BÖTTGER STONEWARE: WHAT SCIENCE CAN TELL US

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Figure 1. "Emergency money" (coin mounted as a pendant), dated 1922. Private collection.

In recent years, Böttger stoneware has come under increased scrutiny from collectors and scholars as attributions and dating are called into question. In an effort to better understand the Böttger red stoneware body, a study has been designed to determine if modern scientific and analytical techniques might provide useful information. An explanation of the study is presented here, but the project is still in an early phase, and final results will not be forthcoming for several years. A number of extremely complex issues are involved, and they must be approached with great care and objectivity, for the subject deserves nothing less.

Two questions were posed for this study. First, is it possible to distinguish Böttger stoneware from "not Böttger" stoneware based on the composition of the body? Second, are there elements in the composition of the Böttger red stoneware body at various dates that if combined with visual analysis might lead to better ways of dating this material? Curators, conservators, and scientists are joining forces in a project organized by the Nelson-Atkins Museum of Art in collaboration with the J. Paul Getty Museum and the Porcelain Collection of the State Art Collections, Dresden, in an effort to answer these questions.

Red stoneware was the first ceramic body successfully produced by Johann Friedrich Böttger. As a young alchemist recently arrived in Dresden, Böttger was assigned to ceramics experimentation by Ehrenfried Walter von Tschirnhaus, a gentleman scientist and

Figure 2. Medallion commemorating the birth of Johann Friedrich Böttger, dated 1982. Private collection.

economic advisor to Augustus the Strong, Elector of Saxony and King of Poland. Augustus's passion for porcelain is well-known, and it was he who supported the experiments that led to the discovery of the red stoneware body and ultimately to the white hard paste porcelain for which Meissen is so justly famous. Although the exact date is unknown, the red stoneware body was apparently developed in 1706-7. This date is confirmed in a written report of 1736 by one of Böttger's first assistants, Paul Wildenstein, a miner from Freiberg. Wildenstein stated that tests with "red porcelain" were conducted in 1706 in Meissen and 1707/8 in Dresden.[1] Other contemporary accounts support those dates. When Dr. Jacob Bartolomaus, one of the Meissen factory's first official arcanists wrote "Erlernung des rothen und weißen Porzellains" [The Learning of Red and White Porcelain], a treatise dated January 6, 1708, he stated that red stoneware was invented by the beginning of that year. A glass cutter is listed in the factory records in July of 1708, suggesting the body had been perfected and thought was being given to its decoration.[2] Although stoneware was more developed technically and artistically than porcelain, Böttger soon achieved his goal of producing a white hard paste porcelain, and Augustus the Strong founded a porcelain manufactory in 1710, installing it in the Albrechtsburg in Meissen. In the same year, red stoneware was exhibited at the Leipzig Fair along with the newly developed white porcelain.

Meissen appears to have been primarily a stoneware factory from 1710-1712.[3] Various forms with diverse decoration were made and sold, some following the Chinese red stoneware models from Yixing and some following European metalwork prototypes. The secret of red stoneware manufacture was sought by rival princes at an early date, and unscrupulous workers were happy to oblige. Samuel Kempe, one of Böttger's associates, absconded to Prussia, and with his assistance red stoneware was made at Plaue about 1713. Examples of Plaue's wares were offered for sale at the Leipzig Fair in 1715.

Unfortunately, no recipes for Böttger's red stoneware body survive from the early years of production, but the earliest ingredients are mentioned in a manuscript of 1736 stating: "and as they found the clay from the Plauen Grund is rather liquid, they added instead a flux of the firmer Nuremberg Red [clay] or earth."[4] According to other contemporary accounts, clay from a number of different sources evidently was used. Samuel Stöltzel, the early compounder and kilnmaster writing in 1725, and the arcanist, Johann Christian Schatter writing in 1738, both confirm the predominant use of clay from Nuremberg and red clay from the Plauen Grund near Dresden.[5] They also mention yellow clay, and they note the use of red clay from Okrilla near Meissen and clay from Zwickau southwest of Dresden. Stöltzel also states that the clay from Nuremberg used by Böttger could be purchased at merchant Bohmes in Dresden. The recipes listed by Schatter are interesting but useful only to a point, for they simply list proportions of different types of clay.

In *Oryctographia Norica* [Nuremberg Fossil Lore] of 1708, Johann Jacob Baier discussed two clays from the Nuremberg area which produced a red body when fired. Baier said of the first, a red clay from Troschenreuth: "it is being extracted in such large quantities that one wagon after the other can be loaded quickly and … it can be sold at a very cheap price."[6] The second clay was rarer and "not as easily available to foreigners," for Nuremberg was in Bavaria and Dresden was in Saxony.[7] Baier also noted the more common of the two Nuremberg clays was used for medicine. As Böttger was formerly an apothecary's apprentice, he already may have been familiar with it.[8]

Firing red stoneware presented special problems. The clay mixture had an extremely small *sinter interval,* or range between the point at which the materials fuse and the point at which they melt.[9] Stöltzel, the kilnmaster, reported that "this brown porcelain must be baked in the same kilns and capsules [saggers] as the white transparent porcelain, only with lower temperatures, and must all very carefully be observed....and is still subject to many fatalities, more than the white transparent

Figure 3. Cup and saucer, 1711-15. The George R. Gardiner Museum of Ceramic Art (G83.1.565.1&2).

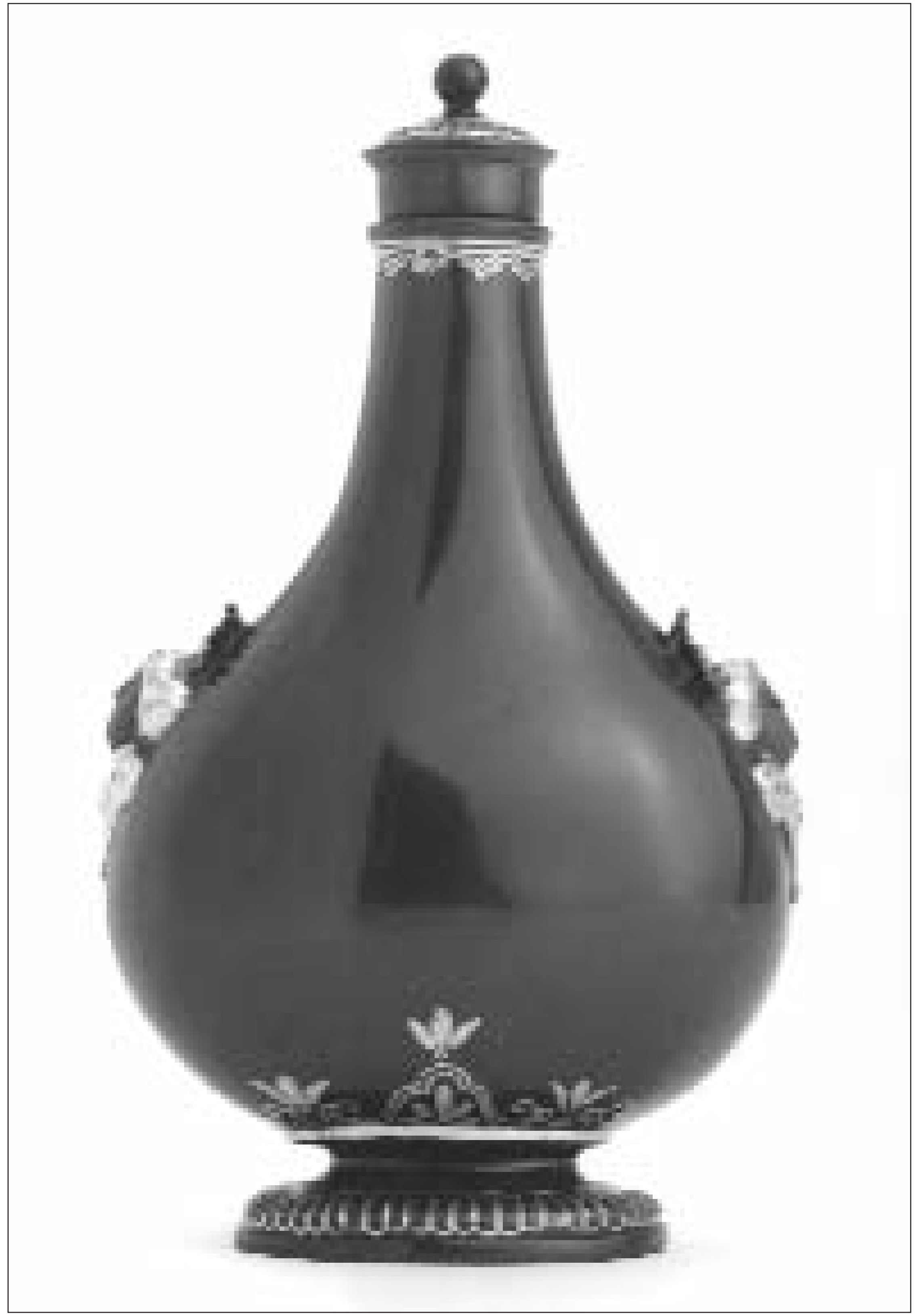
porcelain."[10] Differences in color of Böttger stoneware may be attributed, at least in part, to the vicissitudes of the firing process.

The resulting higher cost of red stoneware manufacture and the perfection of the white porcelain body may have led to decreased public demand for the red bodied ware around 1714. Polished stoneware appears to have been manufactured only occasionally at Meissen after 1717, but "stoneware" appeared in catalogues until 1735 listed at very high prices.[11] It was apparently a favorite of Augustus the Strong, and he continued to purchase it until his death in 1733. Schatter's recipe book of February 1738 lists six mixtures for red porcelain, but the recipe book of 1741 lists none.[12] It has been assumed, therefore, that the production of red stoneware was completely discontinued about that time.

At present, there are no firm indications the Meissen factory revived the red stoneware body in the 19th century, but it was nevertheless valued and apparently highly regarded during that period. "Red Porcelain – Böttger period" was included in the exhibits of the *Exposition Retrospective d'art Industrielle* in Brussels in 1888, for example, and Gottfreid Semper (1803-1879), the architect of the Dresden Opera House wrote in 1863 that stoneware "put its inventor, Böttger, in as high a position as did his brilliant success in the detection of the true secrets of porcelain manufacturing."[13]

At the beginning of the 20th century, Ernst Zimmerman, the Director of the Dresden Porcelain Collection, and Dr. Julius Heintze, the technical director and works inspector of the Meissen factory, explored the composition and techniques for manufacturing Böttger stoneware. They conducted the first scientific analysis of the body, and in July 1907 they recorded the following chemical composition of a tankard, the one object they tested: 65% silicon (SiO_2), 20% aluminum (Al_2O_3), 9% iron (Fe_2O_3), 2% calcium (CaO) and magnesium (MgO), 3% alkalis, and traces of manganese (MnO_2).[14] The 20th-century reinvention of

Figure 4. Flask and lid, 1711-15. The Nelson-Atkins Museum of Art (F96-1/1A,B. Purchase: The Lillian M. Diveley Fund, an anonymous donor, and Mr. and Mrs. Earl D. Wilberg.)



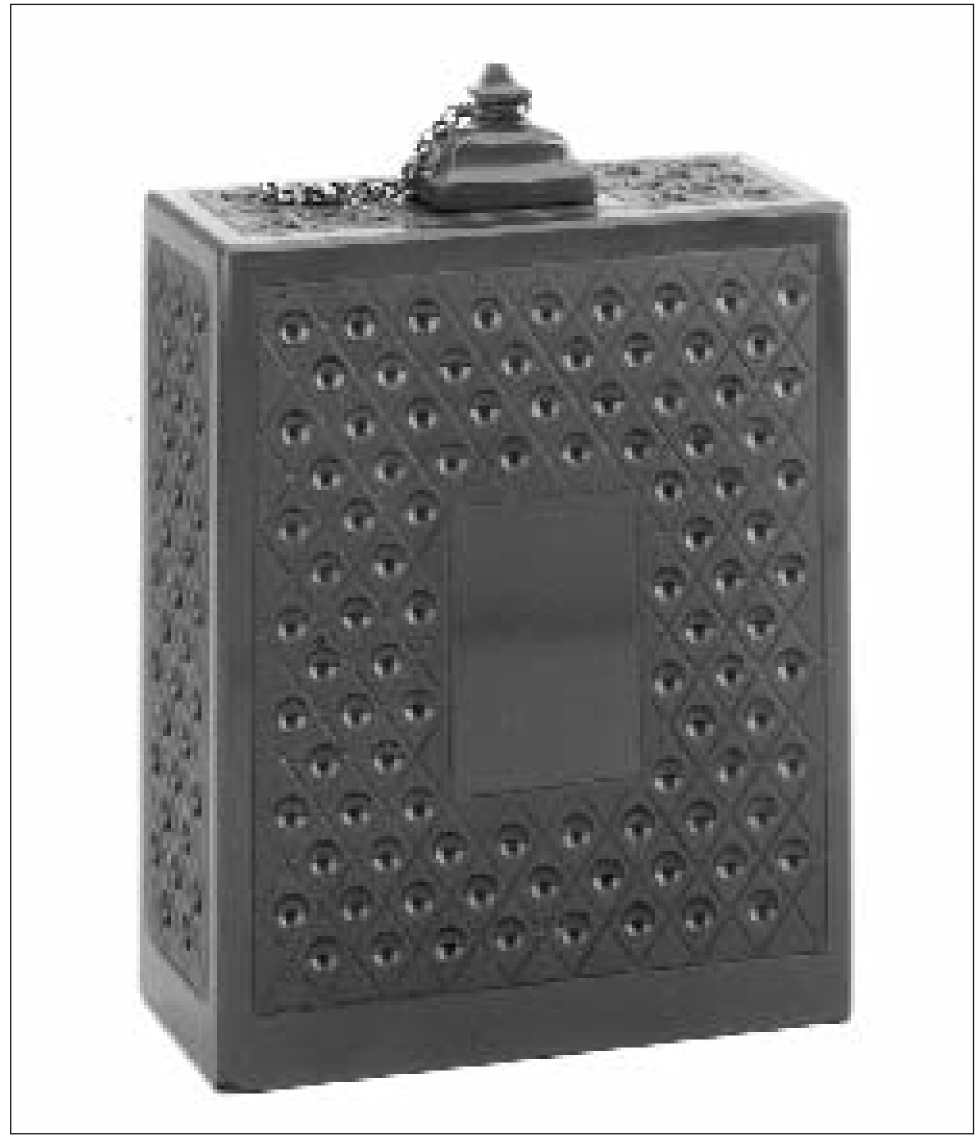


Figure 6. Tea caddy and lid, after 1845, according to thermoluminescence tests.

the red stoneware at Meissen was based on their research. This work took a number of years, but about 1919 Dr. William Funk was finally successful in producing a commercially viable body. He used two types of clay, but unfortunately, only the suppliers are known, not the geographical area from which the clay came. It is known that a red clay from the Meissen area was used, and the clay from one of the suppliers may have come from Nuremberg as it did in the 18th century. Funk must have encountered technical problems in his work, for approximately 130 compositions were tested and recorded by the end of 1920.[15]

The new mixtures developed by Funk included the addition of feldspar as a flux. Variations in color were achieved by adding manganese, and Funk apparently was able to make the mixture more plastic by adding ground kiln wasters. He also developed a useable slip so items could be cast.[16] "Böttger stoneware" gained a firm place in the production of the Meissen factory in the 1920's and was particularly favored for sculptures and small decorative objects such as wall plaques and medallions. The "emergency money" made for the Saxon Finance Ministry in the years 1920-22 *(fig. 1)* was perhaps the best known use of the reinvented stoneware body, but sculptures in "Böttger Stoneware" are recorded well into the 1930's. Apparently, some single pieces were also made in an attempt to adapt Böttger's

Figure 5. Bottle with engraved decoration, 1711-15. Private collection.

Figure 7. Bowl, cup and saucer, undetermined date. Private collection.

technology to new products. In structure and degree of water absorption, the bodies developed by Funk were closer to Chinese redwares than to Böttger's stoneware.[17]

The Meissen factory next revived the red stoneware body around 1982 in conjunction with the 300th anniversary of Böttger's birth. The wares produced at that time included both utilitarian wares and decorative objects such as medallions *(fig. 2).* Cutting and engraving were attempted for decoration, but judging from the examples still at the factory, these techniques were not revived with great success. In the 1980's, improvements in processing the raw materials and the ability to carefully regulate the firing process resulted in a high density body. The final product was very close to Böttger's original red stoneware and to the structure of porcelain. In the 1990's, red stoneware continues to be made at Meissen in a variety of forms and in several body colors.

The first extensive scientific analysis of the Böttger red stoneware body was conducted in the 1980's in Germany at the Freiburg Mining Academy and at Weimar.[18] The study, undertaken by Dr. Bernd Ullrich, focused on Böttger and later Meissen stoneware, but it also included red stonewares from Plaue and China in an effort to better understand the composition of the body. The study entailed microscopic examination, elemental analysis and detailed studies of each body's density by measuring its water absorption.

Ullrich examined samples using scanning electron microscopy equipped with an electron probe microanaylzer (or EMPA) to obtain a quantitative analysis of the principle elements in the body. Statistics were presented for the following eight elements: sodium (Na_2O), magnesium (MgO), aluminum (Al_2O_3), silicon (SiO_2), potassium (K_2O), calcium (CaO), titanium (TiO), and iron (Fe_2O_3). Ullrich employed XRF (X-Ray Fluorescence Spectroscopy) equipped with special instrumentation to detect trace elements present in the body, but apparently he was not able to measure them. Zirconium, rubidium, strontium, yttrium, niobium and lead are mentioned, but no quantitative analysis was given. The trace elements were fairly consistently present throughout the entire group with the exception of lead. It was believed to be a contaminant from materials used to glaze some red stonewares, not an element in the raw clay.

The body of previous scientific work has been very useful and informative, but the project presented here focuses on obtaining an accurate quantitative analysis for as many trace elements as possible in hopes of detecting even slight differences in body composition at various dates. A study of this type obviously requires a group of securely dated objects. There are four possible means of composing a sufficiently large group of dateable objects to produce reliable results. The first way is to date objects through scientific testing. Only thermoluminescence testing is potentially useful in this regard.[19] Viewed with skepticism by some, the TL test is generally acknowledged as an accurate method of dating, and it is admissible evidence in a court of law. Thermoluminescence testing has been done successfully on Böttger stoneware, but there are drawbacks and limitations. The test does not give an exact date, only a

Figure 8. Bowl, detail of footring, undetermined date. Private collection.

date range. Unfortunately, TL testing is also slightly destructive. It requires a core sample (a sample taken from inside the wall of an object) and many pieces of Böttger stoneware are too thin-walled for the extraction of a sample.

The second and most practical means of assembling a group of securely dated objects is to accept the date of objects of excellent provenance. Fortunately, a large and well-documented group of these wares exists from the 18th century, for Böttger stoneware survives in several important collections. The Porzellansammlung in Dresden is the greatest repository of securely dated Böttger stoneware, for it houses objects owned by Augustus the Strong. Although most of these objects fortunately remain in Dresden, over the centuries, a few of them have found their way into other collections around the world. Due to time constraints, objects now in North American collections were used exclusively for the first phase of this study, and only objects bearing the famous "Johanneum" inventory numbers were accepted as having an undisputed provenance *(fig. 3).*[20] Other extremely well-documented objects such as those owned by the Margraves of Baden were also accepted as 18th century *(See fig. 4).* Objects actually bearing dates, such as the "emergency money" of the 1920's constituted the third securely dated group, and objects purchased new in Dresden in the 1980's and 1990's constituted the fourth.

In the end, the "control group" of securely dated objects numbered fifteen examples varying in date from c. 1710 to c. 1995. Three other objects clearly appearing from visual analysis to be 18th-century were also tested. These eighteen closely dateable objects were then compared to a group of seven objects whose dates and/or origins were questioned based on visually determined anomalous characteristics of construction or body composition. The total test group, therefore, was composed of twenty-five objects. Lids were counted as separate objects as were cups and saucers.

The eighteen closely dateable objects included the following five examples from the period 1710-15: a pokal from the Arnhold Collection, New York, (Johanneum number 212./R in black enamel), a cup and saucer from the Gardiner Museum, Toronto, (each with Johanneum number N.75/R in black enamel), and a flask and its lid documented in a Baden-Durlach estate inventory of 1805-09 now in the collection of the Nelson-Atkins Museum. A bottle exhibiting an engraving technique and style particular to the early 18th century *(fig. 5)*, and a baluster jar and its cover on the art market in the spring of 1997 also were accepted as 18th century based on visual analysis, but they lack "Johanneum numbers." Five pieces of "emergency money" from the 1920's, a saucer and a medallion from the 1980's, and two medallions and a figure of a hedgehog purchased new in 1995 completed the control group.

To analyze the test group, a number of methods were considered. A non-destructive test yielding a quantitative elemental analysis of the body was considered most desirable, but the choices were quickly limited. Neutron activation, perhaps the most accurate test, is used successfully on softer bodies such as terra cotta and Italian maiolica, but it is destructive and, therefore, was rejected. Atomic absorption, another very accurate analytical technique, is also destructive and was deemed equally inappropriate.[22] Research led to the choice of two complimentary non-destructive scientific techniques to advance this study. First, to provide a general semi-quantitative analysis of the body, twelve objects of known date and five of questioned date were examined using Scanning Electron Microscopy (SEM) with energy dispersive X-ray spectrometer (EDX) operating in a variable pressure mode.[23] It was not possible to examine the other eight objects in the test group using EDX for they were either too large to fit in the chamber of the SEM, or they could not be transported to one of the SEM facilities for the initial study. Before placement in the SEM, each sample was cleaned with reagent grade ethanol to remove any contaminants that might be present on the surface.[24]

In addition to providing an initial semi-quantitative analysis of the elements in the body, EDX also presented a visual image of the surface of the specimen.[25] It examines the surface to a depth of 50-100 microns and detects elements from beryllium to uranium on the periodic table of elements. EDX is not good for studying trace elements, and the size of the object or sample is also limited. Most SEMS cannot accommodate objects larger than a tennis ball. EDX has the great advantage of being able to analyze very specific particles in the body, however, and a white or black speck appearing on the screen can be studied and the elements identified.

The second and most important analytical technique employed in this study was PIXE, Particle or Proton Induced X-ray Emission. PIXE is a system for elemental analysis. Using PIXE in an external beam mode, it is possible to measure elements from sodium to lead on the periodic table of elements.[26] PIXE is non-destructive, and as the size of the sample is nearly unlimited, very large objects can be analyzed. PIXE induces the emission of x-rays characteristic of the elements in the sample by irradiating the sample with protons. It analyzes materials such as pottery to a depth of only 15-20 microns, but the depth can be decreased by changing the angle of the beam. As only the surface of the sample is examined, this was considered a perfect technique for studying unglazed ceramics. PIXE is able to detect trace elements far better than XRF or EDX; it can detect concentrations as low as parts per million. Thought to be up to one thousand times more sensitive than EDX and more sensitive than X-Ray Fluorescence (XRF), the degree depending on the XRF system used, PIXE analyzes the materials as percentage of composition by weight for the elements. The beam can be made as large as a millimeter, but by scanning the surface, it can map the elemental composition across a surface and average the numbers to get a more accurate reading. Areas up to 2-3 millimeters with a ½ millimeter beam size were scanned for this study. In the case of the red stonewares being analyzed, a florescence fortuitously appeared on the surface of the pots, so the exact location of the test area was known. Each area to be analyzed was cleaned prior to analysis with an ethanol swab. The instrument was calibrated using the glass standards of the National Institute for Science and Technology, formerly the United States National Bureau of Standards.

From three to five different areas were analyzed per object, and each area was analyzed under three different conditions of filtering and proton beam energy to detect elements in different regions of the periodic table. The first reading was done in a stream of helium gas so that lighter elements could be detected down to sodium or magnesium. The subsequent readings for the elements with higher atomic weights were done with various filters to obtain the proper readings. A quantitative analysis was obtained for sixteen elements: aluminum (Al_2O_6), silicon (SiO_2), sulfur (SO_3), chlorine (Cl_2O), potassium (K_2O), calcium (CaO), titanium (TiO_2), chromium (Cr_2O_3), manganese (MnO), iron (Fe_2O_3), copper (CuO), zinc (ZnO), rubidium (Rb_2O), strontium (SrO), zirconium (ZrO_2), and lead (PbO).

All of the twenty-five objects in the test group were analyzed using PIXE. Initial results indicate that overall, the Gardiner cup and saucer are most similar to the Pilgrim Flask and the baluster jar and cover. The Pokal is most similar to the Pilgrim Flask, but with even less manganese. The Pilgrim Flask and lid, the baluster jar and cover, and the Gardiner cup and saucer show the presence of a significant amount of lead. With one exception, the coins from the 1920's bear more similarities to each other than to the other objects. The coins exhibit a much higher level of manganese, a finding consistent with the known addition of manganese to the recipe in the 1920's. The medallion made to commemorate Böttger's birthday in 1982 and a saucer purchased new in 1984 exhibited the same high levels of manganese as the "emergency money." Of the three objects purchased new in Dresden in 1995, a medallion commemorating Böttger and a medallion commemorating porcelain modeller Johann Joachim Kaendler, were closely related to each other in composition. Indeed, all of the 20th-century coins and medallions were more closely related to each other than to the 18th-century objects. Significantly, the "emergency money" from the 1920's, the objects from the 1980's, and the medallions from the 1990's were found to have a much higher manganese-iron ratio in comparison to all the other objects in the study.

The seven objects of questionable date and/or origin can now be divided roughly into two related groups, based on visual evidence and PIXE analysis. In the first group, one of two tea caddies *(fig. 6)* was determined by thermoluminescence testing to date after 1845. Stylistically, it might be seen as related to the 1920's, but this object is not especially similar in composition to the coins tested from that period. It is not similar to objects tested from c. 1715, however, or to the objects tested from the 1980's and 1990's.[27] At present, the object in the test group of twenty-five most closely related to the first caddy and its lid is a second tea caddy of similar form and decoration. The lid of the second tea caddy is different in body composition and is most closely related to the Baden flask in the control group of dateable objects. The bodies of the two tea caddies are very similar to each other not only in composition but construction.

The second group of anomalous objects includes a bowl of unusual size, a tall cup or beaker, and a saucer *(fig. 7)*. These teawares appear to be high-fired and dense; they ring when tapped. They are glassy in surface appearance, and there are few impurities visible to the naked eye. All of these objects have tall, precise footrings *(see Fig. 8)*. According to PIXE analysis, the bowl, cup and saucer are most related to each other. They are not like the coins from the 1920's, the modern medallions, or the 18th-century Baden flask which has three times the amount of titanium. They are most

similar to the two tea caddies, but the three teawares have half the calcium of the caddies. The saucer, but only the saucer, bears similarities in composition to the saucer from the 1980's.

Although results from this initial study raise interesting issues, definitive conclusions are yet to be drawn. To allow the best possible chance of answering the two questions posed at the beginning of this paper, and in hopes of producing the most accurate possible final result, the number of objects tested and examined in this study must be increased. Objects from the two groups of wares presented at the end of this paper are of particular interest as are unusual forms in silver mounts and shards from which scientists might take pieces. If readers have objects or shards of interest, please contact the author.

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NOTES

1. Hannes Walter, "Der Werkstoff Böttgersteinzeug und seine Weiterentwicklung," in *Symposium anläßlich der Johann-Friedrich-Böttger-Ehrung* (Dresden-Meissen, 1982), p. 40.
2. *Ibid.,* p. 41.
3. *Ibid.,* p. 41-42.
4. *Ibid.,* p. 40.
5. *Ibid.,* p. 41.
6. *Ibid.,* p. 41. Clay from Troschenreuth was still being used in ceramics manufacture as late as the 1980's.
7. *Ibid.,* p. 41.
8. From Roman times, certain red clays were commonly thought to have healing properties, and Böttger's red stoneware was sometimes referred to as "Terra Sigillata" in contemporary sources. See Maureen Cassidy-Geiger, "The Japanese Palace Collections and Their Impact at Meissen," *International Art and Antiques Dealers Fair 1995 Handbook*, pp. 15-24, for further discussion.
9. Hannes Walter, "Der Werkstoff Böttgersteinzeug," p. 41.
10. *Ibid.,* p. 42.
11. Otto Walcha, *Meissen Porcelain* (New York, 1981), p. 31.
12. Hannes Walter, "Der Werkstoff Böttgersteinzeug," p. 42.
13. *Ibid.,* p. 39.
14. *Ibid.,* p. 42.
15. *Ibid.,* p. 43.
16. *Ibid.,* p. 43.
17. *Ibid.,* p. 45.
18. Bernd Ullrich, "Vergleichende Untersuchungen an historischen deutschen und chinesischen Steinzeugen des frühen 18. Jarhunderts," *Silikattechnik* 41, no. 10 (1990), pp. 328-330.
19. This dating technique is based on the principle that an object absorbs and accumulates radiation over time. The firing process drives off the accumulated radiation, hence re-setting the radiation clock to zero. Therefore, any measured radiation can have accumulated only since the time of the object's last firing, usually the date of manufacture. A sample taken from the object and then heated gives off a glow or luminescence that is carefully measured to determine the date of the object's last firing.
20. Augustus the Strong's collection was first inventoried in 1721 with additional entries up to 1727. The various ceramic wares were listed in separate chapters, and the corresponding numbers were placed on the bottoms of the pieces, either painted in black or wheel cut and filled with black. The collection was re-inventoried in 1770 and 1779; these inventories still exist in sets of five volumes each.
21. See Michael Hughes, Hugo Blake, John Hurst and Timothy Wilson , "Neutron Activation Analysis of Italian Maiolica and Other Related Medieval Italian Ceramics." *The Ceramics Cultural Heritage*, edited by P. Vincenzini (Florence: Techna, 1995), p. 521. The authors clearly demonstrate that by careful analysis of the body, it is possible to indicate a place of manufacture.
22. Atomic absorption requires a sample of 10-100 mg. which is completely destroyed in the course of the test. The sample is put in solution and light of the particular elemental frequency is directed at it and the absorption is measured. Had shards been available for this study, atomic absorption would have been possible. It has been used successfully on Japanese porcelain. See Oliver Impey, *The Early Porcelain Kilns of Japan; Arita in the first half of the Seventeenth Century* (Oxford: Clarendon Press, 1996), Appendix 2, p. 144.
23. The scanning electron microscope images the object; the EDX analyzes it.
24. Two different instruments were used, a Hitachi S-2460N, and a Jeol JSM-5800. The software performing the analysis was the same on both instruments: Noran Voyager III.
25. EDX was employed as a screening technique. In addition to the control group of closely dateable objects, seven pieces of stoneware of undocumented date were examined, one piece of early 18th-century glazed and lacquered Böttger red stoneware, three pieces of 18th-century English redware, and two pieces of Chinese redware from Yixing. The present study unfortunately lacks Dutch stoneware and documented wares from Plaue. For data on the Dutch stoneware, the author relied on Christian Jorg's lecture "Yixing and its European Imitations," a lecture presented at the Ceramics Fair in 1990 and later appearing as an article "On Some Physical Characteristics of Chinese and European Red Wares," published in *Archeometry* 34, I (1992), pp. 43-52.
26. The analyses were done by Dr. Charles P. Swann of the Bartol Research Institute at the University of Delaware.
27. Production of the 1920's should be more closely examined. As previously noted, there were 130 recorded recipes created c. 1920.