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SHAC Spring Seminar, 10 April 2026 - *Remembering Bill Brock*
Maison Française, Oxford

Title: "Burning Diamonds: Lavoisier, Guettard, and the 1771 Development of Reduction Firing and Hard-Paste Porcelain in Paris"

I would like to start by saying how much I appreciate being here and taking part in this special conference to commemorate the life of Bill Brock. Brock's texts form an indispensable introduction to the history of chemistry. As a resource, his publications are a rich repository of knowledge that continue to suggest ideas for expanded study. The histories that he developed included not just the big stars of the field, but also those influential thinkers whose work and efforts grounded and supported the work of others but were less well-known. Taking his lead, in today's talk, I focus on the well-known story of Antoine Lavoisier's experiments with diamonds, but I have shifted the perspective to include the figures in the background, including Lavoisier's mentor and teacher, Jean-Étienne Guettard, whom Brock recognized as the "cantankerous bachelor geologist" who first recommended that Lavoisier study with Guillaume François Rouelle. While historical hindsight has often narrowed the discussion of diamond-burning experiments to the subsequent discovery of oxygen by Lavoisier, the series of experiments were embedded in the pursuit of the commercial development of hard-paste porcelain production in France, in which Guettard was a key researcher. In this talk, I frame the diamond-burning experiments within the broader context of artisanal practice and show that a wide community of participants had influential roles.

Very often, the development of European porcelain has been told exclusively as a German story, with slim acknowledgement that the development of hard-paste porcelain developed independently elsewhere. German production began at Meissen in 1710, and Germany remained the sole European producer of hard-paste porcelain for most of the eighteenth century. In France, the path to hard-paste porcelain production required sixty

additional years of effort.[1] As the story is frequently told, the names of familiar Parisian savants, such as Macquer and Darcet, have been repeated together so often that they appear to have always acted in unison on porcelain research, when the case, as I show, is far different.[2] The centuries-long race to create a French porcelain that could rival those made in China and, later, Germany, was contentious, with distinct groups of researchers protecting their discoveries from their rivals.

The final stretch in the French quest for hard-paste porcelain took place between 1750 and 1771. Dramatic public debates over porcelain took place at the same time that Lavoisier's crucial work toward the discovery of oxygen began. Importantly, the laboratories at Sèvres were a key location for experiments in diamond-burning that interested Lavoisier at a critical moment in his research and helped inform his understanding, leading to the discovery of oxygen. Additionally, as I discuss in detail below, in 1771, kiln-firing techniques were revealed that could change the results of a firing substantially, creating a white porcelain from impure clay pastes.[3] These methods were known only to a handful of manufacturers, who did not fully understand the mechanisms, or the chemistry involved. However, with the development of Lavoisierian chemistry, the firing techniques could be understood as "reducing" the oxygen from within the porcelain itself.[4]

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[1] The story of Johann Friedrich Böttger at Meissen is well known. Janet Gleeson, *Arcanum* (New York, 1999); Suzanne L. Marchand, *Porcelain: A History from the Heart of Europe* (Princeton, 2020).
[2] Charles Coulston Gillispie, *Science and Polity in France: End of the Old Regime*. (Princeton, 2004), 406-7.
[3] Henri Louis Duhamel du Monceau, "L'Art de faire les pipes à fumer le tabac," Descriptions des arts et métiers 4, 1 (Paris, 1771).
[4] I discuss this further below. On reduction firing, see Gregg Conway, "Pottery Reduction Firing with a Fuel-Burning Kiln," *Leonardo* 9, 2 (1976).

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Western Fascination with Porcelain

From its first European discovery by voyagers such as Marco Polo in the thirteenth century, through the end of the eighteenth century, the material porcelain represented one of the most compelling challenges across Europe, both for its importation and for its technological secrets.[5] The qualities of Chinese porcelain – whiteness, hardness, translucency, and fineness of decoration – were unknown among European pottery types, making them sought after among the highest ranks. Factors such as trade rivalries, warfare, outdated styles, lack of control over production, and restricted access to markets, contributed to the drive to create locally produced European porcelain.[6]

From the Medici forward, European rulers and their artisans desired to replicate Chinese styles and materials.[7] The innovations achieved various sorts of soft-paste porcelain, which, while white and glassy, were susceptible to scratching and more easily broken than Chinese examples had been.[8] Owing in part to the secrecy of Asian potters, and to the differences in material resources and technology, European hard-paste porcelain production

[5] Lin Meicun and Ran Zhang, "A Chinese Porcelain Jar Associated with Marco Polo," *European Journal of Archaeology* 21, 1 (2018): 39-56.
[6] On the trade in porcelain see: Robert Finlay, "The Pilgrim Art," *Journal of World History* 9, 2 (1998): 141–87; Anna Jackson and Amin Jaffer, (London, 2004); Maxine Berg *Goods from the East* (Houndmills, 2015), 46-84; and Julie Emerson et al. *Porcelain Stories from China to Europe* (Seattle, 2000).
[7] On economic aspects of the porcelain industry, and the development of European industries, see Maxine Berg, "From Imitation to Invention," *Economic History Review* (2002), 1–30.
[8] *Edwin Atlee Barber, Artificial Soft Paste Porcelain (Philadelphia, 1907), 5-6.*

remained elusive until the early eighteenth century, when Dresden scientists working for Augustus the Strong succeeded in creating hard-paste porcelain in 1708.[9]

Through the early nineteenth century, nearly all aspects of pottery and porcelain manufacture had remained the property of skilled trades learned through apprenticeship in closed workshops and manufactories. There was little open or shared information related to the vast body of specialized understanding on faïence, stoneware, and porcelain making. At all levels, manufacturers and artisans had been engaged in efforts to create import substitution products, and their achievements were proprietary secrets. Governments and private interests, alike, participated in industrial espionage. Notably, the Jesuit priest François Xavier d'Entrecolles observed Chinese practices at Jingdezhen and sent letters back to France in 1711 and 1722 with critical information on the types of materials utilized. Although attentive to detail, d'Entrecolles had little experience with the industry, which limited his ability to interpret the finer points of Chinese practice.[10] In 1722, Antoine Ferchault de Réaumur (1683-1757) received only small amounts of highly processed materials. Regrettably, the samples of kaolin — hard-paste porcelain's key ingredient — had undergone all the preparatory steps of levigation and refinement and were ready to be used in a clay paste. Numerous mineralogical clues had been removed.[11] Working with limited information, Réaumur was unable to develop a true, hard-paste porcelain despite his prolonged efforts.

[9] Robin Hildyard, *European Ceramics* (London, 1999), 46-49.
[10] His letters were published in limited distribution in 1717, and 1724, respectively, before being more widely circulated in 1735. Pounds, "Discovery of China Clay," 21; Pollard, "Letters," 57-9.
[11] D'Albis, "Methods of Manufacturing Porcelain," 39-40.

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Later in the century, three critical, independent groups carried this research forward. The first included Louis, duc d'Orléans (1703-1752); the naturalist Jean Étienne Guettard; the naturalist Didier François d'Arclais de Montamy (1702-1765); and a potter named Le Guay.[12] Guettard had first-hand knowledge of Réaumur's porcelain tests and was engaged in creating a mineralogical study and map of France. He recognized that raw Chinese kaolin samples acquired by the duke were identical to the minerals he had collected from the clay beds at Maupertuis, in La Manche, approximately 40 miles southwest of Bayeux.[13]

Guettard had become the first to discover a kaolin source in France, but his discovery was kept quiet while the group carried out tests at the duke's property at Bagnolet. In 1751, after successfully creating a series of small porcelain objects, Guettard deposited a secret notice of his discovery with the academy, and Louis purchased a plot of land where the kaolin was located. While promising, this porcelain was never put into large-scale manufacture, in part because the early tests did not produce a pure white finished product. The duke's early death in 1752 prevented any further research from taking place at Bagnolet.[14]

The second group was headed by Louis Léon Felicité de Brancas, comte de Lauraguais (1733-1824) and his personal physician and collaborator, Jean Darcet (1724-1801). Likely present for some of the experiments at Bagnolet, or otherwise having seen the research, the comte de Lauraguais and Darcet became interested in the pursuit of porcelain for themselves. The count set up a laboratory at his Left Bank residence, the hotel de Lassay.[15] He employed

[12] George Lechevallier-Chevignard, La manufacture de porcelaine de Sèvres (Paris, 1908), 69-70.
[13] Saggars are used to enclose wares in fuel-burning kilns, to protect the surface of the wares.
[14] Guettard, Mémoires sur différentes parties des sciences et des arts, t.1, xxj.
[15] Henry Guerlac, "Some French Antecedents of the Chemical Revolution," Chymia 5 (1959): 84-6.

Le Guay, as well as Darcet's friend, the doctor Augustin Roux (1727-1776). Importantly, this was research that the count could only perform in the wake of Guettard's discovery. Through a dubious arrangement with de Montamy, the comte de Lauraguais had, in fact, taken control of all the late duke's research, notes, and materials related to porcelain, including a set of fired samples.[16]

Darcet and the count succeeded in making a porcelain paste that they claimed was equal in quality to Chinese porcelain. The count boasted of their status as the makers of the first French hard-paste porcelain, unaware of Guettard's sealed papers at the Academy. After fourteen years, Guettard was released from secrecy by the fourth duc d'Orléans, Louis-Philippe I, and was able to claim his priority over the discovery of French kaolin. Although Lauraguais possessed the samples from Guettard's research, he pretended not to know of them, and Le Guay denied any of the experiments at Bagnolet were successful. In 1765, following a year of public arguments, the sealed documents were opened to reveal Guettard's description of the processes by which the porcelain pastes were created at Bagnolet. This dispute, in which Guettard's primacy in the business was ultimately supported, brought about the first public discussions related to the mineralogical and chemical nature of hard-paste since those of Réaumur in the 1720s.[17]

Although Guettard had produced the first real French hard-paste porcelain, only the third group of researchers, at Sèvres, was able to make long-term use of the results, if not of

[16] Friedrich Melchior Grimm, Correspondance, littéraire, philosophique et critique par Grimm, Diderot, Raynal, Meister, etc (Paris, 1878), 52-4.
[17] For the aspects of the story, see Gillespie, Science and Polity: Old Regime, 406-8; and Guerlac, "French Antecedents of the Chemical Revolution," 73-112.

the kaolin sources located by either Guettard or Darcet.[18] Macquer learned of a kaolin deposit at Saint Yrieix in 1768.[19] Following a series of complex examinations of the raw materials, Macquer and his assistant, Étienne Mignot de Montigny (1714-1782) were able to create trials of a hard-paste porcelain at Sèvres. In 1769, Macquer presented a memoir and some pieces of porcelain to the Academy; although he did not reveal his exact procedures at this stage, his work soon afterwards led to the institution of the first native French manufacture of porcelain, with production beginning in 1771.[20]

Among other factors, this timing was likely influenced by the recent revelation of special firing techniques used by Charles Marie Roussel of Saint Omer. In 1730, Roussel, a French manufacturer of ceramic tobacco pipes, had discovered that a series of actions taken during various stages of firing could eliminate the reddish colouring brought on by the presence of iron in the clay and render the finished product white. In the key year of 1771, Roussel revealed his secret publicly for the first time, which Henri-Louis Duhamel du Monceau, published in "L'Art de faire les pipes à fumer le tabac."[21] The processes described in detail how Roussel closed off the kiln for brief periods of time during the firing, and, towards the end of the firing, loaded the kiln with a higher quantity of fuel (wood) than normal, firing this way for an hour.[22] Duhamel's memoir coincided with the commencement of hard-paste production

[18] As I discussed in Chapter Two, Guettard's 1765 memoir to the Academy attracted the attention of the minister Bertin, who provided funding for Guettard to complete his mineralogical atlas of France as a result. This project, in turn, enabled Lavoisier and Guettard to travel together for geological fieldwork.
[19] Brongniart, Arts céramiques, v. 2, 1844, 503-4.
[20] Brongniart, Arts céramiques, v. 2, 1844, 495.
[21] Henri Louis Duhamel du Monceau, "L'Art de faire les pipes à fumer le tabac," Descriptions des arts et métiers 4,1 (France, 1771), 11-12; Brongniart, Arts céramiques, v. 2, 186-7.
[22] The actions described include those necessary to create a reducing (oxygen-deprived) firing atmosphere in the kiln. In reduction, the oxygen needed by the fire is drawn from the chemically

at Sèvres, and would have been of particular interest to Macquer in his research, particularly as it provided a method for making use of less-pure sources of clay to create white porcelains. Two years later, in 1773, Macquer's brother, Philippe, included a discussion of Roussel's methods in the *Dictionnaire universel*.[23] That Roussel's methods were utilized at Sèvres is clear from Alexandre Brongniart's description of the changes he later made to the firing processes, which eliminated an unnecessary set of intermediate steps described by Roussel.[24]

From Porcelain to Diamonds: Lavoisier and the Discovery of Oxygen

Darcet had spent several years in research on porcelain, and other substances, including refractory minerals and combustibles. He drew his work into a memoir on porcelain presented to the Academy in 1768. Darcet's incidental research was arguably more influential than his work on kaolin. The end of the memoir contained a startling notice regarding experiments in the burning of diamonds, which had previously been thought to be impervious to fire.[25] Experiments of this type were not entirely new, but the earlier trials were limited and not well-known, and the expense was largely prohibitive. It was an extravagance that was perhaps driven by the environment surrounding the laboratories of the comte de Lauraguais at his Parisian residence, the Hôtel de Lassay.[26] In 1771, Macquer invited an audience to the workshops at

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bonded oxygen in the ceramic wares themselves, rather than from the air. This action can produce noticeable changes in the fired product. On reduction firing, see Gregg Conway, "Pottery Reduction Firing with a Fuel-Burning Kiln," Leonardo (Oxford) 9, 2 (1976).

[23] Philippe Macquer, *Dictionnaire raisonnée universel des arts et métiers* (France, 1773), 460-61.

[24] Brongniart, Arts céramiques, vol.1, pt.1 (1844), 228.

[25] Guerlac, "French Antecedents of the Chemical Revolution," 85-6; Christine Lehman, "What Is the "True" Nature of Diamond?" Nuncius 31, 2 (2016).

[26] Pierre Rousseau, Journal Encyclopédique 31, 4 (July-December 1771): 331-3; Gillispie, Science and Polity: Old Regime, 407.

Sèvres in which a group of seventeen savants and officials, including Darcet, Antoine Louis Brongniart, Cadet de Gassicourt, Fourcroy, and Lavoisier, witnessed the repeat of Darcet's trials.[27] The pyrotechnic display and the novelty of the experience encouraged the opening of a new course of scientific inquiry.

The questions the race for porcelain had raised directly factored into the research of Lavoisier, who had just begun independent work in natural history and chemistry. He did not yet have his famous laboratories at the Arsenal and was working in a more central location, probably near the Palais Royal.[28] The diamond experiments contributed to Lavoisier's emerging understanding of oxidation processes and the atmospheric conditions which allowed the diamond to burn, or those which protected it. Diamonds exposed to the air, either within an open crucible or encased in a protective crucible or *saggar* disappeared completely, and, when monitored in an open furnace, could be seen to glow and to emit a colourful phosphorescence. Partially consumed diamonds that were left to cool had areas which had blackened. However, it was common practice among jewellers and lapidaries to heat flawed diamonds to improve their clarity. They did so by encapsulating the diamonds with protective layers, shielding them from the damaging effect of the air. Existing chemical knowledge could provide no explanation for the chemical basis of their practice.[29]

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[27] On the series of experiments, see Antoine-Francois de Fourcroy, "Diamant," Élémens d'histoire naturelle et de chimie, t.2 (Paris, 1786), 379-392.
[28] Viel, C. "Did Lavoisier Have a Laboratory Other than That of the Arsenal?" *Revue d'histoire de la pharmacie* 42, 307 (1995): 369-73.
[29] Antoine-Francois de Fourcroy, "Diamant," Élémens d'histoire naturelle et de chimie, t.2 (Paris, 1786): 379-392.

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Like Lavoisier's first academic memoir on gypsum of 1764, which considered calcination and the release of chemically bound water, the burning of diamonds brought the presence of the atmosphere into the picture. It did so in such a way that the action of the fire could be seen in the effects that surrounded the diamond in mid-transformation. Like charcoal, it was possible to witness the diamond as it reacted with the atmosphere around it and then vanished. Additionally, the 1771 description of Roussel's firing techniques showed that the atmosphere also played a role in the outcome of fired pottery. Much like the encased diamonds, Roussel's kiln techniques prohibited the entry of fresh air to fuel the fire, which was the key to observable chemical and physical transformations that included whitening the porcelain paste. Both phenomena pointed to a similar mystery. In both cases, the kiln fuel and the diamonds were affected differently by the presence or the absence of air. Famously, Lavoisier realized that these effects could be measured to a high level of precision, and he devised special equipment to accomplish this task.[30]

The role of the unfired clay pastes used to encase the diamonds during the experiments have seldom been more than a footnote. Darcet used unfired clay in all of his experiments, which misled him into the belief that diamonds could be burnt without the presence of air. However, Macquer and Lavoisier both observed that the outcome of the diamond-burning

[30] See Guerlac, Crucial Year, 76-113; Christine Lehman, "What Is the "True" Nature of Diamond?" Nuncius 31, 2 (2016): 361-407; Hunt, "Melting of Platinum," 79; In the following decade, Guyton de Morveau was the first to show that diamonds and charcoal had the same chemical composition; Lehman, "À la recherche de la nature du diamant: Guyton de Morveau successeur de Macquer et Lavoisier," Annales historiques de la Révolution française 383, 1 (2016).

experiments were altered depending on whether an unfired or partially vitrified clay paste was used or if the crucible had previously been fired to its maturity. Lavoisier understood that the difference in the two materials had a significant effect on the outcome. Publicly, Lavoisier attributed the amount of air present when using unfired clay pastes as containers to the porosity of the material during firing. However, the differences between the interior colour and the exterior colour of the fired crucibles may also have given him some clue as to the differences in the internal and external atmospheres, as the areas that has undergone reduction would appear whiter.

In the process of the experiments on diamond burning, Macquer and Lavoisier could also consider the effect that various atmospheres and processes had on the character of the fired porcelains, or the effect of the firing on the clay pastes as they were heated and then vitrified. The survival or the disappearance of the diamonds provided evidence for understanding the kind of atmosphere surrounding the porcelain during the experiment. This added knowledge could benefit improvements in the manufacture of porcelain.

Looking from hindsight, in reading Lavoisier's *First and Second Mémoires sur la destruction du diamant par le feu*, written in 1772, but published in 1776, it is easy to overlook the repeated references to the porcelain crucibles. These now-inconspicuous references to experimental objects made of hard-paste "porcelain de Sèves" were in fact quiet assertions of the priority and the singular success of the Sèvres-based chemists in the development of a true French hard-paste porcelain between 1769 and 1771. In the experiments performed by Macquer and Lavoisier at Sèvres, a hard-paste Sèvres *sucrier* was used as a crucible. That this sugar dish closed tightly and acted effectively as a scientific apparatus was a subtle testament to its quality

of production, and it needed only a small amount of unfired clay paste to seal it completely during the experiment.

In conclusion, this talk has demonstrated the existence of a deeper connection between artisanal knowledge and practice and the development of Lavoisierian chemistry. By following the lead of William Brock and his attention to the wider context of Lavoisier's education and mentoring, we can gain a stronger sense of his early flashes of insight and rigorous ways of examining what were, as yet, still little understood actions. The instructive, highly visible experiments in diamond burning and porcelain development took place just before the start of what Henry Guerlac called "Lavoisier's Crucial Year" of 1772.[31] Lavoisier, Macquer, and Cadet de Gassicourt continued to experiment with the combustion of diamonds, and Lavoisier also experimented with phosphorus and sulphur, compounds which react strongly in the presence of oxygen. The combination of these efforts brought about Lavoisier's discovery of the role of oxygen, providing a foundation for modern chemistry.[32]

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[31] Guerlac, Crucial Year, 1961.
[32] In modern terms, *oxidation* and *reduction*, and in Brongniart's terminology, oxyder (to oxidize) and désoxyder (to de-oxidize). Brongniart, Arts céramiques, v. 2, 1844, 186-7.

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