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REFINING THE DATABASE FOR WHITE MARBLES: ISOTOPE ANALYSIS OF 18TH CENTURY MARBLE BUSTS BY JEAN-ANTOINE HOUDON

Katherine A. Holbrow

Abstract

This study examines the quarry provenance of marble sculptures by the French master sculptor Jean-Antoine Houdon (1741-1828), using light stable isotopes of carbon and oxygen in combination with petrographic techniques. Houdon’s famous portraits of heroic figures from the French and American Revolutions have enjoyed immense popularity for centuries, and have been copied so extensively and expertly that accurate attribution by art historians can be very difficult. However, documentary records from the Archives Nationales in Paris and the Académie Française in Rome reveal that marble for these sculptures was carefully selected from a limited group of Italian quarries. Using this information, 25 new samples were collected from the Torano valley quarries at Carrara and added to the pre-existing quarry database to provide a more accurate basis for comparison. Samples from thirty-one sculptures attributed to Houdon were compared to this expanded and improved database, and the comparison shows that a) the isotopic signatures of both groups fall within an extremely narrow range and b) the two groups are closely aligned. The results suggest that in circumstances where quarry sources are well documented historically, isotopic provenance determination may be useful for authenticating artwork of specific artists and periods.

1. Introduction

This study examines the marble sculptures of French master sculptor Jean-Antoine Houdon (1741-1828), using light stable isotopes of carbon and oxygen in combination with other techniques to identify marble quarry sources and thus to assess groups and trends.

Houdon’s work provides an ideal test case for examining the usefulness of isotopic and petrographic techniques. A large body of marble sculpture work attributed to Houdon is available for study, as well as numerous contemporary and later copies. The extent and quality of the copying, by Houdon’s atelier, contemporaries, and others since, are extraordinary. His choice of thinkers and politicians of the enlightenment for subjects, and his individualistic, intimate treatment of features and expressions struck a chord with the public and engendered wide demand. Houdon’s renderings of Franklin, Jefferson, and Washington speak so effectively of the ideals of American independence that they remain, literally, the symbolic currency of the nation.

Within the last few decades, instrumental techniques have been developed that can fingerprint calcite on an isotopic level, allowing scientists to match marble samples from sculptures with known quarries, and thus trace a sculpture’s primary source (Craig and Craig 1972; German et al. 1980; Herz 1985; van der Merwe et al. 1995 and others). As the technique of isotopic analysis becomes more widespread and the instrumentation more advanced, attempts have been made to apply the method, originally developed to identify Greco-Roman quarry sources, to
more recent works of art (Black and Nadeau 1990; Herz et al. 1995; Holbrow and van der Merwe 1997). Is the database relevant to later works such as white marble sculptures from rococo and neoclassical France? Is other information useful in conjunction with quarry source data? A fresh approach seems necessary to address these different circumstances.

Examination of such relatively recent works as Houdon’s provides an opportunity to integrate detailed examination of the sculptures themselves with historical research and isotopic analysis. Primary resource documents on marble quality and availability, quarrying and purchasing procedures, the role of the Académie des Beaux Arts in Rome and other related subjects are available from scholarly publications and the Archives Nationales in Paris. This information allows more precise quarry sources to be selected and sampled for comparison with Houdon’s sculptures. Using the improved database for comparison, thirty-one works attributed Houdon were sampled and analyzed using x-ray diffractometry and measurement of the stable isotope ratios of carbon and oxygen.

2. Individualism and replication in the work of Jean-Antoine Houdon

To make chronological sense of a large body of highly finished white marble sculptures that are attributed to a single artist, similar in treatment and often repetitive in subject matter, can be a particularly difficult task for art historians. The sculptures of Jean-Antoine Houdon form one such group. Traditional art historical assessment of the artist’s style combined with documentary research on provenance can answer many questions. In the case of an artist as popular as Houdon, however, the best-known works are so widely and continuously reproduced that technical and scientific analyses become necessary to augment historical research. For example, Houdon's famous portrait of Thomas Jefferson is circulated nationwide from the U.S. five-cent coin, and the artist’s idealized busts of young children continue to be reproduced in all media and sizes today (Figs. 1 and 2).

![Figure 1. Left: Jean-Antoine Houdon, *Thomas Jefferson*, 1789, marble. Boston Museum of Fine Arts, Boston, MA. Right: reproduced on US five-cent piece.](image-url)
While many of these renditions are easily distinguishable from the originals, other copies are expertly conceived and may be contemporary in date. Like many artists of his time, Houdon frequently reproduced his own works. In addition, students and lesser artists made copies for study and for sale, in recognition of Houdon’s skill. As early as 1794, Houdon himself complained that copyists were cutting into his profits: "...people are constantly copying my works, distorting them and putting my name on them; while others, still less honest, simply copy them and put their own name on them... defrauding me thus of my labor." (Arnason 1975, Appendix 3).

This situation has made attempts at art historical classification difficult, and it is perhaps for this reason that no catalog raisonné of the artist exists. Louis Réau, whose two-volume treatise on Houdon was published posthumously, collected primary source documents to begin the task (Réau 1964). H.H. Arnason suggests that more than 2000 works of all media by Houdon are thought "very likely" to exist; he presents and thoroughly discusses a group of approximately 330 works, of which 116 are marble. The "incredible proliferation of duplicates authorized and supervised by the artist," Arnason points out, requires a canon to establish standards for authenticity and provenance. (Arnason 1975, vii and 36) A number of scholars have made efforts to trace the provenance of a specific work or group of works and efforts are currently being made to address the need for a catalog raisonné, but scientific and technical contributions lag behind.
In a period when uniqueness of manufacture was not a virtue and all sculpture was reproduced, portraits were the most replicated. They functioned not strictly as fine art, but also as snapshots do today. Several of Houdon’s works were aimed at the broadest possible market, as for example the portraits of the philosophers Voltaire, Diderot and Rousseau. Houdon's contract for the bust of popular actress Sophie Arnauld survives, committing the artist to the production of thirty plasters as well as a finished marble version (Fig. 3), while as many as 100 busts of Voltaire may have been produced by Houdon (Arnason 1975). Others, such as the portraits of the Brongniart children or Houdon’s own daughters, use individual likenesses as ideals of childhood innocence, giving them popular appeal to a much broader market.

Houdon's massive output was made possible, in part, by the hierarchical workshop system in place in France at the time. In an 18th-century sculpture atelier, a number of technicians typically worked beneath the master sculptor. Technicians or practiciens contributed heavily to the finished products, roughing out the forms from a model produced by the master and completing as much of the marble work as ability (and wages) would allow, before a final "réparé" by the artist (Le Normand-Romain 1981; Réau 1964). Three technicians accompanied Houdon on his trip to the United States, to assist with the sculpting of George Washington. Some of these minor sculptors worked simultaneously for more than one artist as well as for themselves. Vincent Mazetti, who claimed in a letter to d'Angiviller to have "executed" Pajou's Bossuet, and "worked the figure" for Houdon's Marechal de Tourville (Réau 1964, 53), signed as a witness on Houdon's marriage certificate (Arnason 1975, 78).

Figure 3. Jean-Antoine Houdon, Sophie Arnould, 1775, marble. Louvre Museum, Paris.
3. 18th-century French marble: preferences and availability

3.1 Statuary marble and Carrara

Before such analytical techniques as isotopic fingerprinting can be usefully applied, a database of sample marbles must be available for comparison. Many isotope samples have been collected and published, and a master database was available for this study thanks to the generosity of Norman Herz [1]. Not all the data are relevant here, however. The most useful database is drawn only from relevant samples. Different regions have imported and carved specific marbles for many different reasons, including economics, war and other trade disruption, and changing aesthetic tastes. Art historical and social history sources can pinpoint the quarries that provide the best possible reference collection for the artist in question.

A number of quarries in the southern Mediterranean do produce marbles of the consistent color, softness, and quality preferred for sculpture. Although many of these Greek, Turkish, and North African marbles are typically larger-grained and cooler in color, they are commonly found in southern Mediterranean sculpture and architecture. Two regions, Mount Pentelikon near Athens and ancient Dokimeion (now Afyon; controlled by Turkey in the 17th century), do produce fine-grained white marbles. Petrographically, these marbles are certainly another possibility for any sculptor. The poor political climate between Turkey and the west restricted access to these areas at the time of Houdon’s work. An 1816 letter from Benjamin Latrobe to Senator Nathaniel Macon discusses available marble and eliminates these Turkish-controlled quarries: “The Parian and Pentelic Marbles of antiquity are not inferior to ours, but they are very superior to that of Italy. They are however inaccessible, being in the hands of the Turks...”(Fairman 1927, 32).

Some domestic white marble, quarried at St.-Béat in the Pyrénées, was used by French sculptors of the period. Other factors being equal, one might assume it would have been preferred as more easily accessible and politically expedient (Bresc-Bautier and du Mesnil 1986). This marble, however, has a larger grain size, more foliation and is harder and more brittle than Carrara marble. Not only is the stone more likely to split during carving, the large grains are also quite visible and the result can be a mottled effect (Fig 4). A portrait bust of Madame de Pompadour by Pigalle is one example of Pyrénéan marble used for sculpture (Fig 5).

Of all the marble available, the stone quarried in the Carrara region (which includes more than 40 quarries in three valleys) dominated the European market. The visual quality of Carrara marble was one reason for its broad use. The marble has a warm tint, producing a creamy ivory sculpture that appeals aesthetically. The carving properties of Carrara marble also made it desirable. Geologically formed by the metamorphic recrystallization of calcium or magnesium carbonate, marble is relatively soft, easy to cut, and takes a high polish. Carrara marble in particular has an extremely fine, even grain and very few impurities, making it prized by carvers. Peter Rockwell, in his *Art of Stoneworking*, describes Carrara statuary marble as “highly receptive to fine detail, as well as giving the impression of very high relative tensile strength. Extended arms and fingers… do not pose insurmountable problems… one of the two or three finest carving marbles known.” (Rockwell 1993, 27).
Figure 4. Calcite petrographic thin sections. Top: Carrara marble, unpolarized light, 100x. Bottom: Pyrenéen marble, polarized light, 100x.

Figure 5. Jean-Baptiste Pigalle, Madame de Pompadour, 1748-51, marble. Metropolitan Museum of Art.
Even at Carrara, marble of a quality suitable for sculpture is fairly rare. Although the Carrara region is large, the majority of marbles found there are of the gray-striped *calacata* type and other coarser grade marbles suitable for building (Fig. 6). White *ordinario*, found in fairly large quantity, is described by Rockwell as “off-white tending toward gray, frequently with lines or areas of darker gray... often seems slightly harder than the statuary marble... Its principal defect is the cold white to gray of its color, which makes it much less visually attractive than the statuary variety.” (Rockwell 1993, 27). Bedding planes and weak areas formed by streaks of soft impurities also make hand carving more difficult; such striped marble is more commonly used today with the advent of power tools for carving.

Only a few Carrara quarries consistently produced the fine-grained, white, statuary-grade marble so desired by the sculptors and patrons of the eighteenth century. Dolci has identified Ravaccione, Polvaccio, Betogli, Mandria, and Crestola in the Torano valley of Carrara, and Fantiscritti quarry in the Miseglia valley as producers of *statuario* (Dolci 1980). Others narrow the list still further. Klapisch-Zuber describes the marble of Betogli, Mandria, and Crestola as “semi-statuary,” and Mandria and Crestola marbles are yellowish in color, and marked by violet and yellow veins (Klapisch-Zuber 1973). Only small white blocks can be obtained from Mandria and Crestola, both of which bear numerous veins of pyrite and magnetite. Rockwell rates Betogli marble *ordinario*, rather than *statuario*, and it has been rejected by at least one discriminating French sculptor: in a 1774 letter to his friend and agent Vitale Finelli in Carrara, Clodion demands only the best marble, and specifically warns “not Betogli.” (Griseri 1961, 164).

Polvaccio was the quarry best known for its pure white *statuario* (Fig. 7). In 1741, Michel-Ange Slodz, Houdon’s teacher, described Polvaccio as the place “from which are extracted the most beautiful marbles” (Souchal 1966, 51). Even here, production was irregular, and primitive
excavation techniques a continual risk. A tourist describes the collapse of this quarry in the mid-18th century:

a little before I went to Serravezza, there occurred the collapse of the most famous and richest quarry of statuary marble called Polvaccio, so that for a great period of years, at least, one could not extract marble... and that of Pianello in said place, having marble not much good for statues, but only useable for working flat... (Klapisch-Zuber 1973, 89 note 6).

Figure 7. Polvaccio, 19th-century, engraving. Comune de Carrare, Italy.

The quarries at Seravezza (located approximately 20 km southeast of Carrara), exploited by Michelangelo and producing very fine white statuary marble, must be considered as another possible source for French sculpture. Seravezza is not mentioned as a source in documents preserved in the Archives Nationales and the Académie. Because the two regions are relatively close, however, the term “Carrara” occasionally refers to Seravezza as well.

Thus, although the Carrara region initially appears to be a broad source for sculpture marble, mineralogical variations within the region have been recognized for centuries by discriminating artists and patrons. When the finest and whitest marble was desired, the quarries which produced it consistently were limited to a very few: Polvaccio, Ravaccione, Fantiscritti, and Seravezza.
3.2 Marble availability and access

Documents in the *Archives Nationales* in Paris, and published correspondence from the *Académie Française* in Rome indicate that from 1750 to 1790, the marble available for sculpting was drawn from a very small pool indeed. Within France, the rigid structure of government made trade and imports difficult:

Nowhere was this system of State encouragement (direct subsidies, interest-free loans, concessions, exclusive privileges) carried so far as in late 17th- and 18th-century France, where *manufactures royales* and privileges secured loans and subsidies, honorific titles and practical monopolies (Miller et al. 1987, VI:430).

This statement especially applied to marble, which was an elite and rare material. Since 1700, the King had enforced a monopoly on all marble production, reserving the best for Royal projects and then selling the remainder at fixed prices through his *Sûrintendant des Bâtiments*. In 1725, absolute control was extended to all shipments entering France, and in 1765, French quarries were required to submit reports and samples to the King. Failure to comply was punishable by fines and confiscation. These strict controls and prices made domestic marble, from St-Béat, actually more expensive and unobtainable than that from Carrara (Bresc-Bautier and du Mesnil 1986).

Delays and restrictions in obtaining, transporting and distributing marble in Paris were considerable. French marble agents, including the King’s agent, purchased their marble blocks through marble workers and sculptors at Carrara, in the Ripagrande depot in Rome (Le Normand-Romain 1981), or at nearby ports such as Livorno, where Clodion picked up his marble blocks for Abbé Terray’s commission (Bailey 1993). In Carrara, the quarries were controlled by the local landowner, the Comte de Carrara. Marble was initially purchased from the Comte at a price that reflected costs of extracting and carting it to the nearby port at Massa (Montagu 1989).

When a particular project arose which required special attention, a French agent might be sent to select and purchase the marble personally. A 1741 letter from the *Directeur* of the *Académie* in Rome and the *Directeur des Bâtiments*, sums it up thus: “the work done by an intelligent man who is on the spot is very different than that of one who must work through the hands of the merchants”(de Montaiglon 1875-1892, IX: 444:4371). Slodz, sent to Carrara to find large blocks for Coustou’s horses (now on the Champs Elysées), took nine months to find marble suitable to the project, while Clodion, on a similar mission in 1774, wrote to the *architecte du roy* of the difficulties in procuring large blocks (Thirion 1885).

Although its primary purpose was to provide classical training for young artists, the *Académie* in Rome also provided French sculpture patrons with an important base from which to purchase marble. In their published correspondence, the *Directeur des Bâtiments* and the *Directeur* of the *Académie* in Rome discuss the quality of the marble, the availability of different types, and record details of many purchases (de Montaiglon 1875-1892). During their stay in Rome,
sculpture students were introduced to the quarries of Carrara and the mechanics of selecting and negotiating marble purchasing. These Rome-trained artists (including Slodz, Canova, Clodion, and Chinard) became the preferred purchasing agents for the Crown, arranging to visit Carrara and select high-quality blocks. Although in principle unpaid, such commissions were desirable as they allowed artists to stay in touch with the agents for the Crown, who were the source of all Royal commissions being made back in France. Chinard’s letter of 1806, offering such service, is a masterpiece of flattery: “I will find my recompense in the satisfaction of aiding the ‘immortels’ who direct the glory of the arts for the enlightened Ministry who protects them.” (Archives Nationales F21 476)

Once shipped to Marseilles, the marble imports were under the control of the Directeur des Bâtiments. Réau refers to the praticien Vincent Mazetti, shipping blocks from Italy for Houdon and other sculptors, and requesting storage space in a government warehouse (Réau 1964). After arriving in Paris, state-purchased marble was stored in one of the King's warehouses at Chaillot, rue Louis-Grand, or (after 1772) La Muette (Bresc-Bautier and du Mesnil 1986).

Members of the Académie had strictly limited access to the royal marble stores. Only royal commissions entitled one to this marble, which had been selected and reserved for the King. Inventories of the dépôt des marbres at Chaillot show that larger blocks of marble were ordered with specific building or sculpture commissions in mind, and were tagged accordingly. Larger blocks were designated both an artist and a subject. Warehouse inventories also show that the vast majority of the marble came from Italy. There are very few mentions of blocks from Greece, and none of purchase or order of Greek statuary-grade marble (Archives Nationales O1 2065-2101; O2 315).

The delays and restrictions met with in acquiring marble seem to have led to a certain amount of sharing and lending of marble blocks and related services. Clodion, officially sent to Carrara to select marble for the King, was also expected to purchase additional blocks for commissions of his patron, Abbé Terray, at the same time. This marble was then shared out to the four artists commissioned by the Abbé (Poulet and Scherf 1992).

Expedience led Houdon to use his own marble for the production of his one Royal commission, the Maréchal de Tourville. In a hurry to see his work in marble, Houdon negotiated to provide his (previously purchased) block on condition that it be replaced by the Crown. On 7 October, 1780, D'Angiviller's agent, Cuvillier, agreed:

Houdon will use his own block. We will replace it with one of the same size. The block will be chosen by Houdon from among those waiting at Carrara and Marseilles for the King and he will choose one of paste and grain approximately equal to the block that he delivers and that this same block given him in exchange, will be delivered free of postage and handling to his atelier in Roule (Réau 1922,370).

The Crown's reluctance to replace the block (Pierre later claimed conditions were "trop juste") protracted the negotiations, and by July 1782 Houdon is writing directly to d'Angiviller, and has still not received his replacement block (Réau 1922).
The international political situation also affected the availability of marble. War between France and Britain and depredations during the French and Indian War (or Seven Years War) slowed down shipping from 1756-1763. A period of relatively free trade followed the war, during which commercial enterprise flourished and Italian marble was used extensively for sculpture, and during which the bulk of Houdon's work was produced. This flood of trade lasted until the American Revolution placed France at war again in 1778. Royal and aristocratic expenditure on luxuries such as marble was being paid for by more and more forced, no-interest loans under Terré, Necker, and Calonne (Hirst 1910). The result was inevitable: in 1789 the Revolution effectively halted trade in luxury goods for the remainder of the century, due to domestic upheaval as well as difficulties in gaining access to Carrara (by 1793, France was at war with most of Europe). The Commision Temporaire des Arts was formed to deal with reports of looting at the Chaillot depot, and through the years of 1794-1795 steps were taken to provide surveillance and protection of the State supplies. In 1794, Clodion negotiated with the Commision Temporaire des Arts for the return of an unused block from a canceled commission (Tuete 1917).

Although artists like Houdon continued to produce marble sculptures during the 1790's, they were probably using up old inventory. The marble trade did not revive until Napoleon’s conquests stabilized the French economy and opened new markets through the Treaty of Amiens in 1802. In an 1808 letter, M. Henraux, the commissioned agent for marbles for the French government, tells of boats full of marble, stranded on the Italian coast by the depredations of the English (Archives Nationales F21 573). Other officials note the excessive price of transport during the war and the fact that the Royal depot has not been replenished for a long time (Archives Nationales O2 315).

Thus the available historical documentation and contemporary examination of the marble and quarries indicate that Polvaccio and possibly Ravaccione were the primary source of large white blocks for French monumental sculpture in the late 18th - and early 19th -centuries. With the possible addition of Fantiscritti, it seems likely that these quarries were the source for most small marble blocks as well although clearly more variation is to be expected here. While other statuario quarries should be considered as well, these quarries must be well represented in the database.

4. Marble Analysis

4.1 Factors used to determine marble provenance

Historical research shows that French 18th-century sculptors were selective in their choice of marble. Can these marbles be distinguished analytically? Because a great deal of the isotopic data overlap, this technique cannot be used alone. To be useful, the isotopic data must be limited to as small and appropriate a group as possible. White marbles, the only color of interest here, are isolated first. Next, the marble is sorted by grain size. As mentioned earlier, Carrara marble is noted for its extremely fine grain. The maximum grain size seen at Carrara is only 1.5 to 2 mm (as compared to as high as 12 mm maximum grain size found in Greek, Turkish and North African quarries). The mineral composition of the marble is also important: some quarries
produce dolomitic marbles (i.e., with a magnesium carbonate content of more than 10%). Although this does not affect the visual appearance significantly, the mineralogy is easily detected by means of x-ray diffraction (Moens et al. 1988; van der Merwe et al. 1995).

### 4.2 Isotopic and petrographic techniques

Because of these distinctive features, marble samples should first be distinguished by measuring grain size and/or by x-ray diffraction. The mass of isotopic data can then be reduced to a few, distinguishable quarry fields. All stone samples (both geologic and sculptural) were initially examined using a 10x hand lens, for general color, mineral inclusions and distribution, and approximate grain size. Where samples were large enough, a portion was mounted and polished for petrographic examination. Examination of the polished section provides valuable information concerning grain size, texture, and grain size caused by metamorphic pressure in the stone, as well as very limited qualitative identification of accessory minerals. The mounted sample also remains available for further analyses. X-ray diffractometry was employed to establish whether the marble is calcitic or dolomitic, and the average grain size estimated by hand lens and/or through examination of a thin section. The results of these measurements were combined to identify the most probable quarry sources for the various samples.

All of the sculptures examined here were found to be calcitic and to be very fine-grained, with an average grain size of less than 1 mm in diameter (often much finer). These facts limit the possible quarry matches to only three Mediterranean regions: Mount Pentelikon, Dokimeion, and Carrara/Seravezza, eliminating white marble from St-Béat and most Greek and Turkish sources.

Of the instrumental analytical techniques explored for identifying marble, isotopic fingerprinting has emerged as one of the most useful. Carbon dioxide is extracted from the calcite mineral phase of the stone using phosphoric acid, and the isotope ratios of $^{18}\text{O}/^{16}\text{O}$ and $^{13}\text{C}/^{12}\text{C}$ measured in a mass spectrometer. Isotope ratios for each element are compared to the PDB standard, and the result expressed as $\delta$ or deviation from the standard, in parts per thousand (‰).

Studies have shown that several factors can influence the accuracy of isotopic analysis of marble. Weathering, contamination, natural variations in the rock, and the presence of inclusions or accessory minerals may cause shifts in isotope ratios. The analytical precision for the measurement of $\delta^{13}\text{C}$ is typically about 0.1‰; the new data reported here have precision of about 0.05‰. By contrast, isotope ratios within an outcrop or quarry have been estimated in earlier studies to vary up to 2.0‰, and variations have been found within a single, apparently homogenous slab of as much as 1.0‰. Weathering and contamination of the stone were also found to skew results considerably (Herz 1985; Herz and Dean 1986; van der Merwe et al. 1995).

The sculptures examined here produced far more consistent results than these earlier test cases. Aesthetic choices during this period ruled that blocks with only minimal inclusions or accessory minerals be used for sculpture, and that weathered and discolored outer surfaces of the quarried block be discarded. Consequently, data from the sculptures examined shows much less variation than the geologic samples tested in the publications cited above, by virtue of this pre-selection
(and also since, having been kept continually indoors since cut from a fresh block, weathering is thereby omitted as a factor).

Statistical analysis of the sculpture data remains impractical; due to limitations of removing marble from valuable sculptures, it is often impossible to take more than a minute sample. Approximately 5 to 10 mg of marble were collected from each sculpture, typically from the back, underside, or bottom edge (if possible at the site of a previously existing chip or flaw) using a small chisel. Sculpture samples were analyzed using a VG PRISM mass spectrometer at the Peabody Museum, Harvard University, using a common bath autocarbonate system and synthetic standards. Where duplicate runs were possible, the variation in $\delta^{13}C$ was 0.05‰ (Schrag 1997).

New geological samples (collected from quarries) were taken from fresh cuts at least six inches deep to avoid distortion from weathering. Each sample weighed approximately 1 kg. The geological samples were analyzed by Dr. Chris Hayward, geologist at the Natural History Museum in London (Hayward 1997).

4.3 Customizing the Carrara isotopic database.

Most Carrara data currently in use was obtained from a study of the Carrara quarries carried out in 1986 by Norman Herz and Nancy Dean (Herz and Dean 1986). Because the data were first collected for sourcing of ancient monuments and sculptures, the database has some gaps when used with later works. Isotopic data from the Torano quarries Polvaccio and Ravaccione, as well as the Miseglia quarry of Fantiscritti, should be included for best results. A map of the Carrara quarries sampled by Herz and Dean shows that these areas are not well represented (Fig. 8). Only one sample is identified as Polvaccio, for instance, which was a quarry of central importance in the period in question here. To redress this need, a trip to the Carrara quarries was made in 1997 (Fig. 9). There, additional samples were collected by Dr. Hayward and the author, focusing on the Torano valley quarries historically known to produce *statuario*. Figure 10 shows the Carrara map with the new sampling locations marked [2].

Twenty-three new samples from Polvaccio are plotted in Figure 11, along with the original Herz and Dean database of all fine-grained, calcitic white marbles. A detail of the Carrara fields is shown in Figure 12, with the new data points indicated as a darker color. Herz and Dean have already pointed out that two quarries, Seravezza and Mandria, can be isotopically distinguished from other Carrara quarries, and they are outlined (Herz and Dean 1986).
Figure 8. Map of Carrara quarries, reproduced from Herz and Dean 1986.

Figure 9. Collecting marble samples in Carrara, 1997.
Figure 10 Map of Carrara quarries, reproduced from Herz and Dean 1986, with new sampling locations added.
Figure 11. Graph: Isotopic analysis of fine-grained white marbles.

Figure 12. Graph: Isotopic analysis of Carrara quarries.
On examining Figure 12 it can be seen that, within the Carrara region, the Torano *statuario* quarries form a highly discrete group. Ninety percent of the data from Polvaccio clusters within 1‰ in oxygen isotope ratio, and 0.4 ‰ in carbon. The range is smaller than the previous “Carrara” field, which included architectural-grade marble, *calacata*, Betogli, and other geologically (but not art historically) significant quarries.

It is also apparent that data from the quarries producing lesser-quality stone such as Colonnata and Betogli are more dispersed. The most sought-after stone is located further up the Torano valley, and this is the source of the most tightly clustered discrete data. Crestola Basso, located on the extreme edge of the marble-producing region, taps a separate (and much smaller) marble layer in the earth and produces more random isotopic ratios. Because time and logistical constraints precluded collecting samples from the Miseglia valley, only two samples were available from the Fantiscritti quarry. Although it is accessed from the Miseglia valley, Fantiscritti exploits the same marble vein as the Torano quarries. It is located on the other side of the same mountain as the Polvaccio quarries, and today connects to the Torano valley by a tunnel. These data also plot at the center of the *statuario* data field. A relationship between the homogenous, unveined white marble that artists’ preferred visually, and an extremely narrow isotopic range is evident.

### 4.4 Isotope data for marble sculptures

It has become clear that from 1750 to the turn of the century, statuary marble shipped to France through the offices of the Crown was strictly limited in source as well as narrowly defined on an elemental level. Do the sculptures themselves corroborate this evidence? By comparing isotopic data from quarries with samples drawn from actual marble sculptures, patterns in sculpture production emerge.

Previous research in this area allows a larger picture of marble usage over time to emerge. During earlier research at the National Gallery of Art from 1994 to 1998, all the marbles in the collection were sampled and tested (Herz et al. 1995). Some of these data are reported here, sorted by date (Figs. 13 and 14). Figure 14 plots 19th-century sculptures and shows a broader spread of data points. It can be speculated that by this time, trade restrictions were loosened, international trade had expanded, and artists had more options for obtaining marble.

Figure 13, plotting French works dating from 1744-1790, shows a very tight grouping, clearly reflective of the historical and economic situation described above. The sculptures plot almost completely within the newly defined "Torano *statuario* group". Data for nine of the eleven works vary by only 0.6‰ in the oxygen isotope ratio, and less than 0.3‰ in the carbon.
The data for the National Gallery of Art collection show that only a tiny percentage of non-
ancient, western European works were produced from Greek or Turkish marbles, with the vast
majority identified as being from Carrara. For the period in question, samples plot well within
the isotopic field assigned to the Carrara region. The question of whether Seravezza marble was
used is also resolved. While the proximity of the two regions may have caused the quarries to be
referred to interchangeably, analytical evidence indicates that Seravezza was not used. Of all the
18th-century French works sampled, only one data point might fall within the Seravezza quarry

Figure 13. Graph: Isotopic analysis of French sculptures, 1744-1790.

Figure 14. Graph: Isotopic analysis of 19th-century European sculptures.
field. Until further evidence arises, it seems reasonable to conclude that Seravezza was not a common source for French sculptors. Mandria can be distinguished isotopically. Active use of Mandria quarry during the period with which we are concerned is not documented, and no National Gallery of Art sculptures analyzed matched Mandria, so there is no positive evidence that the French used these quarries.

5. Houdon

Can a single artist’s work be usefully assessed in the context of these new data? The National Gallery’s six sculptures by Jean-Antoine Houdon provided a starting point for addressing this question. An additional 25 works from nine other institutions, some well documented and others less so, were sampled and analyzed. Figures 15 shows the resulting data, plotted against the newly defined Torano statuario field.

Houdon's sculptures can now be evaluated within the context of this newly defined group. Figure 16 shows the same data in closer detail. Numbered points refer to the itemized data table shown in Figure 17. The curatorial attributions of the different sculptures are not all equally firm, and the items sampled include some considered to be “after Houdon” as well as well-dated works and some unknowns. Comparing this curatorial information to the points plotted on Figure 16 reveals some encouraging correlations.
Of the five works thought to be “after Houdon” or only “possibly” Houdon, three plot outside the Torano statuario field. Madame Clothilde from Waddesdon Manor, which according to the curatorial documentation “may or may not be by Houdon” (Seeley 1997), is of Pentelic marble. As no other Pentelic marbles have been identified in Houdon’s oeuvre, the data reinforce the doubt expressed by the curator. The White House’s George Washington, considered “after Houdon”, also plots outside the Torano statuario field as does the similarly attributed Benjamin Franklin.

Of the seven works believed to be by Houdon, but dating after 1800, four lie outside the “Torano statuario” field. While such a small selection is hardly representative, it does suggest that the more varied marble use after the Revolution, seen on a larger scale in Figure 14, is consistent with this artist’s production.

Dating sculptures by identifying the stone from which it was carved involves inherent uncertainty. Because the marble blocks might be saved for years before being carved, a Torano statuario block could be used decades or centuries after it was quarried. Thus the isotope data for post-1800 works is less useful for interpretation purposes, even if a larger body of sampled sculpture were available. During the early nineteenth century, government commissions still used Torano statuario, since the Ravaccione quarry was exploited during the Napoleonic era. Of the four later works that fall inside the “Torano statuario” field, two, Napoleon and Josephine, are imperial commissions.
### Data table: sculptures attributed to Houdon

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<th>#</th>
<th>Location</th>
<th>Title</th>
<th>$%$</th>
<th>$%$</th>
<th>Date</th>
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<td>1.87</td>
<td>1778</td>
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</tr>
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<td>Laetitia</td>
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<td>George Washington</td>
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<td>1.76</td>
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<td>-1.43</td>
<td>2.37</td>
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</tbody>
</table>

Bold-face type indicates well-documented works. Question marks following the date indicate doubtful authenticity. Curatorial information was provided from curatorial files of participating museums, with additional information from Anne Poulet of Anne Poulet Art Resources.

**Figure 17.** Data table: sculptures attributed to Houdon.
While the possibility of using old blocks of marble also holds true in the case of pre-
Revolutionary France, the historical evidence discussed previously suggest that rarity and high
demand allowed little sculptural marble to sit unused for long. The larger body of data also
makes interpretation slightly less speculative.

Of the 19 works thought to be by Houdon, and with a presumed 18th-century date, only three
sculptures plot outside the Torano *statuario* field. The National Gallery of Art’s *Alexander
Brongniart, 1777*, whose provenance is uncertain, is one outlier. This marble could be from
Seravezza, rather than Carrara. Two others, the National Gallery of Art's *Louise Brongniart,
1777*, and the Huntington Gallery’s *Sabine, 1791*, plot very close to the Torano *statuario* field,
but are also outside.

The very tightly clustered group, comprising three portraits of Voltaire from the National Gallery
of Art, the Victoria and Albert, and Versailles, forms another pattern worth noting. The very
large number of portraits of the famous scholar (estimated by Arnason at over 100) implies that
there might be less of the hand of the artist in these works. The overlapping data points could
suggest that the group was produced from the sections of the same marble block. This is also true
of *Napoleon* and *Josephine*, clearly carved as a pair.

6. Conclusions

By using historical material to focus the scientific analysis, then using scientific results to
confirm art historical observations, interesting and potentially useful comparisons may emerge.
This is especially so in a period such as 18th-century France, where political and historical
circumstances confine the data fields to very narrow ranges. Exploring these changes in the
French use of statuary marble, then developing an improved and expanded data base of both
Carrara quarry marble and marble sculptures in museum collections focusing on that use,
produces a deeper understanding of a specific period and its artists. Evaluated by this method,
Houdon’s sculptures show interesting groupings and anomalies that could be pursued, and may
relate to authenticity and date.

Dating sculptures by sourcing marble will always have inherent limitations. Although historical
research may be able to confirm still further the precise quarries exploited at any one time in the
historical era, the possibility always remains for idiosyncratic marble usage: blocks saved or
reused from different eras, etc. The isotopic data thus must always show likelihood rather than
limits. It can only highlight trends and groupings that merit further historical and stylistic
evaluation.

Likewise, the database of marble sculptures is still too small for statistical analysis. As more
museums analyze their collections, and as fingerprinting techniques continue to improve, the
information will become a highly useful authentication tool. Even with this small body of works,
the results are promising enough to suggest the method should be pursued.
Endnotes

1. The database for stable isotope analysis of white marbles, made available by Dr. Norman Herz of the University of Georgia, contains data from numerous sources, both published and unpublished, including: Craig and Craig 1976; Herz and Dean 1986; Moens et al., 1988; and Jongste et al. 1995.

2. Hayward and Holbrow research was supported by the Samuel H. Kress Foundation and by the Andrew W. Mellon Foundation, 1997.

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