double sulfates. Brauner did not obtain neodymium and praseodymium compounds, but rather obtained different spectral data for the two new elements. Six weeks before Auer’s publica-

tion, Gorceix obtained the same spectral lines as those shown later by Auer's compounds. Gorceix found no sustainable explanation for his experimental results, and did not claim priority over the "discovery" of a new element. We found no reference to any testing or repetition of Gorceix's experiments by other researchers. It seems, judging from his publications, that Gorceix was primarily interested in confirming the existence of didymium in monazite sands. Brauner and Gorceix based their findings on the decomposition of didymium on spectral data, but in the case of didymium, as Robert Bunsen observed in 1866, the occurrence of "unusually narrow" spectral lines makes for a difficult interpretation. William Crookes (1832-1919), in 1886 and again in 1889, discussed the possibility of an even greater divisibility of didymium than that predicted by Auer.⁵²

Modern chemists may find it surprising that even after didymium was found to be a mixture of neodymium and praseodymium, some chemists persevered in studying didymium as an "element". Even more surprising, many chemists still believed, in late 19th / early 20th centuries, that neodymium and praseodymium could be divided into new "elements" on the basis of empirical (mostly spectral) data. Richard Böhm's book, mentioned above, presents useful data for that purpose. Further, many orthodox chemists investigated new "simple compounds" as elements. Carl von Scheele, in 1901, after many analyses, asserted that praseodymium has in fact an elemental nature.⁵³ Konstantin von Chroustschoff (1852-1912) announced in 1897 a third component of didymium, the supposed "element" glaucodidymium, although this was never confirmed. For Eugene Demarcay (1852-1903), the discoverer of europium (1901), neodymium was, without a doubt, an element (1898).⁵⁴

Against current and almost universally accepted emerging chemical facts, some chemists insisted on the divisibility of the two new elements isolated from didymium. In 1892, Paul Albert Schottländer (1843-1897), who earned a doctorate in Würzburg and was an amateur chemist in Berlin (1886/1896), published observations of the crystallization of double nitrate of praseodymium and ammonium:

*from the components of praseodymium, one element considered to be a metal presented only one absorption line (λ 468,9) [...]. The other praseodymium components constitute two groups, which seem to suffer separation during the crystallization process. One of them we call Pr_{α} [...] and the other Pr_{β} .*⁵⁵

Also, for the Americans, Louis Monroe Dennis (1863-1936), from *Cornell University*, and his student Emile Monnin Chamot (1868-1950), praseodymium was

supposedly divisible (1897).⁵⁶ The same opinion was expressed in 1899 by Friedrich W. Muthmann (1861-1913).⁵⁷ Richard Böhm, in 1902, interpreted the spectral lines of praseodymium as pertaining to three "components" of the metal: Pr_{α} (λ 596,8 and 589,6), Pr_{β} (λ 481,1 and 440,0, announced by Cleve in 1878), and Pr_{γ} (λ 469,0), identical to Di_{η} described earlier by Gerhard Krüss (1859-1895) and Lars Nilson (1840-1899).⁵⁸

A POSSIBLE EXPLANATION FOR A PARADOX

In 1885, the empirical observation that didymium did not exist as an element, being confirmed as a mixture of neodymium and praseodymium, was insufficient to immediately remove it from the practices and activities of many chemists. We have thus another example of the persistence in science of ideas and facts that are no longer acceptable. Such persistence is perhaps better understood as the resistance of some chemists to altering the body of data and beliefs guiding their practices. It is also an example of how scientific methodologies may justify anachronisms. "*Even formally excluded from the row of elements – wrote Böhm in his text from 1905 – exclusively practical motivations led to a discussion about its preparation since for obtaining its components chemists frequently use materials rich in didymium as a raw material.*"⁵⁹ An 1898 paper by André Job (1870-1928),⁶⁰ professor at the *Conservatoire National des Arts et Métiers*, which described "new chemical compounds derived from cerite metals", registers the preparation of oxalochloride of lanthanum obtained from lanthanum sulfate, for which he suggests the formula $(C^2O^4)Cl^2La^2$. Dissolved in hot water, this salt decomposes into lanthanum oxalate and lanthanum chloride. So far, this is nothing unusual. However, Job also mentions that it is necessary to start with very pure lanthanum that is free from cerium and didymium (this in 1898), with the "spectroscope showing no more any signs of didymium", and various new analytical methods developed by Job himself showing no signs of cerium. In the same paper, Job refers to the preparation of the same type of salt with cerium and with didymium, alluding to the didymium oxalonitrate prepared previously by Cleve. Richard Böhm suggests that this situation could be explained by the evolution of chemistry itself:

*Since older scientists studied very little or nothing about spectra, lacking therefore a resource to confirm the absence of lanthanum, they took for didymium oxide all products which precipitate as oxalate in an acid solution containing didymium and lanthanum, but not cerium.*⁶¹

The situation just described is not unique to the field of chemistry. But how is it possible for an exact, methodologically structured and practiced science to continue to operate on obsolete data? Even though there may be a practical justification for the reluctance to reject falsified beliefs, is this not a case of *bad science*? Or *bad scientists*? Was there an excessive emphasis on empirical facts? Or was practice too distant from theory?

A possible explanation would be a general unawareness of the latest research results on didymium. However, this is not the case here; the international chemical bibliography had already incorporated neodymium and praseodymium, while excluding didymium from the series of elements. Alternatively, this could be the result of an isolated group of researchers studying the “cerite metals” unaware of the newest literature, and therefore continuing to work on outdated data. This situation is often observed in the scientific practice of the so-called (geographically) “peripheral science”, where the diffusion of new information is often slower.

There may be other explanations originating from the theoretical frameworks prevalent in different countries. We know from history that the anti-atomist thinking of positivists like Jean-Baptiste Dumas (1800-1884) and Marcelin Berthelot (1827-1907) had a negative influence on the evolution of several aspects of French science. But disbelief in the existence of atoms as real and concrete entities did not prevent chemists from discovering new elements, as is proved by Mendeleevian *eca*-elements gallium (1875, Lecoq de Boisbaudran), scandium (1880, Nilson) and germanium (1886, Winkler).

In other words, science may progress in the sense of making discoveries, despite false beliefs or wrong theories. This fact could in turn psychologically explain why we experience a kind of inertia or resistance from the scientific community when promptly revising beliefs or theoretical frameworks in the face of anomalies, as it may not be necessary to do so to make new discoveries. In this case, the high level of complexity in the experimental study of rare earths elements adds to this inertia. Revising theoretical frameworks in light of anomalies conflicts with the desire to prioritize new discoveries, which in turns explains why scientists may choose to ignore such anomalies and carry on with their research programs.

The desire for priority also explains the hasty communication of new rare earths discoveries that were later found to be just mixtures, or rediscoveries. Physicists and chemists know all too well Max Planck’s quote on the triumph of new theories: it is not caused by the strength of their arguments, but by the death of the defenders of the older views. The best example of this

in chemistry is the rapid triumph of Lavoisier’s Oxygen Theory: after the death of its most prominent opponent, Joseph Priestley (1804), adherents of the old theory rapidly left the scene. The “old chemistry” then ceased to exist with the death of its last representative, Anders Retzius (1742-1821).

In the case of the “element” didymium, we are not discussing theories, but rather the reluctance to accept the fact that it is a mixture and not an element. Its falsification occurred during a period of “normal science” (in *Kuhnian* sense) in chemistry. The general theoretical framework of chemistry is not being called into question, but we may identify some problematic methodological aspects of laboratorial work, such as overreliance on spectral data. Due to the prolific amount of work on rare earths, we can find many situations resembling the case of didymium, or cases where scientists were reluctant to accept well documented falsification.

And we also find amongst the history of rare earths discoveries examples situated at the other end of the spectrum; cases where elements were well confirmed and widely believed to exist, and yet some were reluctant to accept them (not only for scientific reasons). George de Hevesy’s (1885-1966) and Dirk Coster’s (1889-1950) hafnium (1923) was unanimously accepted only after George Urbain’s celtium, discovered six months before, was shown to be the same as lutetium, discovered by Urbain himself in 1913, from another mineral, samarskite.

When discussing rare earths elements, it is important to consider the enormous difficulties faced by chemists. The properties of rare earths elements are so similar that identification, isolation and purification are extremely difficult. Chemists often misinterpreted mistakes, sometimes thinking a mixture to be a “new” element, and sometimes concluding that different samples of the same element were different elements. Franco Calascibetta points to theoretical and experimental problems:

*The vast number in the family, their appearance, multiplication and then disappearance, have several times been linked, in both the last and the current century, to important theoretical aspects of chemistry, including Mendeleev’s periodic system and later Moseley’s discovery and the new definition of atomic number.*⁶²

Before the invention of spectroscopy, notably that of Bunsen and Kirchhoff (1859),⁶³ chemists had at their disposal very difficult, troublesome and labour-intensive methods for identification and characterization of these elements. Notwithstanding, experimented chemists like Brauner, Auer, Marignac or Urbain were still able to

characterize new elements using only “classical” analytic methods.

An initial limit to an apparently unlimited number of possible elements was Mendeleev’s number of empty spaces (elements still unknown) in his Periodic Table, which indicated that there is indeed a limit to the number of possible rare earth elements (1869). Convinced Mendeleevians suggested new graphical representations of the table that allowed the correct location of the elements still to be found, as in the tables of Brauner (1902)⁶⁴ and of Alfred Werner (1905)⁶⁵. Brauner included 19 rare earth elements in his table, seven of which were still unknown at the time. Werner proposed 15 rare earth elements, two of them (between neodymium and samarium) not yet discovered. After Henry G. J. Moseley’s (1887-1915) studies with X-ray spectroscopy in Oxford (1913) it was finally possible to define the “atomic number” of elements and conclude that the maximum theoretically possible number of rare earth elements is 14. Two of these were not yet known: atomic number 43 (technetium, 1937) and atomic number 61 (promethium, 1945). Finally, by combining empirical knowledge with theory, it was possible to determine which ones exist in the vast universe of possible rare earth elements – exhaustively described by Marco Fontani and coworkers.⁶⁶

In other words, elements confirmed based on empirical facts alone, but in disagreement with theory, could finally be discarded. Joseph William Mellor (1869-1938), in his extensive treatise on Inorganic Chemistry, presents a table with 73 supposed rare earth elements discovered between 1794 and 1920.⁶⁷ Out of these, 15 were mixtures and 25 were never confirmed. Empiricism without proper theoretical foundations leads to error. This explanation, of course, does not apply just to the case of didymium.

Still other (non-scientific) motivations exist for didymium’s persistence, and these are exclusive to didymium. Didymium, when still believed to be an element, was used in the production of special glasses for the protective goggles of glassblowers. Even after its falsification, the term didymium continued to be used, meaning the fraction remaining after the removal of all cerium content from monazite (this fraction contains 46% lanthanum, 34% neodymium, 11% praseodymium, and some samarium and gadolinium). Mixtures of neodymium and praseodymium, like a ‘false didymium’, were used as catalysts and in the glass industry. Ludwig Moser (1833-1916) founded a factory that produces glassware (*Josef Moser & Söhne*) in 1857 in Karlsbad (Bohemia), now Karlovy Vary, which used neodymium and praseodymium salts to obtain a great variety of irides-

cent colours, producing objects much appreciated during the *Art Nouveau* and *Art Déco* periods. In the 1920s, the chemists of Karlovy Vary again mixed neodymium and praseodymium salts, a kind of ‘synthesis’ of didymium, obtaining several pigments.

One more reason has been presented to explain didymium’s longevity. F. Szabadváry and C. Evans (1996) offered a fanciful explanation for the permanence of the term “didymium” in the chemical literature: that Auer published his paper on the isolation of neodymium and praseodymium from didymium in an obscure chemical journal, the *Monatshefte für Chemie*.⁶⁸ But in Auer’s time, and for many decades, this journal was all but obscure.

EPILOGUE – RUDIMENTS OF AN INDUSTRY

*Unfortunately, rare earths constitute an additional example of underused Brazilian natural resources, thanks to lack of strategic policies of management*⁶⁹ is the sad conclusion of chemist Osvaldo Serra (*1943) on these resources, which are known for their history, occurrence and prospection, but were never really considered seriously by the academy and industry. At the same time, Serra mentions a phenomenon that is not restricted to Brazil, but that occurs worldwide: the dismantling of mineral processing industries not only causes unemployment, but also the disappearance of knowledge and rare skills and abilities necessary for mineral processing procedures.

The recent resumption of extraction, separation and purification of rare earths in Brazil is actually a new start, as all that was previously known about these procedures was lost. Until 1914, Brazil was the world leader of rare earth extraction, but it brought no benefit to the country: “the ballast of Brazilian ships” created richness elsewhere. Decades later, Brazil began a timid industrial exploration of monazite sand with the foundation, in 1942, of the *ORQUIMA S.A. (Organo-Química, later Indústrias Químicas Reunidas)* in São Paulo, with a factory in Santo Amaro/São Paulo.⁷⁰ In 1946, *ORQUIMA* began to process monazite sand not from Bahia (because of the long distance) but from the States of Espírito Santo (where it was discovered in 1896 and has been processed since 1906 by *MIBRA – Société Minière et Industrielle Franco-Brésilienne*) and Rio de Janeiro.

ORQUIMA Company developed and used with perfection all the know-how necessary for the extraction, processing, isolation and purification of rare earths – especially during the 20 years in which the Polish chemist Pawel Krumholz (1909-1973), a former assistant of Fritz Feigl (1891-1971) in Vienna, was in charge as tech-

nical director. Krumholz, along with an accomplished group of coworkers, produced at ORQUIMA an internationally acclaimed work on rare earths.⁷¹ ORQUIMA processed 2000 tons of monazite annually, producing compounds of cerium, lanthanum, neodymium, samarium, thorium, zirconium, with a purity of up to 99.99%. It was nationalized in 1949 and acquired by the *Comissão Nacional de Energia Nuclear – CNEN* – in 1960, during the nationalistic and state-centralizing policies of the governments of that period, and transferred later to the *NUCLEMON (Nuclebrás Areias Monazíticas)*. All ORQUIMA's activities were sadly paralyzed in 2002; lacking the deserved support, the enterprise failed.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the following: René and Peter van der Krogt, Delft, Netherlands; William Jensen, University of Cincinnati and *Oesper Collection for the History of Chemistry*; Organic Chemistry Department 'Ugo Schiff', University of Florence; Marco Fontani, University of Florence; Laura Colli and *Museo di Storia della Scienza*, Florence; *Museu de Arte de Santa Catarina/MASC*, Florianópolis, Brazil.

REFERENCES

- Gorceix, H., Inaugural Speech, Ouro Preto Mining School, October 12th, 1876.
- Maar, J. H., "História da Química, vol.II, de Lavoisier ao Sistema Periódico", Papa-Livro, Florianópolis, 2012, 544.
- Karpenko, V., *Ambix*, **27**, 77-102 (1980).
- Anonymous, *Manufacturer & Builder*, **122** (7), n° 976, 84.
- Cláudio Vieira Dutra, professor at the Federal University of Ouro Preto, was the first to draw attention to these facts, in 2002, and to him pertains the priority of including this novelty into the history of chemistry. Dutra, C. V., *Revista da Escola de Minas, Ouro Preto*, **55**, 185-192 (2002).
- Alves, G. L., "O Pensamento Burguês no Seminário de Olinda", Editora da Universidade Federal de Mato Grosso do Sul/Editora Autores Associados, Campo Grande e Campinas, 2001.
- Maar, J. H., *Scientiae Studia*, **2**, 33-84 (2004).
- Cunha, L., "A Universidade Temporã", Editora Civilização Brasileira, Rio de Janeiro, 1980.
- Figueirôa, S., "Um olhar sobre o passado", Editora da Universidade Estadual de Campinas, Campinas, 2000. Manuel Ferreira da Câmara (1762-1835), member of the National Assembly, proposed in 1823 the creation of an University in Rio de Janeiro, the "Instituto Brasília" (Campos, E. S., "História da Universidade de São Paulo", Editora da Universidade de São Paulo, 2004, p.27).
- Habashi, F., *Bulletin of the Canadian Institute of Mines*, **90**, 103-114 (1997).
- Carvalho, J. M. de, "A Escola de Minas de Ouro Preto – o Peso da Glória", Editora da Universidade Federal de Minas Gerais, Belo Horizonte, 2002.
- Schwarcz, L., "As Barbas do Imperador", Cia. das Letras, São Paulo, 1998.
- Santos, N. P. dos, *Revista da SBHC*, **2**, 54-64 (2004); Filgueiras, C. A., *Química Nova*, **11**, 210-214 (1988).
- Schwarcz, L., *op. cit.*, pp. 125-158, 416-436.
- Silva, C. B. da, *Revista da Escola de Minas, Ouro Preto*, **67**, 319-340 (2014).
- Figueirôa, S., "As Ciências Geológicas no Brasil. Uma história social e institucional, 1875-1934", Editora Hucitec, São Paulo, 1997, 123-124.
- Dutra, C. V., *op. cit.*, 186.
- Atêncio, D., *Brazilian Journal of Geology*, **45**, 143-158 (2015).
- Costa, A. R. da, Santos, P. C. M., *Revista da Escola de Minas, Ouro Preto*, **59**, 347-353 (2006).
- Ambrosio, U., *Anais do IV Seminário Nacional de História da Ciência e da Tecnologia*, Caxambu, 1993, 96-99.
- Carvalho, J. M., *op. cit.*, 50-51.
- Carvalho, J. M., *op. cit.*, 92-97.
- Gorceix, H., *Anais da Escola de Minas de Ouro Preto*, vol. **I** (1881), preface.
- Carvalho, J. M., *op. cit.*, 56-57.
- Carvalho, J. M., *op. cit.*, 98.
- Carvalho, J. M., *op. cit.*, 66, 96.
- João Pandiá Calógeras (1870-1934), engineer and geologist, was Minister of Agriculture (1914/1915), Finance (1915/1917) and War (1919/1922), and presided the Brazilian delegation to the Versailles Conference (1918/1919). He authored several books on History, Economy, International Relations. Dias, M. M., "O Brasil em Versalhes – Calógeras e a Política Internacional", Anais do 3° Seminário Nacional de História da Historiografia, Ouro Preto, 2009.
- José Pires do Rio (1880-1950) served as government minister and as mayor of São Paulo 1926/1930.
- Francisco Sá (1862-1936) was minister in 1909 and 1922/1926 and senator from 1906 to 1927. Calógeras, Francisco Sá and Pires do Rio, were typical representatives of the so-called "First Republic" (1889/1930); all had technological training as engineers and exert-

- ed strong influence on economic questions.
30. Guimarães, D., *apud* Carvalho, J. M., *op. cit.*, p. 132. Djalma Guimarães (1894-1973), Emeritus Professor of the Universidade Federal de Ouro Preto, was perhaps the most important Brazilian geologist, discoverer of the great niobium reserves near Araxá/Minas Gerais (1931/1932).
 31. Derby, O., *Science*, **1** (8), 211-214 (1883).
 32. Haitinger, L., Peters, K., *Sitzungsberichte Akademie Wien*, 1904, 159-160.
 33. Leonardos, O., “A Monazita do Estado da Bahia”, Departamento Nacional de Produção Mineral, Rio de Janeiro, 1937.
 34. For a critical review and production history of “Notorious”, see “Notorious” (1946): Hitchcock’s mature and intricate espionage masterpiece”, <https://cinephiliaandbeyond.org>. The screenplay was written by Ben Hecht (1894-1964).
 35. Langmuir, A., “Index to the Literature of Didymium”, Smithsonian Miscellaneous Collections, Washington, 1893.
 36. Herzfeld, O., Korn, O., “Chemie der Seltenen Erden”, Springer, Berlin, 1901.
 37. Fontani, M., Costa, M., Orma, M., “The Lost Elements”, Oxford University Press, 2015, 40.
 38. Böhm, R., “Die Darstellung der Seltenen Erden”, 2 volumes, Veit & Co., Leipzig, 1905.
 39. Hillebrand, W., Norton, J., *Annalen der Physik (Pogg.)*, **155**, 633-639 (1875); *ibid.*, **156**, 456-474 (1876).
 40. Selleri, S., Fontani, M., “Cent’anni dalla scomparsa di Ugo Schiff”, Consiglio Regionale, Florence, 2016, 63-80.
 41. Frerichs, F., *Berichte*, **7**, 331-366 (1878).
 42. Gorceix, H., *Anais da Escola de Minas de Ouro Preto*, **4**, 29-48 (1885).
 43. Gorceix, H., *Compt. Rend.*, **98**, 1446-1338 (1884).
 44. Gorceix, H., *Bull. Soc. Min. France*, **7**, 179-182 (1884).
 45. Gorceix, H., *Anais da Escola de Minas de Ouro Preto*, **4**, 29-48 (1885).
 46. Gorceix, H., *Compt. Rend.*, **94**, 1446-1448 (1884).
 47. Gorceix, H., *Bull. Soc. Min. France*, **8**, 32-35 (1885).
 48. Gorceix, H., *Compt. Rend.*, **100**, 356-358 (1885).
 49. Böhm, R., “Die Verwendung der Seltenen Erden”, Veit & Co., Leipzig, 1913.
 50. Cleve, P., *Bull. Soc. Chim. France*, **21**, 196- (1874).
 51. Auer von Welsbach, C., *Monatshefte für Chemie*, **6**, 477-491 (1885).
 52. Crookes, W., *Chemical News*, **60**, 27- (1889)
 53. Scheele, C. von, *Z. Anorg. Allg. Chem.*, **27**, 53-57 (1901).
 54. Demarçay, E., *Compt. Rend.*, **126**, 1039-1041 (1898).
 55. Schottländer, P., *Berichte*, **25**, 378-394 (1892).
 56. Dennis, L., Chamot, E., *J. Am. Chem. Soc.*, **19**, 799-809 (1897).
 57. Muthmann, W., Stützel, L., *Berichte*, **38**, 2653-2677 (1899).
 58. Böhm, R., *Z. Angew. Chem.*, **15**, 1282-1299 (1902).
 59. Böhm, R., *op. cit* (1905), 469.
 60. Job, A., *Compt. Rend.*, **126**, 246-248 (1898).
 61. Böhm, R., *op. cit.* (1905), 470.
 62. Calascibetta, F., *VII Convegno Nazionale di Storia e Fondamenti della Chimica*, L’Aquila, 1997, 259-272.
 63. Bunsen, R., Kirchhoff, G., *Annalen der Physik (Pogg.)*, **110**, 161-189 (1860).
 64. Brauner, B., *Zeitschr. Anorg. Chem.*, **32**, 1-30 (1902).
 65. Werner, A., *Berichte*, **38**, 914-921 (1905).
 66. Fontani, M., Costa, M., Orma, M., “The Lost Elements”, Oxford University Press, 2015.
 67. Mellor, J., *apud* Calascibetta, *op. cit.*, p. 264.
 68. Szabadváry, F., Evans, C., “Episodes from the History of Rare Earth Elements”, Kluwer Academic Publishers, Dordrecht, 1996, 64.
 69. Sousa Filho, P., Serra, O., *Química Nova*, **37**, 753-760 (2014).
 70. Serra, O., *J. Braz. Chem. Soc.*, **22**, 811-812 (2011).
 71. Vichi, E., *Química Nova*, **6**, 152-156 (1983).