PROFILE OF AN ORIGIN: A CHEMICAL AND PHYSICAL CHARACTERIZATION STUDY OF HISTORIC BRICK AND CLAY FROM THE ASHLEY RIVER, SOUTH CAROLINA.

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ABSTRACT

The goal of this thesis is to develop an adapted scientific methodology for identifying the clay region or source location for a particular brick used in early Charleston, South Carolina. The focus of the paper will be on the Ashley River region. It will review previous scholarly research, theses, and publications on Charleston brick, geology of the river and selected analytical methods with intent to build on this topic. A justification is also given for the selection of the materials and testing methods used for the study. Through chemical and physical characterization testing, of clay sites and bricks of known historical structures along the river, it is hoped that regional identifications can be made. The thesis further recommends continual research in the expansion of the study area.

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INTRODUCTION

Historic brick and brickwork around Charleston, South Carolina has been thoroughly researched but no one has taken the steps to connect brick to their location of origin. This thesis takes this next step to help create an adapted methodology to identify brick and a regional brick family. The three major rivers surrounding Charleston; the Ashley, Cooper and Wando, each supported brick making facilities on their banks that supplied the area with well made brick. The Ashley River, the region of study, is highly researched but little investigation has traced brick of the Charleston region to its banks.

This thesis first reviews the previous research in the areas of brick history in the South Carolina Low Country, geology of the river, clay found in the region, similar brick and ceramic provenance studies and analytical methods used with ceramics. This overall view lays the framework for what is found in the area and what methods have been successful.

This study analyzed eight brick samples and two clay deposits. The brick sites are justified through past research and availability of materials; these sites are Colonial Dorchester, Lord Anthony Ashley Cooper's settlement and Drayton Hall Plantation. The two clay sites were at or near previous brick manufacturing sites; Colonial Dorchester and Church Creek. All the characterization testing was completed at the National Brick Research Center near Anderson, South Carolina, under the direction of Dr. Dennis Brosnan. The choices of analytical methods used were guided by Dr. Brosnan's experience and expertise. The methods used were: Archimedean density and porosity, moisture content, loss of ignition, mercury intrusion, colorimeter, standard petrographic thin section analysis, x-ray fluorescence, x-ray diffraction, thermal expansion, and thermal gravimetric firing.

The thesis describes testing methods and the processes used to conduct them. Following these, results are shown in graphs, photographs, and tables. The analysis section explains the findings through visual, chemical, microscopic and other physical characteristics while evaluating the results in perspective to previous studies. In the last section the study concludes with the summation and future phases.

CHAPTER 1: HISTORY OF BRICK AND THE ASHLEY RIVER

1.1 Geology of the Area

Charleston is located on the coast of South Carolina at the convergence of three major rivers; the Ashley, Cooper and Wando. These water ways have played a major role in the developing population growth of the area. The clays from these riverbanks helped build Charleston and the surrounding plantations. The region of study for this thesis is the Ashley River.

The east coast of North America has an ever changing shoreline, because of the daily rise and fall of the tides and the warming and cooling trends of the earth. Geologists and archaeologists have studied these multiple climatic changes through the analysis of sediments of the soils. There is evidence of drastic shoreline changes in the Low Country of South Carolina over the past 20,000 years. The current counties of Berkeley, Charleston and Dorchester, located in the lower Coastal Plain of South Carolina, have land terraces that indicate the former shoreline (such as those found in Goose Creek, in the Cooper River region.) These terraces extend along the entire east coast of the continent. Dr. Charles Kovacik, a Geology professor at the University of South Carolina, has noted that, "Changes in sea level through time resulted in the formation of these terraces; most are composed of sandy soils with some gravels derived from beach and deltaic deposits associated with the shorelines."[1] Modern sea levels only occurred in the past 5,000 years and it was then that the Ashley, Cooper and Wando Rivers formed.

[1] Charles Kovacik and John Winberry. South Carolina: The Making of a Landscape. (Columbia, SC: University of South Carolina Press, 1987), 21.

All three rivers have a wide range of surrounding environments including coastal beaches, thick forests, swamp lands, and marshes. This range of environs and raw materials, such as clay for brick making, encouraged early development by Europeans. In 1664, a surveyor for the first Lord Proprietors remarked on the soil he found on the coast of Carolina; "rich ground of a grayer colour, they have made Brick of the Clay which proves very good."[2]

1.2 Early Brick History in the South Carolina Low Country

The first English settlement, established in 1670, was located about three miles above the current site of Charleston on the Ashley River. A decade later the settlement relocated to Oyster Point, on the peninsula at the convergence of the Ashley and Cooper Rivers. This new development, known as the "Grand Modell," was a city plan designed by Lord Anthony Ashley Cooper, the first Earl of Shaftesbury.[3] This design established Charles Towne as the urban center of the colony. In 1682, Thomas Newe arrived in Charles Towne and wrote about his initial view of the town. He stated that "The town which two year since had but 3 or 4 houses, hath now about a hundred houses in it, all are wholly built of wood tho [sic] there is excellent Brick made, but little of it."[4] Within the first decades of English settlement, there were a few large brickyards. Most of were located along the Cooper or Wando Rivers. The Dutchman Jan van

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[2]A .S. Salley Jr. *Narratives of Early Carolina*. (New York, NY: C. Schribner's Sons, 1911), 68.

[3] More on Lord Ashley's view of the "Grand Modell" see South Carolina Historical Society's "The Shaftesbury Papers" or to see more on how Lord Ashley's plan was implemented by colonial Charlestonians see Emma Hart's *Building Charleston: Town and Society in the Eighteenth-Century British Atlantic World.* (London. University of Virginia Press. 2010). This "Grand Modell" was a plan that was used many times in Colonial English Settlement; there is no known designer of the first "Grand Modell." Lord Ashley used this plan to set up Charles Towne.

[4] A.S. Salley Jr. *Narratives of Early Carolina*. 181.

Arrsen made brick along the Cooper River at Medway Plantation as early as 1686.[5] Sites have also been located on the Ashley River as early as the mid-1670s.[6]

By 1700, Charles Towne had grown tremendously. The Gentleman Surveyor-General of North Carolina, Thomas Lawson, commented that Charles Town had "very regular and Fair Streets, in which are good buildings of Brick and Wood, and since my coming thence, has had a great additions of beautiful, large Brick buildings."[7] Brick buildings were likely owned by the wealthy citizens or groups who wanted to display importance of power by using more expensive and permanent building material. Brick construction was also found on the plantations outside the city. Dr. Emma Hart, a professor at the University of St. Andrews, Scotland, noted that, "Until the 1730s, Charleston house builders had used local wood to construct almost all but the most expensive houses, making the townscape look somewhat temporary in nature and wholly vernacular in style."[8] This abundance of wood provided great fuel for the fires that occurred in the colonial period. 1698, 1710 and 1740 saw horrendous fires that challenged the first few generations of the town.[9] It was after the great fire of 1740 that Charles Towne was forced to change its approach towards construction and town planning. (Figure 1.1) As a result of the extensive destruction, the General Assembly immediately passed an act that controlled all new

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[5] Marie Ferrara Hollings. *Brickwork of Charleston* (unpublished master's thesis, University of South Carolina, 1978). 5. A few different spellings of the last name have been used. Marie Ferrara Hollings, *Brickwork of Charleston*, and Samuel Gaillard Stoney, *Plantations of the Carolina Low Country*, cites Van Arrsen family at Medway but a later reference in Lucy Wayne's thesis, *Burning Brick*, cite the last name as "van der Dussen."

[6] Brockington and Associates. *Archaeological Investigations at 38DR83A, St. Giles Kussoe House/ Lord Ashley Settlement.* (Mt. Pleasant, SC: Brockington and Associates, 2010).

[7] John Lawson. *A New Voyage to Carolina (1700).* (Middlesex: Echo Library, 2007), 3-4.

[8] Emma Hart. *Charleston: Town and Society in the Eighteenth-Century British Atlantic World.* (London, University of Virginia Press, 2010), 68.

[9] Most of these early fires swept through many of the residences and commercial buildings of the early settlement. The fire of 1740 took out most of Charles Towne. Historic Charleston Foundation has an interactive map that displays the area of destruction during the 1740 fire. This map is located at http://www.historiccharleston.org/experience/charleston_fires.html.

construction, stating that "no dwelling house, shop, ware-house, barne [sic], stable, or any other building whatsoever, of timber, (unless the said timber be upon the very spot of land) shall be erected or set up within the lines of the fortification of Charlestown, but of brick, unless in particular cases, as herafter is directed by this Act."[10] It further directed that if a building were constructed of timber it would "be deemed a common nusance [sic], and the owner of such frame building shall enter into a bond of recognizance, in such sume [sic] as the said commissioners, or any three of them, shall think fitting, to demolish the same."[11]

This act clearly referenced the *1667 Rebuilding Act of London,* and followed its overall preference for brick. This act stated that, "in regard that building with brick is not only more comely and durable, but also more safe against future perils of fire."[12] The Low Country lack of stone and an increased need for new, permanent, governmental, ecclesiastical, large social buildings spurred the growth of the brick industry in Charleston.

During the mid-eighteenth century new brickyards continued to be established along the surrounding rivers. Hollings notes that, "Bricks were made near Charlestown on the Wando River, on the Back River in Goose Creek Parish, in Christ Church Parish, on the Ashley River, and

[10]David McCord. The Statutes at Large of South Carolina: acts, records, and documents of a constitutional character. (City of Charlestown Statutes, South Carolina Room, Charleston County Public Library, 1840)
[11] ibid.: Most of the statute was ignored and many officials did not follow through with the guidelines. Many houses were built of wood in the city limits during this time.
[12] Great Britain and Danby Pickering. *The Statutes at Large from the Twelfth Year of King Charles II to the Last Year of King James II*. (Cambridge, London: Joseph Bentham (printer),1763), 235-236.: Section Seven of the Act is "And in regard the building with brick is not only more comely and durable, but also more safe against future perils of fire; (2) be it further enacted by and with the authority aforesaid, That all the outsides of all buildings in and about the said city be henceforth made of brick or stone, or of brick, and stone together, except door-cafes and window-frames, the brest summers, and other parts of the first story to the front, between the piers, which are to be left to the discretion of the builder, to use substantial oaken timber instead of brick or stone, for conveniency of shops; and that the said doors brest summers and window-frames be sufficiently discharged of the burthen of the fabrick by arch-work of brick or stone, either straight or circular." (written in old English, but trasnscribed by author)

on the Cooper River."[13] A few prime areas were making large quantities of brick, they include Parnassus Plantation, on the Back River, Boone Hall, and Brickyard Plantation on the Wando River and its tributaries. (Figure 1.2 and 1.3) Most plantations focused primarily on the production of profitable crops such as rice, indigo and cotton. Plantations along certain tidal rivers, such as the Wando, however, found the water too saline and could not drain fields properly for these lucrative crops. Brick making became another method of economic prosperity; Twenty-three brick yards have been identified along the Wando River prior to the Civil War.[14]

Lucy Wayne, in her doctoral thesis about Low Country brick making, mentions that "Brickmaking was a natural selection based on the presence of all of the necessary elements for the industry, as well as the close relationship which existed between these plantations and the Charleston commercial community."[15] The plantations along the Ashley, Cooper and Wando Rivers held the three ingredients needed for successful brick manufacturing. Navigable rivers hauled the merchandise to the consumers. Materials, such as Clay and sand, were found along the rivers, while the fuel source for firing brick was found in the abundant forests that existed on the plantations. Lastly, slaves provided the labor needed to produce the thousands of individual brick each day. During the mid-eighteenth century, the African slave population increased

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[13] Marie Ferrara Hollings. *Brickwork of Charleston*. 15.

[14] Lucy Wayne. *Burning Brick: a Study of a Low Country Industry*. (PhD Diss., University of Florida, 1992), 9.
This number (23) may have increased due to more archeological excavations and shovel tests due to increased development in the area.

[15] Lucy Wayne. *Burning Brick*. 14.

greatly to the point that the slave population outnumbered the white Europeans.[16] This made a large work force available in many fields of skilled and unskilled labor, including brick making.

Dr. Hart notes that "Throughout the colonial period, Charleston was the epicenter of urban life in the Low Country and increasingly a point of reference for the South Carolina backcountry and for Georgia, North Carolina and Florida."[17] For example, the construction of St. Michael's Anglican Church at the corner of Meeting and Broad Streets required a large amount of brick. Brick for the buildings were made at several sites in the Charleston area but over half of the total brick came from Zachariah Villepontoux. [18] Charleston historian Gene Waddell wrote that "The masonry work on the church continued to progress rapidly. By July 1, 1753, 624,700 brick had been purchased, and by October 12, a total of 1,021,940 bricks had been actually laid."[19]

St. Michael's was not the only major construction during the mid-eighteenth century. Structures such as the State House, fortifications surrounding the city, and Charles Pinckney's double house were constructed of brick made at local plantations. Certain names soon became

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[16] Wood, Peter H. *Black Majority: Negros in Colonial South Carolina from 1670 through the Stono Rebellion.* (New York, W.W. Norton & Company, 1974), *.:* "During the quarter century after 1695 this racial balance shifted markedly, so that by the time the colony's Proprietors gave way to a royal government in 1720, Africans had outnumbered Europeans for more than a decade."*(pg 131)*

[17] Emma Hart. *Building Charleston: Town and Society in the Eighteenth-Century British Atlantic World*. 2. No other settlements in the frontier of the southern colonies were close to Charleston's influence and size. Only later did Camden, South Carolina, become a town of size. Although Camden still heavily relied on Charleston, Hart wrote that "By the 1770s, the town [Camden] functioned as a backcountry processing center selling dry goods, gathering wheat and flour, and accommodating travelers on their way through the colony. But importantly, these were all processes that occurred in support of Charleston's place as the major market of the region." (52)

[18] G.W. Williams. *St. Michael's Episcopal Church Records: St. Michael's Episcopal Church Records of 1751-176.* (transcript, South Carolina Room, Charleston County Library, accessed 2010). The church kept records of all the materials bought for the construction of the church building. For the purchasing of bricks the records are divided by date, quantity of brick and brick makers. The quantity ranges from 3000 to over 12000 bricks at a time. The names of brick makers include Jas. Withers, Peter Sanders, Humphrey Sommers, Zachariah Villepontoux and Shobel. Out of the eighteen recorded purchases of brick eight were from Villepontoux.

[19] Gene Waddell. *Charleston Architecture: 1680-1860*. (University of California, Wyrick, 2003), 108.

synonymous with good brick manufacture, such as Villepontoux, Goodbe, Horlbeck, Gordon and Snow.[20] Some projects specified brick to look like a certain Charleston maker's style. St. Stephen's Church building committee even demanded that "the Size of the moles to be equall [sic] in Bigness to Mr Zachry VILLEPONTOUX's."[21] Research suggests that brick was not always shipped from large brickyards but was often made close to the site of construction.[22] This likely lowered the cost of the project if clay was available on the property. Thus smaller production was occurring along with the larger, well known, brick yards of colonial Charleston.

The need for brick continued even during the Revolutionary War, as Charleston was a growing metropolis. At the end of the eighteenth century, it was one of the largest cities in the developing nation. Walter Fraser, a professor of History at Georgia Southern University, states that "By the early 1770s the city's permanent and transient population reached approximately 12,000 persons."[23] By 1779, Dr. Alexander Hewatt, an early historian of South Carolina and Georgia, wrote "The town, which was at first entirely built of wood… has often suffered from fires… Now most of the houses are built of brick."[24] A few years later "Timothy Ford, who arrived in Charlestown in 1785, found that, 'None of the dwelling houses rise higher than three

[20] Lucy Wayne. *Burning Brick*. 51: Wayne lists (table three) known brick makers and, if known, their plantation during different eras from 1740 through 1860. These are not all large, commercial brick yards but plantations recorded as making brick or that had brick kilns on the property.
[21] Jane Searles Misenhelter. *St. Stephen's Episcopal Church, St. Stephen, SC*. (Church Record, State Print Co., 1977), 9.: the church eventually hires "Mr Zachry Villepontoux" for the job in which he later signs a brick in the church, along with the bricklayer William Axson in 1767.
[22] Lucy Wayne. *Burning Brick.:* "Brickmaking occurred wherever suitable clay and fuel were available. Often, the bricks were made at the site of the building to be constructed." (5)
[23] Walter Fraser. *Charleston! Charleston! (Columbia, SC, University of South Carolina Press,* 1989), 135.
[24] Bartholomew R. Carroll*. Historical collections of South Carolina : embracing many rare and valuable pamphlets, and other documents, relating to the history of that State from its first discovery to its independence, in the year 1776. (AMS Press, 1972)..*502.

stories, and by no means a majority so high; tho [sic] a pretty good proportion of the buildings especially of brick, may be termed tolerably good."[25]

Brick continued to be popular for construction into the first half of the nineteenth century with an emphasis on "fire resistance." Robert Mills' Fireproof Building, which was originally built as a state office building with storage for district records, was the first building in the city constructed with the purpose of "fire resistance." This building, located at the corner of Meeting and Chalmers Street, was constructed from 1822-1827. Colonel John Gordon was a contractor for the project but also a large brick maker along the Wando River. "Altogether, Gordon furnished and laid 947,500 Bricks, nearly as many as for St. Michael's Church"[26] Although, the final stylistic elements did not match Mill's plans, the building's emphasis on fireproofing was maintained with brick construction.

The production of seventeenth, eighteenth, and early nineteenth-century brick in the Low Country relied on slave labor. Mechanization of brick manufacture started in the United States in the early nineteenth century with the invention of the pug mill and molding machines. "In an industry so well organized," Harley J. McKee, an early preservation architect, wrote, "machinery could readily be introduced to perform some parts of the process while others continued to be done by hand in the traditional way. Not until the end of the nineteenth century did the entire manufacture become mechanized."[27] The Charleston area lost its large free labor force after the Civil War which triggered a change toward mechanized brick production. The Horlbeck family of Boone Hall changed to machines after the Civil War and soon controlled

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[25] Timothy Ford. "Diary of Timothy Ford, 1785-1786." *South Carolina Historical and Genealogical Magazine*, XIV. (South Carolina Historical Society, 1913), 141.

[26] Gene Waddell. *Charleston Architecture: 1680-1860*. 169.

[27] Harley J McKee. *Brick and Stone: Handicraft to Machine.* "Building Early America: Contributions toward the History of a Great Industry" (Editor Charles E. Peterson, Mendham, NJ, The Astragal Press, 1976), 82-84.

Charleston's brick industry. This modern brick differed in density, shape, texture and color. Handmade Charleston "Grey" brick has its own visual characteristics and elements that make it unique to the Low Country area and to different regions within the vicinity.[28] This study will focus on one of those regions; the Ashley River.

1.3 The Study Area: The Ashley River

1.3.1 History of the Region

The Ashley River, the target of this research, is short and narrow, and penetrates only thirty miles inland. It is fed by the headwaters of the Cypress and Wassamassaw Swamps, near Summerville. The Ashley Scenic River Management Plan states that "The swamps meander for about 30 miles until they form the channel given the name 'Ashley River,' which flows for another 30 miles where it meets the Cooper River at Charleston Harbor (and as the locals say, the Ashley and Cooper rivers 'form the Atlantic Ocean.")[29] At the headwaters, the Ashley River channel is only the size of a small creek and easy to cross. This becomes even narrower during low tide. Many creeks also tie into the river along the way, which greatly affects its size and flow.[30] The width grows as it nears Charleston to about a quarter of a mile. The bed of the river has likely changed over the past 5,000 years but not greatly in the past three hundred years, the time period of this study.

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[28] Marie Ferrara Hollings. Brickwork in Charleston. .: The term Charles 'Grey' Brick is clarified by Hollings in her thesis. "In the late seventeenth and early eighteenth century in London, red bricks lost their popularity to grey stock bricks. With the numerous London-published architectural books available in the colonies, the term 'grey' was borrowed. Locally made bricks which are a burnt brown in color were called 'Carolina grey bricks." (pg 11)
[29] The Ashley Scenic River Advisory Council. Ashley Scenic River Management Plan. (Management plan in partnership with The South Carolina Department of Natural Resources, January 2003), 16.
[30] Ibid: These creeks include "Dorchester Creek, Eagle Creek, Coosaw Creek, Olive Branch, Popperdam Creek, Macbeth Creek, Keivling Creek, Church Creek and Bulls Creek." The Council was formed from a local advisory council. Formed in 1999, this representative group of nineteen people worked with the Department of Natural Resources to create a management plan for the future of the Ashley River.

Even with the relatively short length of this river, there are four distinct regions along its course.[31] They are identified by aesthetic quality and water type. Section one is located from Sland's Bridge to Colonial Dorchester. This region has many overhanging trees, such as bald cypresses and sweet gums, but the water itself is fresh. The lower half of this section turns brackish due to the presence of salt. At this point, tidal activity is apparent.

Further downstream, from Colonial Dorchester to the CSX railroad trestle, in section two, the Ashley River expands.[32] Here, each shore of the river has large flood plains with marsh. The Advisory Council wrote that, "Further downstream the brackish water turns saline and the marsh vegetation changes from pickerelweed and cattails to black needlerush, and finally, smooth cordgrass."[33] Each of these types of plants depends on different forms of water, some more saline than others.

The third section of the river extends from the railroad trestle to the Mark Clark Expressway (I-526.) This section, now heavily developed, contains historic St. Andrews Parish Church with the creek that that shares the name, Church Creek.[34]

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[31] Ibid: these were identified by the Ashley Scenic River Advisory Council in 2003 when conducting a study of a 22 mile corridor of the river that extended from Sland's Bridge, outside of Summerville and considered the start of the river, to the I-526 overpass called the Mark Clark Expressway, which is located a few miles west of downtown Charleston.

[32] Ashley River Historic District, National Register Nomination expansion. (Depart of Interiors, National Park Service, 2011. The CSX railroad trestle is currently located just south of the intersection of Ashley River Road and Bee's Ferry Road. The Ashley River Historic District's National Register of Historic Places nomination (of 1994) states that "This double-tracked railroad trestle, built for the Atlantic Coast Line Railroad between 1922 and 1935, is a single-leaf bascule-type bridge, powered by a gasoline engine which operates a two-ton concrete counterweight to life the draw span." The trestle is now owned and operated by CSX Transportation. The Ashley River District Expansion nomination of 2011 expands this history. It wrote that the site is also the location of two previous historical resources, first a nineteenth-century ferry location owned by Joseph F. Bee, and Fort Bull, a Civil War earthwork in the confederate defenses.

[33] ibid

[34] Old St. Andrew's Parish Church. *Church History.* http://www.oldstandrews.org/history.asp (accessed February 2011): St. Andrew's Episcopal Church was one of the first churches constructed by the Church Act of 1706 passed by the colonial assembly. Construction of the church started the same year and the

The last section is below I-526 and ends at the tip of the peninsula. The river in this section is much wider and is heavily influenced by the incoming and outgoing tides. This is the location of Charles Towne Landing State Historic Site, the original site of English settlement in South Carolina.

The Ashley River has been in constant use since the first English settlement in 1670. When the first ship landed at Albemarle Point (now known as Charles Towne Landing), a small settlement was created. Jonathon Poston, a Charleston historian, has noted that by 1680 "it was decided that the proprietary colony of Carolina would erect a new town on the site formerly called Oyster Point, the present day Charleston."[35] This move, however, did not prohibit further development up the river.

Not long after 1670, early settlers began purchasing the surrounding wilderness, through proprietary grants to form large baronies. The 1696 map by Pierre Mortier marks the location of all the settlements along the River and the surrounding regions.[36] (Figure 1.4) At this time the southwest side of the river held forty-six properties and forty on the northeast side. These properties were held by the preeminent people of the day such as lord proprietors Lord Anthony Ashley Cooper, the Earl of Shaftesbury, and Sir Peter Colleton. Some early plantations, such as the Ponds, are documented as being fully established before 1700.

Shortly after the map was drawn, the town of Dorchester was established near the beginning of the river. This small settlement was laid out in 116 plots including the St. George

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core of the building still remains. Other resources, including the extension of the Ashley River District (2011) and the Ashley River Study by the Berkeley-Charleston –Dorchester Council of Government, mention that this site was also a part of St. Andrew's Town and Ashley Ferry Town. None of these settlements lasted past the mid-18th century.

[35] Jonathan Poston. *Buildings of Charleston: A guide to the City's Architecture.* (Columbia, SC: University of South Carolina Press, 1997), 24.

[36] Pierre Mortier. *Carte Particuliere De La Caroline Dresse sur les Memoires le plus Nouveaux Parle Sieur Sanson…. 1696.*

parish church and a tabby fort with a powder magazine. This settlement did not last long and was abandoned soon after the Revolution.[37]

During the mid-eighteenth century, large plantations such as the Ponds, the Laurels, Middleton Place, Runnymead, Magnolia and Drayton Hall were developed. (Figure 1.5) Many of the houses on these lands (some of which still survive today) were stately brick homes that were likened to fine country estates found in England. Large landscaped gardens, such as those at Middleton Place, were also part of the river scenery.

The early Low Country economy was based on agriculture, including the exportation of indigo, inland rice, and corn. A small industry also produced naval stores, from the turpentine, pitch and tar of the pine trees.[38] This brought great wealth to the region, but by 1770 a new method of rice cultivation changed the economy. The Ashley River Historic District National Register nomination describe this agricultural change

> "By 1770 a new method of rice cultivation, in river swamps fed and controlled by tides, was introduced. With the shift to tidal swamps from inland swamps both the production and quality of South Carolina rice increased dramatically. This development, however, made the inland swamp rice fields along the Ashley less efficient and less profitable. Property along the river immediately north of Charleston was unsuitable for rice production due to the high salinity of the water and the high marl content of the riverbanks. Property further north was unsuitable due to poor drainage and the river's inability to irrigate the rice fields. Though some rice continued to be cultivated in the cypress swamp region of the upper Ashley, it was not of the best quality and was not produced in large quantities."[39]

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[37] Ashley River Historic District, National Register Nomination expansion. (Depart of Interior, National Park Service, 2011), 11.: The town and fort were abandoned due to large amounts of damage during the American Revolution. Also, the *Old Dorchester State Park Visitor's Guide* by Daniel J. Bell, states that the Congregationalists that first settled the town left for a new settlement in Georgia two decades before.

[38] Ashley River Historic District, National Register of Historic Places. (Department of Interior, National Park Service, 1994), 11 .

[39] Ashley River Historic District, National Register of Historic Places Nomination. 11.

This change in rice cultivation and the heavy involvement of the area in the American Revolution slowed the economy of the region.[40] But soon after 1800, the introduction of the long-staple, or Sea Island cotton brought wealth to the Ashley River plantations.

During the antebellum era, the Ashley River continued to be the driving force in the region's growth of prosperity. Boats, barges and ferries were built for the transportation of produce, goods and people. In 1771 a formal road was established as well beside the river. This road became the primary transportation artery after the Civil War.[41] Around the same time canals were proposed to keep up with demand, but they were never realized.[42] By the 1830s, railroads began to feed these vessels with even greater numbers of commodities and travelers. Prosperity did not last long with the firing on Fort Sumter in 1861 and Charleston's role in the Civil War.

Fort Bull was constructed on the river in 1863 by the Confederate army. The area saw little fighting during the Civil War; however, Union forces did come through the area in 1865. Several residences, such as Drayton Hall, were spared, and still stand today. The war also brought about change to the topography. The *Map of Charleston and its Defenses* has a canal system that connects the Ashley River with the Stono River. After the war, the local economy shifted towards cotton and phosphate production, with the help of freed slaves.[43] From about

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[40] Many resources, including the Ashley River Historic District National Register nomination, Drayton Hall historians, and Drayton Hall's website (http://www.draytonhall.org/research/history/revolution.html), all state the pillaging and burning of the houses and property during the American Revolution. Drayton Hall was spared due to its role as a headquarters for both the American and British military.

[41] Ashley River Historic District, National Register of Historic Places Nomination. 5: Ashley River road was authorized by the Lords proprietors in 1690-1691. The current location was fully established by 1771. Today the road is known as South Carolina Highway 61.

[42] Ashley River Historic District, National Register Nomination Form. Section 8, Page 8. This information is from The Statues at Large of South Carolina, By McCord, Volumes 7 and 13.

[43] Phosphate was discovered along the Ashley River in 1867. N.A. Pratt, M.D., wrote in his book *Ashley River Phosphates: History of the Marls of South Carolina and the Discovery and Development of the Native*

1870 to 1900, the Ashley River flourished through the mining of phosphate. Thus the types of soils in the region have always played a large role in the ebb and flow of the history of the Ashley River.

1.3.2 Ashley River Soils: Clay

Brick is composed of clay, sand, and small amounts of water. The types of clay most prevalent in the Charleston low country have been described in Lucy Wayne's thesis:

> "Lowcountry clays can be divided into five basic types: marls, clayey sands, sandy clays, rich clays and vitreous clays. Marls are generally unsatisfactory alone due to their instability; however, small amounts added to other clays would increase strength and produce color changes. Clayey sands do not contain a high enough proportion of clay to be useful for brick making, although they can be used to sand the molds and table. Sandy clay is probably the best overall materials for face bricks, with a shrinkage rate of less than four percent and good bonding strength, Rich clays have a high proportion of clay and make excellent bricks. Since this type of clay has a slow drying time with high shrinkage, it requires expert skills to produce good brick. Vitreous clays produce a glassy or glazed surface during firing; bricks from these clays have good structural properties. Vitreous clays also make good additive to other clay types."[44]

Other elements may also be present in the clays, such as ferric oxide, lime, magnesia, alumina and manganese. These can change the surface color of the brick to shades of red, yellow, green and black.[45] Early nineteenth-century geologists calculated other elements present in the brick

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Bone Phosphate of the Charleston Basin, that "In 1867, early in the spring, the attempt was renewed, with better hopes of success; and while from May to August of that year selecting a suitable location for such works, and , as Chemists to the North Carolina Geological Survey, searching in Carolinas for native home material which might be turned to profit in the manufacture proposed, I was fortunate enough to discover that a bed or stratum, outcropping within the (10) miles of the city of Charleston, contained as large a per centage [sic]of phosphate of lime as any of the phospahtic guanos imported from the tropical islands, and used in this country and abroad in the manufacture of fertilizers." Pg 13

[44] Lucy Wyane. *Burning Brick.* 72-73: Wayne attained this information from G.C. Robinson and H.S. Johnson's work *Brick Clays of Medway Plantation, Berkeley County, South Carolina*.

[45] Marie Ferrara Hollings. *Brickwork in Charleston*. 6.: "If 5-6 per cent [sic] ferric oxide was in the clay, the bricks would burn hard and red. The presence of lime in the clay allowed little between overburning and underburning. Lime produced a yellow-green color. The presence of magnesia and alumina produced a buff color, ferrous oxide produced a black-green color, and manganese produced a brown color. Control

at two locations along the Ashley River, one at Bee's Ferry and the other at Drayton Hall. Dr. Smith and Professor Charles Upham Shepard, professor of chemistry at the Medical College of Charleston, found lime, phosphate, alumina, magnesium and other "Silicious [sic] matter."[46] These factors are some components of the unique qualities of these early handmade brick.

The different types of soils and clays surrounding the rivers of Charleston have been mapped by the United States Department of Agriculture in their nationwide Soil Surveys. The Ashley River is located in two different counties, and thus has two separate Soil Surveys, one for Charleston County and one for Dorchester County. The Charleston Soil Survey, made in 1971, identifies the locations of over twenty different series of clays, sands and loams, this series is the official name for the type of soil. "These official soil series descriptions are descriptions of the taxa in the series category of the national system of classification. They mainly serve as specifications for identifying and classifying soils."[47]

The two types of clay-like soil in the vicinity were Capers Silty Clay Loam (identified as Cg) and Meggett Clay Loam (identified as Me). Capers Silty Clay Loam was the most abundant along the river in small sectors and along the creeks and tributaries. For example, Capers Silty

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of the air admitted to the kiln affected the use of fuel and determined the reactions (oxidizing and reducing) at the surface of the bricks." Hollings cites Harley McKee, from Introduction to Early American Masonry, for this information.

[46] In N.A. Pratt's book, *Ashley River Phosphates: History of the marls of South Carolina and of the Discovery and Development of the Native Bone Phosphates of the Charleston Basin.* (Philadelphia: Inquirer Book and Job Print, 1868), 6. Pratt tabulated Dr. Smith and Prof. Shepard's data. The first is the "Analysis of Marl from Bee's Ferry: Carbonate of Lime,… 55.00; Phosphate do,… 4.00; Alumina and Oxide of Iron,… 9.00; Silicious Matter,… 32.00; [totaling] 100.00." The other data was from a variety of site in the Low Country, including Wilmington, N.C. One of these sites was Drayton Hall. The results found were "Silica…10.20; Carb. Lime & Mag…68.60; Phos. Do & Ox. Iron… 8.60; Alumina…1.00; Water…4.00." These studies were looking for the evidence of Phosphate for natural fertilizers which were later found and heavily mined.

[47] Department of Agriculture, Natural Resources Conservation Service. *Official Soil Series Description.* http://soils.usda.gov/technical/classification/osd/background.html (Accessed December 2010.)

Clay Loam is found along the creek beds of Church Creek and Bulls Creek not far from St. Andrews Church. This type of soil is "formed in silty clay to silty clay loam sediments on tidal flats that are inundated by 2 to 6 inches of sea water once or more each month. They are poorly drained and are saturated with salt water."[48] This high salt and sulfur content of the soil is not ideal for cultivation. The Meggett Clay Loam was located further in-land, one-and-one-half miles from the River. This series of soil is also poorly drained and has clayey subsoil. The Charleston Soil Survey Report states that "The surface layer of these soils is acid, but the lower part of the subsoil is neutral to moderately alkaline."[49] A large portion of this soil is heavily wooded and can be used for crops if the property is drained and maintained. Further up the river in Dorchester County, the Capers Silty Clay Loam (now identified as Ca) is found in pockets along the river. Another type of clay was identified in this county called Brookman Clay Loam (identified as Br). This was found about one mile from the river and in great amounts at the source of the river. This type of soil is "formed in clayey marine sediment on nearly level, large drainage mainly in the southeastern part of the county."[50]

Clay, the main component of brick, is "a soft, loose, earthy material containing particles with a grain size of less than 4 micrometers (µm). It forms as a result of the weathering and erosion of rocks containing the mineral group feldspar (known as the 'mother of clay') over vast spans of time."[51] Clay minerals are a part of the phyllosilicate group which is composed of about 40 percent water. Clay minerals fall into four distinct groups: kaolinitic, montmorillonite, illite,

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[48] US Department of Agriculture. "Soil Survey: Charleston County, South Carolina. (US Department of Agriculture,1971.) 8-9.
[49] ibid
[50] US Department of Agriculture. 'Soil Survey: Dorchester County, South Carolina." (US Department of Agriculture, 1990.), 7.
[51] The University of Waikato. *What is Clay?* http://www.sciencelearn.org.nz/Contexts/Ceramics/Science-Ideas-and-Concepts/What-is-clay (Accessed January 2011).

and chlorite.[52] The two groups most prevalent in the study area are montmorillonite and kaolinitic montmorillonite. Kaolinitic montmorillonites "consist primarily of kaolinite clays with a low water of plasticity, low shrinkage, low to medium drying strength, and require a medium to high maturing temperature."[53] Montomorillonite was added to brick in smaller amounts to improve plasticity and lower maturity temperatures.[54]

Certain characteristics, such as plasticity and firing temperature, make some clays more desirable for brick manufacture. When the first settlers started building, they found the best locations for brick clay through trial and error. Clay from a select location along a river soon developed historic preference, as noted in early contractual verbiage, with Zachariah Villepontoux's brick at St. Stephen's parish church.[55] Clay and its inclusions may prove to be the key in identifying brick and its source locations.[56]

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[52] The main difference between the four clay mineral groups is the arrangement of ions and the physical size of the particles. Found in: *Clays of Opal-Bearing Claystones of the South Carolina Coastal Plain.* By S. Duncan Heron Jr., Gilbert C. Robinson & Henry S. Johnson in 1965 .

[53] Lucy Wayne. *Burning Brick*. (PhD Diss., University of Florida, 1992), 71.

[54] Henry S. Johnson & S. Duncan Heron. *Brick Raw Material Resources of South Carolina. (South Carolina: Geologic Notes, Vol 4, Sec 2,*1965).

[55] Jane Searles Misenehlter. *St. Stephen's Episcopal Church, St. Stephen, SC.* (Church Record, State Print Co., 1977), 8. "The 7th May 1764- The Commissioners appointed for Building a Church in St Stephens did agree with Joseph PALMER for One hundred and Fifty Thousand merchantable Bricks delivered at the parish Church at Eight pounds per Thousand, the said Bricks to made by the Size of Mr Pontoux's/VILLEPONTOUX/ moulds and to be approved by the majority of the above said Commissioners." The Vestry minutes later state in April 1766 that "the Size of the moles to be equall [sic] in Bigness to Mr Zachry VILLEPONTOUX's." The nephew of Zachariah Villepontoux, Frances Villepontoux appears to have been one of the supervisors and architects of the construction of the church with A. Howard and the bricklaying by William Axon.

[56] Clays found in brick are usually not pure clay. Most are made up of clay with clay-size and larger elements. The larger elements are chert and inclusions. Chert is sedimentary rock rich in silica and inclusions are much larger element seen in the clay. Inclusions can include the larger dark iron spots seen in many of Charleston early bricks.

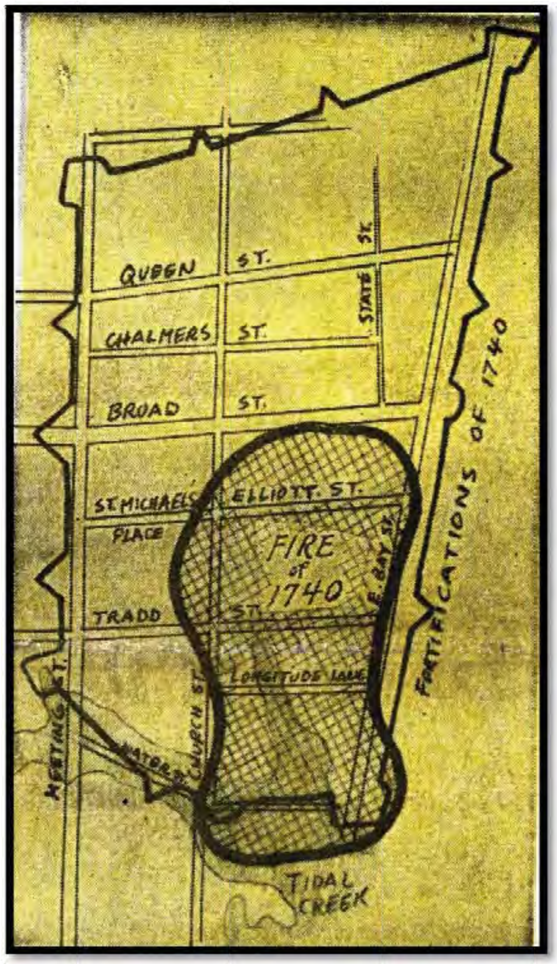

Figure 1.1: Area of Destruction by Charleston's 1740 fire. (Depicted by Post and Courier, November 13, 1960)

Figure 1.2: (above) View of Fosters Creek, off the Cooper River, in Goose Creek, South Carolina. Site of several large brickyard plantations; for example Villepontoux's Parnassus. (Lanphear)

Figure 1.3: (left) Historic brick kiln chimney. Located at Brickyard Plantation, sub-division, in Mt. Pleasant, South Carolina. It was the brick yard owned by the Gordon Brothers in the early nineteenth century. (Lanphear)

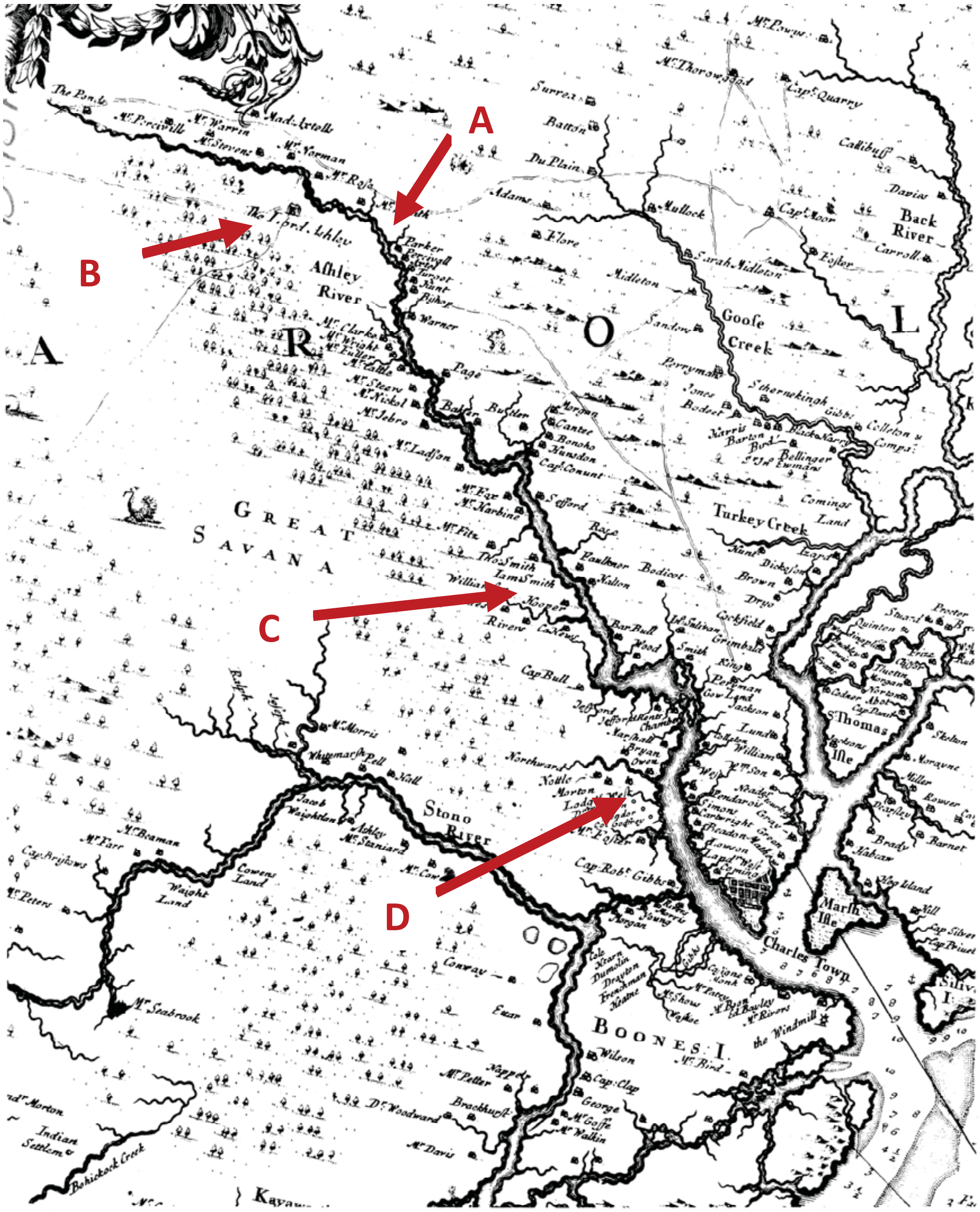

Figure 1.4: A small section of the 1696 Pierre Martier's *Carte Particuliere De La Caroline Dresse sur les Memoires le plus Nouveaux Parle Sieur Sanson….*with the location of each of the testing sites, A)Colonial Dorchester, B)Lord Ashley Site, C)Drayton Hall Plantation and D)Church Creek. (Michael O. Hartley, 1984)

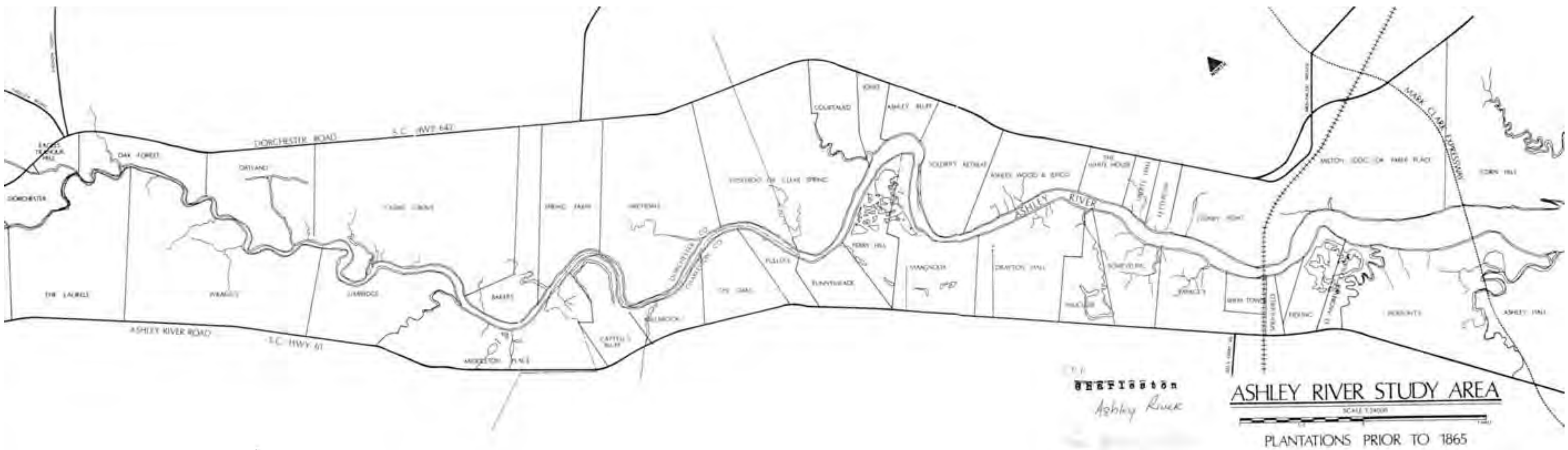

Figure 1.5: Plantations, Prior to 1865, along the Ashley River. Colonial Dorchester to the far left. (From the vertical files at the South Carolina Room at the Charleston County Public Library.)

CHAPTER 2: HISTORICAL AND ANALYTICAL RESEARCH

2.1 Literature Review

This study of Ashley River brick includes the published and unpublished history of the region, surveys of known brick buildings in the area and a compilation of analytical techniques used in the ceramic sciences in order to develop a methodology to identify source locations for specific brick. Previous studies have tried to use historic research and analytical methods to create this connection, but were not successful in this goal. This thesis will build on all of the previous work and add a greater emphasis on ceramic sciences to successfully complete the task.

Two theses; *Burning Brick: a Study of a Low Country Industry*, by Lucy Wayne and *Brickwork of Charleston to 1780* by Marie Ferrara Hollings, have covered the broad history of brick in the Low Country; thus will not be repeated in this study. Hollings' thesis was the first major research produced on brick in Charleston. [57]She compiled the history of its manufacture with emphasis on the plantation brick production process and the people associated with brick making in Charleston through available research. A small typology was created for local brick with measurements and analysis of houses on the Charleston peninsula.

Burning Brick: a Study of a Low Country Industry expanded Hollings' research.[58] Lucy Wayne's doctoral thesis also identified the people and places associated with brick manufacture, but focused on the Wando River region. A list was created with the name of people and plantations who produced brick along the river. Wayne identified the success of the region and, through an archeological tie, located twenty-three former sites of brickyards along

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[57] Marie Ferrara Hollings. *Brickwork of Charleston* (Master's Thesis, University of South Carolina, 1978.)
[58] Lucy B. Wayne. *Burning Brick: a Study of a Low Country Industry*. (PhD Diss., University of Florida, 1992).

the Wando River and its tributaries. She also found that the soil's unique characteristics made this region's brick successful but did not conduct any scientific tests.

The earliest reference of brick making in the Carolinas is found in A.S. Salley's compilation book, *Narratives of Early Carolina*. It includes early records of colonists living in the area, including Robert Horne, Thomas Newe, Thomas Lawson, Thomas Ashe and Dr. Alexander Hewatt.[59] These men commented on the on the brick use and quality in the young town.

Archaeological digs have discovered multiple brick yards and brick kilns throughout Charleston. Recently, Brockington and Associates assisted in the identification of the Lord Ashley settlement along the Ashley River, and provided one of the brick samples for this study. Their report, *Archaeological Investigations at 38DR83A, St. Giles Kussoe House/ Lord Ashley Settlement* (2010), documents the earliest known brick site in Charleston.[60] These circa 1675 brick, likely made on site, have extended the brick history of Charleston almost back to the beginning of European settlement. Brick making along the Ashley River was not as extensive as those brickyards along the Cooper and Wando River, as seen in Zachariah Villepontoux's Parnassus and the Gordon brothers Brickyard Plantation. Lissa Felzer's "*Ashley River Historic District*" National Register of Historic Places nomination form, tells the story of the entire Ashley River region from the beginnings with the Ponds Plantation through national and state historic sites, such as Colonial Dorchester, Middleton Place Plantation and Drayton Hall.[61] No large

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[59] A.S. Salley Jr. Narrative of Early Carolina. "Letters of Thomas Newe, 1682. C. Scribner's Sons, New York, NY. 1911.

[60] Brockington and Associates, *Archaeological Investigations at 38DR83A, St. Giles Kussoe House/ Lord Ashley Settlement*. Mt. Pleasant, SC: Brockington and Associates, 2010.

[61] Lissa Felzer. *Ashley River Historic District National Register of Historic Places nomination form.* National Trust for Historic Preservation Lissa Felzer. *Ashley River Historic District National Register of Historic Places nomination form.* National Trust for Historic Preservation, 2010., 2010

brickyard is known during the colonial period in this area.[62] Only later in the eighteenth century, does Joseph Ioor Waring mention in the Sunday News of Charleston that brick clay is being dug and fired at old Colonial Dorchester.[63] This production continued into the twentieth century with Summerville's brick making company.

The two other brick sample sites were Colonial Dorchester and Drayton Hall. Personal communication with Ashley Chapman[64] and Daniel Bell,[65] who work for the South Carolina State Parks Department, provided many resources for Colonial Dorchester. Their previous work was seen in the *Colonial Dorchester Visitor's Guide*.[66] This guide had a copy of the first map of the settlement and recent archaeology at the site. Daniel Bell provided resources on building the brick powder magazine[67] and brick making reported by Joseph Ioor Waring.[68] Drayton Hall is widely written about for its history and Dr. Carter Hudgins Jr., director of preservation, provided information and brick for the study.[69]

The Ashley River's history, related in Charles Kovacik and John Winberry's book, *South Carolina: A Geography*, gives a broad overview of the many changes that have occurred over the past 20,000 years. These climatic alterations have created the unique soil characteristics found

[62] Lissa Felzer. *Ashley River Historic District National Register of Historic Places nomination form.* National Trust for Historic Preservation, 2010.
[63] Joseph Ioor Waring. "A Shrine of the Past." *The Sunday News (The Evening Post, Charleston, SC)*. 17 November, 1895.
[64] Ashley Chapman. Personal communication with author. (February 2011).
[65] Daniel Bell. Personal communication with author. (February 2011).
[66] Bell. *Old Dorchester State Park: Visitor's Guide.* (South Carolina: South Carolina Department of Parks, Recreation and Tourism, State Park System, 1995).
[67] Commissioners of Fortifications. July 14th, 1757. *Commissioners of Fortifications Journal: 1755-1770.* (Microfilm, Charleston: South Carolina Historical Society).
[68] Joseph Ioor Waring. "A Shrine of the Past." *The Sunday News (The Evening Post, Charleston, SC)*. 17 November, 1895.
[69] Dr. Carter Hudgins Jr. Personal Communication with author. (February 2011)

today along the Ashley River.[70] The locations of clays and other types of soils are noted in the United States Department of Agriculture's Soil Surveys. Maps found in the 1971 Charleston County and 1990 Dorchester County surveys identify the types of soils and clays along with their physical characteristics.[71] The clays found near the shores of the Ashley River are identified as Capers Silty Clay Loam, and Megget Clay Loam in Charleston County and Capers Silty Clay Loam and Brookman Clay Loam in Dorchester County.

The different strata of clay and soils have been continuously studied by South Carolina State geologists. From 1868 with N.A. Pratt and his report *Ashley River Phosphates: History of the Marls of South Carolina and the Discovery and Development of the Native Bone Phosphates of the Charleston Basin*,[72] to S. Duncan Heron Jr., Gilbert C. Robinson & Henry S. Johnson in 1965 with their publication *Clays of Opal-Bearing Claystones of the South Carolina Coastal Plain*.[73]

Modern Concepts of Clay Materials by Ralph E. Grim may have been written in 1942, but the composition of clay and how it is classified has not changed. He also extended his research on clay with the use of analytical characterization testing.[74] Two studies that have tried to incorporate characterization testing are the New Netherland/ New York Ceramic Chemistry Archive and the Brick Analysis of Fort Sumter National Monument. Allan S. Gilbert, Garman

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[70] Charles Kovacik and John Winberry. *The Making of a Landscape*. Columbia, SC: University of South Carolina Press, 1987.

[71] US Department of Agriculture. "Soil Survey: Charleston County, South Carolina." 1971. And "Soil Survey: Dorchester County, South Carolina." 1990.

[72] Pratt, NA. *Ashley River Phosphates: History of the Marls of South Carolina and the Discovery and Development of the Native Bone Phosphates of the Charleston Basin*. Philadelphia: Inquirer Job and Book Print, 1868.

[73] Hernon, S. Duncan Jr., Gilbert C. Robinson and Henry S. Johnson Jr. *Clays and opal-Bearing Claystones of the South Carolina Plain.* Division of Geology. Bulletin No 31. State Columbia, South Carolina. State Development Board. 1965.

[74] Ralph Grim. "Modern Concepts of Clay Materials." *The Journal of Geology* 50 no. 3 (1942): 225-275.

Harbottle and Daniel deNoyelles study, "*A Ceramic Chemistry Archive for New Neatherland/ New York*," employed chemical analytical testing to create a provenance of historic brick.[75] Their precedent set the foundation for this study. The second study, the Brick Analysis on Fort Sumter National Monument, is being conducted by Dr. Denis Brosnan, of the National Brick Research Center[76]. Five brick families were identified from the historic brick analyzed at the fortification using chemical and physical characterization testing. Both of these studies were utilized during this present investigation.

For a project such as this, Dr. Brosnan suggested extensive analysis. The methods employed and researched were moisture content of the clay when received, thermal gradient firing of the clay, X-ray Fluorescence (XRF), X-ray Diffraction (XRD), thermal expansion, Thin Section Microscopy, mercury intrusion, color identification, and Loss of Ignition. All the lab work was conducted at the National Brick Research Center located just outside of Anderson, South Carolina.

Most of the analytical techniques have been used on ceramic for decades. The methodology and reasoning behind these choices are explained in the publications *Characterization Techniques for Ceramists* by Dennis R. Dinger, a retired Professor Emeritus at Clemson in the Ceramic and Materials Engineering field,[77] and *Ceramics: Industrial Processing and Testing* by J.T. Jones and M.F. Berard, from the Iowa State University, Ames, in ceramic

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[75] Allan Gilbert, Gilbert Harbottle, and Daniel deNoyelles. "A Ceramic Chemistry for New Netherland/New York." *Historical Archaeology* 27 no. 3 (1993): 17-56.
[76] Rick Dorrance. Fort Sumter Historic Structures Report. National Park Service. (In editing stage, 2010).
[77] Dennis R. Dinger. *Characterization Techniques for Ceramists*. Kearney, NE: Morris Publishing, 2005.

engineering.[78] These methods have also been used to fully understand the composition and characterization of historic handmade brick. For example, *Subsequent Determination of the Firing Temperature of Historic Brick* (1998) by L. Franke and I. Schumann,[79] *Quantitative X-ray Diffraction Analysis of Hand-molded Brick* (1998) by R.A. Livingston,[80] P.E. Stutzman and I. Schumann and *Thin-Section Petrography in Studies of Cultural Materials* (1994) by Chandra L. Reedy.[81]

This possibility of connecting brick to their brick makers is a matter of great interest throughout the Charleston preservation community. These past papers and theses have started this process. My thesis will take the next step, past the basic history of brick in Charleston, to include other fields in identifying brick derivations due to physical and chemical characteristics. With these resources this project is making headway toward attaining the objective.

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[78] J.T.Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing*. Ames, IA: Iowa State University Press, 1972.
[79] L. Franke and I. Schumann. "Subsequent Determination of the Firing Temperature of Historic Brick." *Technische Universität Hamburg-Harburg* (1998)
[80] R.A. Livingston, P.E. Stutzman and I. Schumann.. *Conservation of Historic Brick Structures*. *Chapter 11: Quantitative X-Ray Diffraction Analysis of Handmade Brick.* Shafesbury, UK: Donhead Publishing Ltd, 1998.
[81] Chandra L Reedy. "Thin-Section Petrography in Studies of Cultural Materials." *Journal of the American Institute for Conservation* 33 no. 2, article 4 (1994): 115-129.

2.2 Justification for Research

The Ashley River was selected for this study due to the amount available research of the history of the people and places located on the river. Even with all the existing research, there is little known about the locally made brick used in the construction of the grand plantation houses scattered along its banks. In past years, brick research has concentrated on the large productions of the Cooper and Wando River, such as the plantations of Zachariah Villepontoux at Parnassus, and the Gordon brothers at Brickyard.[82] Limited attention has been given to Ashley River brick works, thus they became the focus of this study.

Research shows that smaller brickyards were known to have existed before the Civil War along the Ashley River. One such notice can be found in the South Carolina Gazette, March, 1738. It stated;

> "TO BE SOLD a Plantation within a Mile of *Dorchester*, containing 50 Acres of very good Land, with a good Dwelling house on it near the River; where is good Clay and other Conveniences for making Bricks, also two small Lotts [sic] in *Dorchester*, and some small pieces of Land near it: Any one inclinable to buy any or all said Land, may treat with *Tho: Way sen* in *Charlestown*, or Tho: *Way jun* near said plantation."[83]

These smaller private brickyards were used mostly for individual buildings on the plantations or farms. They likely supplied the brick for many of the early structures along the Ashley River:

[82] Marie Ferrara Hollings and Lucy Wayne focused on these brick making plantations with historical research and archeology, in their master's and doctoral theses. Villepontoux and the Gordon brothers were some of the largest brick makers during the 18th and 19th century in the Charleston area. They are also referred to in several resources of early architecture in Charleston, such as Beatrice St. Julien Ravenel's Architects of Charleston (Charleston; University of South Carolina/ Carolina Art Association, 1964.)

[83] *South Carolina Gazette* (South Carolina Room, Charleston County Library: March 2-9, 1738). This sale was near Dorchester and two lots in the village by Thomas Way Sr. and Thomas Way Jr. Dan Bell, South Carolina State Parks, has this reference in his collection at Charles Town Landing.

Drayton Hall, Middleton Place, St. Andrews Parish Church, and Dorchester. This may have also included the brick for foundations of plantation houses such as Runnymead, the Ponds and Archdale. The practice of using nearby clay as a resource dates to the early development of brick construction. Alec Clifton-Taylor, an English architectural historian, stated this common use of local clay; "Whenever possible the clay was dug on site, and ideally, as at Ven House, Milborne Prot, the first considerable brick house to be built in Somerset and dating from 1698-1700, the demands of mansion and garden went hand in hand."[84] Colonial America continued this tradition and in the mid-eighteenth-century; larger brick making production begin to replace these earlier form of production. Local examples of industrial scale brick making existed at Dorchester in the late nineteenth century and around 1900, the Summerville brick making company began a large modern operation two miles up the river from Charleston.[85]

For this study four different sites for brick and two separate deposits of clay were studied. These sites were picked for availability of brick for destructive tests and access to digging clay. The three sites of brick samples are Colonial Dorchester, the Lord Ashley Settlement, and Drayton Hall. The three Colonial Dorchester samples all came from the Charleston Museum collection, Dorchester 1067, 1091 and 1428, and the museum's identification numbers were kept for this study. The small Lord Ashley brick sample was donated from Brockington and Associates who conducted archaeology on the site in Spring 2010. The Drayton Hall samples came from two sites; Drayton Hall 1118 was a sample from the Charleston

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[84] Alec Clifton-Taylor. *The Pattern of English Building.* (London: Faber and Faber, 1987), 220.
[85] Joseph Ioor Waring wrote on November 17th, 1895 an article, *A Shrine of the Past,* in The Sunday News (Charleston, South Carolina). He talked of visits to Colonial Dorchester and how the land is being used today. Waring wrote, "Gone are the busy streets and happy homes, and only a few broken brick remain. Even the land upon which the town stood is being removed; a brick yard stand upon the site, and the soil is being dug away to obtain the clay laying beneath." Reference courtesy of Daniel Bell of the South Carolina State Parks.

Museum and other three samples, Attic, North Flanker, and Pre-Drayton house, were from Drayton Hall's private collection. Clay samples were obtained from Church Creek near St. Andrews Parish Church and from old brick pits at Colonial Dorchester next to the ruins of St. George's parish Church.

The first site, Colonial Dorchester, was one of the first larger townships outside of Charleston. (Figure 2.1) Located at the convergence of the Ashley River and Dorchester Creek (which was known as Bossoe Creek), Dorchester served as a place of trade and distribution. The first settlers were New England Congregationalists who arrived in 1697. By March 23rd, 1697, the town had been planned and land distributed in quarter acre lots.[86] (Figure 2.2) The population of the town never matched that of Charleston; the Visitor's Guide notes that, "In a 1708 account of Britain's North American colonies, writer John Oldmixon claimed that Dorchester was home to 'about 350 souls."[87] This number, the Guide further states, was likely over estimated. The 1742 Samuel Stevens map shows twenty-six of the one hundred sixteen lots platted.[88] No concrete number is known of inhabited lots. Many of the lots were joined and a house was built on both sites. For example, the Izard family house was located on Lots seventeen and eighteen.[89]

There are no brickyards that are directly connected to the colonial era buildings at Dorchester. Many of the earliest structures were built of tabby, brick and wood. One of the first

[86] Daniel Bell. *Old Dorchester State Park: Visitor's Guide.* (South Carolina: South Carolina Department of Parks, Recreation and Tourism, State Park System, 1995). Page five of the Visitor's Guide states, "The town was laid out with 116 numbered lots of a quarter-acre each, neatly arrayed between parallel and perpendicular streets.

[87] Daniel Bell. *Old Dorchester State Park: Visitor's Guide.* 10.

[88] ibid

[89] Ibid. An archeological dig from February 1991, yielded the foundation of the mid-eighteenth century house. *A look into the Past: The Archaeological Investigation of a Dorchester Home* is the Visitor's Guide describes the dig and finding of the brick walls and hard-packed clay floor. These findings helped to establish an idea of what the historic structure looked like. All other description of buildings in Dorchester is faint and non-descriptive.

major structures of brick on site was the powder magazine constructed in 1757.[90] Mr. Humphrey Sommers was commissioned by the Commissioners of Fortifications in Charleston to build the magazine. Sommers, a Charleston contractor, was also involved with the building of St. Michael's Church. During St. Michael's construction he provided brick from his plantation, along with Zachariah Villepontoux.[91] The Commissioners of Fortification Journals does not state where these brick were coming from; just that money was available "for Freight of 14^{m} of Bricks."[92] Although there is no indication of the brick's production, it is likely they came from the river region.

Not long after the magazines publication and St. George's Parish Church were completed, the Congregationalists slowly migrated westward near the Medway River in Georgia.[93] This small but successful village continued to flourish until after the American Revolution. The Ashley River District nomination states that "The village was occupied by British troops during the American Revolution. Prior to their final evacuation they burned the church and the school buildings, and subsequently the village was abandoned."[94] The village fell into disrepair and by the late nineteenth century the land was being used for clay extraction for brick making. These clay pits are the source of the clay samples for this study. By the twentieth century the land was used as a park until the state of South Carolina acquired the property. (Figures 2.3 and 2.4)

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[90] Daniel Bell. Personal communication with author. (February 2011).
[91] Gene Waddell notes that Sommers made brick for St. Michaels in *Charleston Architecture: 1680-1860*. (University of California, Wyrick, 2003) on page 108. This is confirmed in St. Michael's building records (at the Charleston Country Public Library; South Carolina Room, microfilm.)
[92] July 14th, 1757. *Commissioners of Fortifications Journal: 1755-1770.* (Microfilm, Charleston: South Carolina Historical Society).
[93] [93] Daniel Bell. *Old Dorchester State Park: Visitor's Guide.* (South Carolina: South Carolina Department of Parks, Recreation and Tourism, State Park System, 1995), 10.
[94] Ashley River Historic District, National Register of Historic Places nomination form. (NRHP, 2010), 11.

The second property was owned by Lord Anthony Ashley Cooper, one of the first Lord Proprietors, was located somewhere near the headwaters of the Ashley River, but the site had been lost. (Figure 2.1) In 2010, archeologists, including those at Brockington and Associates, participated in the investigation and were able to locate structures from the 17^{th} century. Lord Ashley's settlement was one of the last in the region's fast development. Brockington's report notes that "Despite his efforts, by early 1674, Lord Ashley was becoming frustrated with his colonists since they had taken up all the best land on [the] Ashley River and 'left me not a tolerable Place to plant.' About the same time the Grand Council set aside a 12,000-acre tract on the upper Ashley River for him."[95] Lord Ashley never visited this property but left it in the care of Dr. Henry Woodward. Woodward operated the settlement as a trading post, with the local Westo Native Americans, and grew crops that he sold in Charleston.[96] (Figures 2.7 and 2.8)

There is limited documentation describing the colonial settlement. Many visitors to the site reported that the Grand Chancellor of England's plantation held four cabins with a "trench with a moat and bridge with four pieces of artillery."[97] This settlement did not last long due to Lord Ashley's death in January 1683. The land was then passed to his successor who sold the land to separate buyers.[98] Current archaeological digs have found one of the first structures. The

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[95] Brockington and Associates. *Archaeological Investigations at 38DR83A, St. Giles Kussoe House/ Lord Ashley Settlement.* (Mt. Pleasant, SC: Brockington and Associates, 2010), 10.: Brockington uses a quote from Lord Ashley's collection of papers known as the *Shaftesbury Papers.* (Charleston; South Carolina Historical Society, 2000), 448.

[96] Dr. Henry Woodward operated under the "Direction of Mr. Percivall [sic] my principall [sic] Agent." This quote is from the Lord Ashley's *Shaftesbury Papers*. Mr. Andrew Percival kept an account book of the property since he was dispatched by Lord Ashley to keep track of the property. (Brockington)

[97] Jose Miguel Gallardo. *"The Spaniards and the English Settlement in Charles Town."* South Carolina Historical and Genealogical Magazine. (South Carolina Historical Society, Vol 37, No. 4, October), 135.

[98] Brockington and Associates. *Archaeological Investigations at 38DR83A, St. Giles Kussoe House/ Lord Ashley Settlement.* (Mt. Pleasant, SC: Brockington and Associates, 2010), 11.

brick from this site is very orange in color and not fully fired. Archaeologists suggested that this brick may be the earliest made in the Charleston area, around 1675.

The third site is Drayton Hall, one of the earlier plantations along the Ashley, completed in around 1742. (Figure 2.9) Joseph Mester, a Drayton Hall researcher, noted that "This new architecture was influenced by the English architecture known as Georgian-Palladianism."[99] This large mansion was the seat of the Drayton family's vast plantation holdings. John Drayton, the first owner, built the house with brick that was likely made from clay on site with slave labor. (Figure 2.10) A previous house, remains of which are located beneath the northwest corner of Drayton Hall, was probably also constructed with local clay for brick.[100]

The Drayton family owned several plantations in the Charleston area that produced rice, cotton and indigo. This provided great wealth for this family during the colonial period. After the American Revolution, Charles Drayton made some interior changes to the house to reflect current fashions; however, the exterior did not change drastically. The screen connecting the house to its two flankers was destroyed during military control of the house during the war.[101] The house and the two flankers survived into the eighteenth century. Both flankers fell in 1886 after receiving major damage during the earthquake. The house is owned by the National Trust

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[99] Joseph Mester. *The Architecture and Design of Drayton Hall.* (Charleston, SC: Drayton Hall Resource, 2009).

[100] From archeology in the past few decades, the pre-Drayton structure has been found. Brick and other artifacts have been found and catalogued at Drayton Hall. These bricks do have a slightly different color than the main house. One brick from current excavations is being used for this study. Carter Hudgins Jr. and Sarah Stroud of Drayton Hall's preservation program control this collection.

[101] A watercolor of the house from c 1765 has been located and depicts the house, colonnade/screen and flankers. This watercolor was given to Drayton Hall in September 2007. The watercolor is now in possession at Drayton Hall and can be view at the site or online at http://draytonhall.wordpress.com/2009/08/04/watercolor-mystery-solved-so-far/.

for Historic Preservation and continues to be researched and studied as a museum property. (Figure 2.11- 2.14)

The last site is located at Church Creek, near St. Andrew's Parish Church. (Figure 2.9) This section of the river has Capers Silty Clay Loam along the shores. This type of clay is also seen in many areas along the Wando River where clay was dug.[102] Lucy Wayne notes that many side creeks and tributaries were good locations to dig clay for brick making.[103] This is seen in Horlbeck Creek and Toomer Creek along the Wando River.[104] There is no evidence that clay was dug for brick making along Church Creek, but a brick clamp, or temporary brick kiln, was seen archaeologically in the addition to St. Andrews Church.[105]

The analytical methods chosen for this study allowed for complete characterization of Ashley River brick by determining chemical and physical properties. Past research has only used one characterization technique to create a provenance or brick family, such as the chemistry study of ceramics in New York by Allen Gilbert, Garman Harbottle and Daniel deNoyelles.[106] This study combined historic research and chemistry. Most of the analytical methods used in the New Netherland/New York project were also used for this study. Many methods of analysis for

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[102] US Department of Agriculture. "Soil Survey: Charleston County, South Carolina. (US Department of Agriculture,1971.) 8-9.

[103] Wayne. *Burning Brick: a Study of a Low County industry.* Table 8 pg 105, has a list of brickyard site in the Wando River Basin. Over half of the listed sites were along creeks, such as Darrell Creek, Toomer Creek, Wagner Creek, Horlbeck Creek, Beresford Creek, and Sander's Creek.

[104] Wayne. *Burning Brick: a Study of a Low County industry.* Table 8 pg 105.

[105] There were other buildings in the areas but only St. Andrews Parish Church is still standing. The other sites have been demolished and are known through research and archaeology. The Ashley River Historic District, National Register for Historic Places nomination, expands upon the history of these settlements.

[106] Allan Gilbert, Gilbert Harbottle and Daniel deNoyelles wrote *A Ceramic Chemistry for New Netherland/New York* in 1993 and used chemical analysis on bricks and raw clay to create a provenance for the area. Their goal was "to link artifacts with their source materials based on chemical similarity." (18) But there is more to a brick's characteristics then the elements and minerals it is made of. Some of the physical characteristics have also made brick unique to a certain area. These must also be recorded for a full study of brick.

building materials have been available throughout the mid-twentieth century. Brick and ceramic testing methods have been successfully used since the mid-1960s.[107]

[107] S. Duncan Heron Jr, Gilbert C. Robinson and Henry S. Johnson Jr, in their book *Clays and Opal-bearing Claystones of the South Carolina Coastal Plain*, suggested several methods in identifying clay minerals in 1965. On pages five and six they lists X-ray Diffraction, X-ray Fluorescence, thermal gravimetric analysis, and optical properties which are all tests that were applied for this study. They also included other analysis methods available.

Figure 2.1: Soil Survey Map of Section of the Ashley River.

The left arrow is the location of Lord Anthony Ashley Cooper's settlement where a brick sample was found during archaeology.

The right arrow locates the site of Colonial Dorchester where three brick samples were from and one clay sample was acquired. This section of the Ashley River is near the headwaters.

(From the United Stated Department of Agriculture, 1990 Dorchester County Soil Survey)

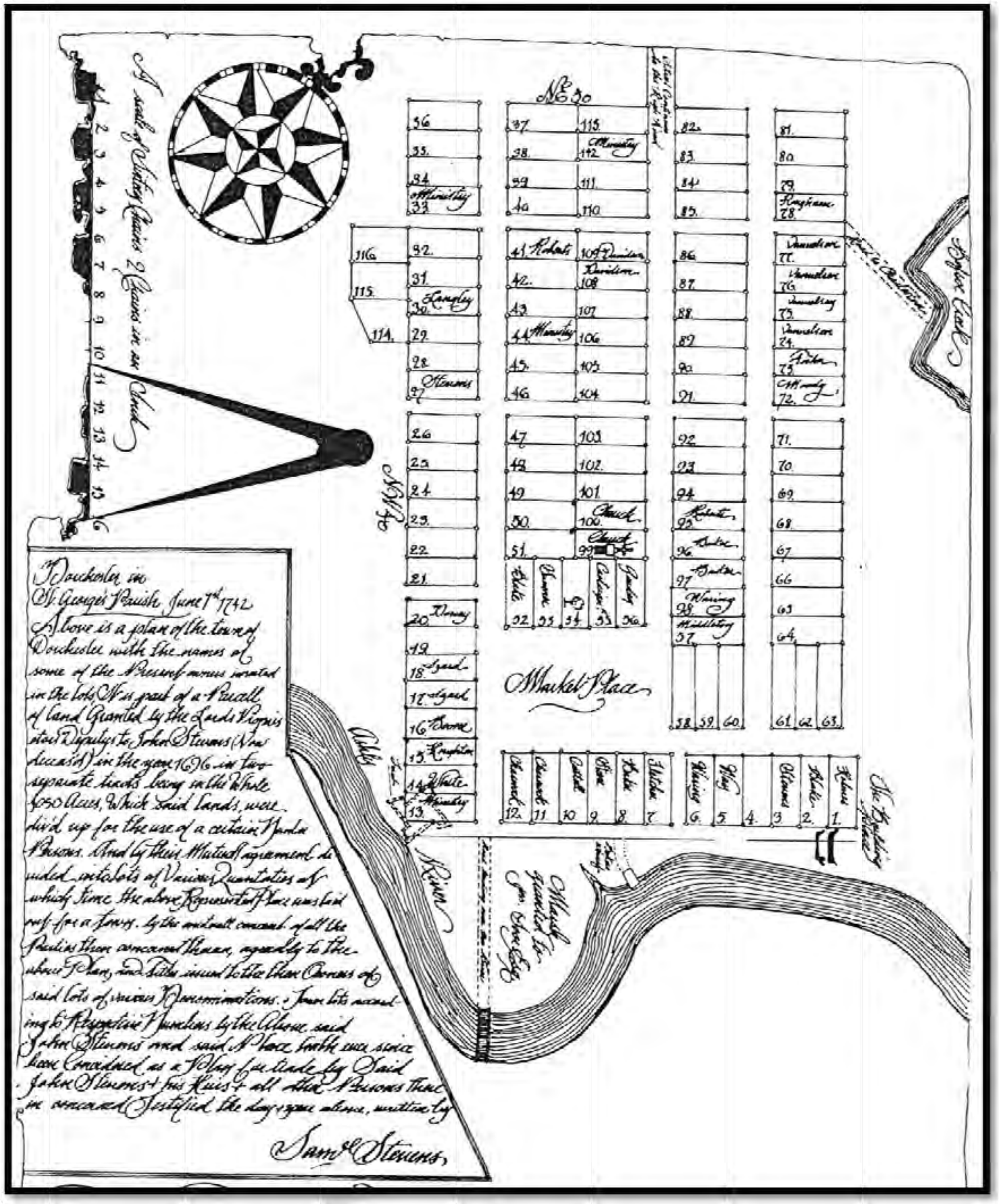

Figure 2.2: Samuel Steven's map of *Dorchester in St. George's Parish, June 7th, 1742.* The fort was located on the far left hand corner of the lots along the Ashley River. The parish church, and its ruins, is located on lots 99 and 100. The marker is the location of the clay sample. (Daniel Bell, South Carolina State Parks and Recreation Collection)

Figure 2.3: Brick sample 1067 from Colonial Dorchester. From the Collection of the Charleston Museum. (Lanphear)

Figure 2.4: Brick Sample 1091 from Colonial Dorchester. From the Charleston Museum Collection. (Lanphear)

Figure 2.5: Brick sample 1428 from Colonial Dorchester. From the Charleston Museum Collection. (Lanphear)

Figure 2.6: Clay sample from Colonial Dorchester. This was the site of clay pits dug in the latter nineteenth century. Several colors are present in the area. Later brick making would selectively choose colors of clay for specialized brick. (Stephanie Hart)

Figure 2.7: Lord Ashley settlement site. Sample brick from this site. Found through archaeology in 2010 by Brockington and Associates. (Brockington and Associates)

Figure 2.8: Brick sample from the Lord Ashley archaeological site. Historic settlement of Lord Anthony Ashley Cooper, contributed by Brockington and Associates. (Lanphear)

Figure 2.9: Soil Survey Map of Section of the Ashley River.

The top arrow is the location of Drayton Hall Plantation. Four bricks were obtained from this site.

The bottom arrow is the location of Historic St. Andrews Parish Church where a clay sample was obtained from the side of Church Creek.

(From the United Stated Department of Agriculture, 1971 Charleston County Soil Survey)

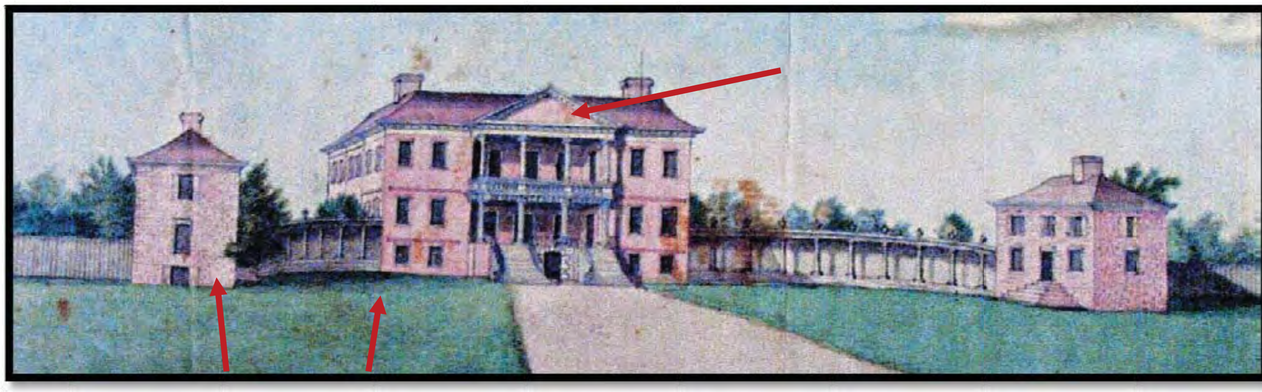

Figure 2.10: Copy of 1765 watercolor of Drayton Hall by Swiss artist Pierre Eugene Du Simitiere. The arrows mark the locations of brick sample. (left) North Flanker foundation, (middle) Pre-Drayton brick that was discovered through archaeology, and (right) brick from the original house's pediment. The fourth brick has an unknown location. (Original watercolor part of Drayton Hall Plantation's historical collection.)

Figure 2.11: Brick sample 1118 from Drayton Hall. From the Charleston Museum Collection. (Lanphear)

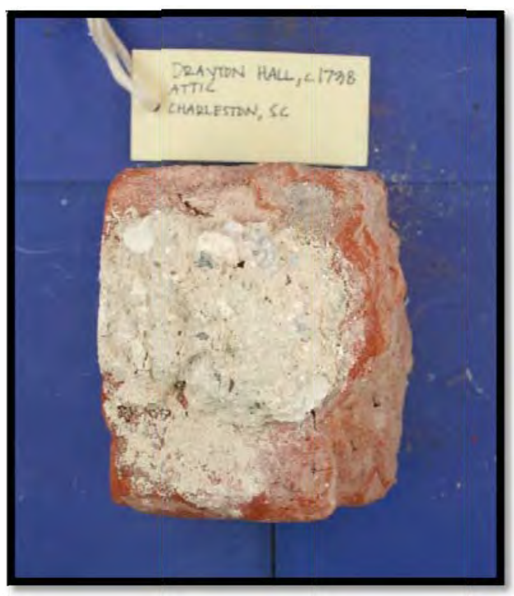

Figure 2.12: Brick sample from the Attic at Drayton Hall. From the collection at Drayton Hall Plantation. (Stephanie Hart)

Figure 2.13: Brick sample from the North Flanker at Drayton Hall. From the collection at Drayton Hall Plantation. (Stephanie Hart)

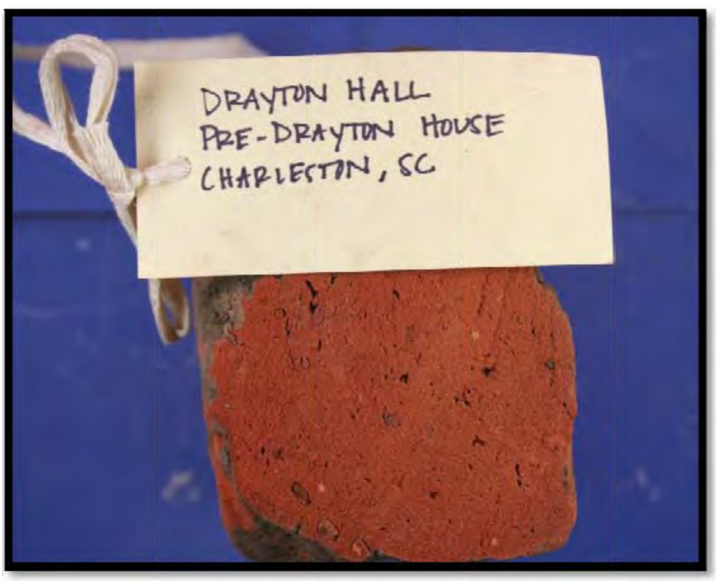

Figure 2.14: Brick sample from the Pre-Drayton house located under the **northwest** corner of Drayton Hall. From the collection at Drayton Hall Plantation. (Stephanie Hart)

CHAPTER 3: TECHNIQUES AND METHODOLOGY

The analytical methods chosen for this study are moisture content of the clay, thermal gradient firing, X-ray Diffraction, X-ray Fluorescence, Thermal Expansion, Archimedian porosity and density, polished thin section microscopy, mercury intrusion porosimetry, and color identification. Dr. Denis Brosnan, a ceramic engineer with the National Brick Research Center, chose these types of analysis because of his years of experience and knowledge of ceramic testing. Building on Dr. Brosnan's work at Fort Sumter, and Gilbert, Harbottle and deNoyelles' projects, this study creates an adapted methodology for comparisons between the fired and raw materials in chemical and physical characterization testing. Research and past experiences, by Dr. Brosnan, found that combining several tests will achieve an accurate depiction of the brick from the Ashley River. Gilbert, Harbottle and deNoyelles' project found this to be true and wrote, "Each technique has its virtues in terms of which elements can be analyzed and the level of refinement, consistency, destructiveness and expense in determining the quantities."[108] This study identifies a unique Ashley River brick family that will tie specific historic brick to their original brickyards.

3.1- X-ray Diffraction

3.1.1 Description of Technique

X-ray Diffraction (XRD) analysis is conducted on raw and fired samples in their powder state over a wide range of incident radiation angles. (Figure 3.1) The test produces identifications of mineral composition of the sample. The XRD can give a qualitative and

[108] Allan Gilbert, Gilbert Harbottle and Daniel deNoyelles wrote *A Ceramic Chemistry for New Netherland/New York* (Historical Archaeology, Vol 27, No. 3, 1993), 22.

quantitative mineralogy through characterization of the crystalline structure. Jones and Berard best describe the action of an XRD.

> "When a beam of x rays strikes a crystalline solid, an interface pattern is produced. This pattern is generated by diffraction of the x rays by the planes of atoms in the crystal in much the same way that a diffraction grating produces an interface pattern with a beam of light. Because the interface (diffraction) pattern is uniquely different for each crystalline substance, x rays diffraction has become a standard method for identifying materials."[109]

The main formula XRD uses in identification of minerals is the Bragg Equation, $d = \lambda/2 \sin \Theta$. Jones and Berard identify "The value of a *d* calculated from the Bragg equation is the interplanar spacing for the particular set of planes responsible for diffracting the beam."[110] This *d* value is unique to each crystalline material, and thus it is used in identifying minerals. When running the XRD instrument the angles of incident radiation are chosen based on the material; this also determines the length of the test, the large degree of angles to be measured correlates to longer testing time. The XRD is not only qualitative but also quantitative in that it can identify the amounts of each mineral present. This analysis works in conjunction with many other methods to confirm results of analysis conducted. Before any tests are conducted two calibrations must be completed. First is "an external standard method where there is a series of standards of known crystalline silica (quartz) content."[111] The second calibration is a calibration curve derived from the plotting peak area versus the quartz content.

[109] J.T. Jones and M.F. Berard. *Ceramics: Industrial processing and Testing*. (Ames, Iowa: Iowa State University Press, 1972), 134-135.
[110] J.T. Jones and M.F. Berard. *Ceramics: Industrial processing and Testing*. 135.
[111] . John P. Sanders. Email correspondence with author. 22 February, 2011

3.1.2 Methodology of technique

To conduct the analysis a small section of the sample brick or dried clay is broken into pieces and placed into a Puck Mill.[112] The Puck then grinds down the sample to a powder form in eight minutes. (Figure 3.2) The XRD instrument can only analyze materials in their powder form due to the ability to directly identify crystalline phases (and mixtures of crystalline phases)."[113] Once the powder state is achieved a small amount of it is placed in a one inch by one inch plastic container with a smooth, flat surface.

The XRD instrument used is the XGEN-4000 made by Scintag.[114] This instrument is enclosed for the safety of the researcher against the X-rays. To begin analysis, the powder sample is placed into the holder of the XRD, and the computer program, Jade, set for the new sample analysis. (Figure 3.3) This includes the setting of the range of angles and steps that the XRD will collect data. In this example the range of angles was set from 5˚ to 65˚ with steps every .02˚. The sample powder is placed in the center of the geometric configuration of the XRF. This location is in-between the x-ray source and the detector. Once the enclosure door is closed and locked the start button is pressed. The total reading time is three hours and twenty minutes.

After all the data is compiled, a schematic graph is formed. There are peaks and valleys that represent certain minerals and forms of minerals. Using the computer program, or through

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[112] A Puck mill is used to grind samples of ore, minerals, ceramics and soils to 200 mesh, or 74 microns, in size. The Puck Mill used by the National Brick Research Center is manufactured by the German company, HERZOG automation corporation. Seen on their website: http://www.herzogautomation.com/.
[113] Dennis R. Dinger. *Characterization Techniques for Ceramists.* 101.
[114] The operation of the Scintag XRD instrument can seen on the University of Minnesota's website: http://www.charfac.umn.edu/InstDesc/scintagdesc.html.

manual assessment, mineral components are identified in the sample material. This entire process is repeated with every sample.

3.2- Thermal Expansion Analysis

3.2.1 Description of Technique

Thermal expansion testing measures the change of length in a fired or unfired sample as it is heated. Before any samples are tested the instrument, a dilatometer, must be calibrated. (Figure 3.4) The lab used an alumina reference standard, which is provided by the manufacturer. This type of analysis is important in determining the firing temperature of brick. L. Franke and I. Schumann, researchers for the NATO-CCMS's (Committee on the Challenges of Modern Society) study entitled *The Conservation of Historic Brick Buildings and Monuments,* wrote that "The dimensions of a clay specimen change with increasing temperature: most significant is shrinkage above approximately 900°C. For an already fired sample, shrinkage starts again at temperatures higher than the original firing temperature."[115] Thus during this three to four hour test, the sample expands with heat being applied until its precise firing temperature. At that peak the clay in the sample starts to vitrify. This is seen by the sample's decrease in size.[116] A thermal expansion coefficient is also determined through this method. This number is determined from the equation:

$$\alpha = \Delta L / L\Delta T.$$

[115] L. Franke and I.Schumann. *Subsequent Determination of the Firing Temperature of Historic Brick. (Technische Universität Hamburg-Harburg.)* Conservation of Historic Brick Structures (Shaftesbury, England: Donhead Publishing Ltd, 1998), 19.

[116] Vitrification causes the sample to not only decrease in size but the pores also decrease in size but this makes the material's strength increase. Conversation with John P. Sanders, Research Associate at the Brick Institute of America, January 2011.

Where ΔL is the change of length that occurs, L is the starting length and ΔT is the change of temperature that occurs over the testing period.[117] This equation can be used for comparison between different locations.

3.2.2 Methodology of Technique

When conducting the analysis, either on brick, or clay, a small one inch long rod is cut with a one-quarter of an inch diameter. This is completed by using a tile wet saw to slowly shape the sample to the selected size. (Figure 3.5) This rod is then placed in the spring loaded holder of the instrument, the Netzsch DIL 402 C Dilatometer.[118] (Figure 3.6) One end of the dilatometer is a furnace with heat controlled by a computer and the other end is a displacement transducer. The transducer is the measuring device, which keeps track of the change in length during the analysis.

When the dilatometer is closed the furnace begins to heat to 1200˚C. This is a slow process that simulates the heating of brick kilns, but at an accelerated rate. During the heating process the increase and decrease of length of the brick sample is recorded in a graphic form of temperature versus time. The experiment heats at a rate of 10˚C per minute. The data is then interpreted by an experienced researcher. Minerals present can be detected through their characteristic reactions during the heating process. This course of action is repeated with each sample. The results are then viewed in a schematic form, where different patterns can discern

[117] Dr. Denis Brosnan. Personal correspondence with author. (March 2011).
[118] Different parts of the Dilatometer are described on the Netzsch website: http://www.netzsch-thermal-analysis.com/en/products/dilatometer/.

the presence of certain minerals such as Quartz and Cristoballite (forms of sands.)[119] This analysis simulates the firing process of brick but again the original time was much longer and many other factors such as consistency of heat and pressure, were part of historic brick firing.

3.3- Loss of Ignition (LOI)

3.3.1 Description of Technique

Another method of investigation is determining the change of weight after firing through Loss of Ignition (LOI) testing. This is to remove any moisture or other elements present in the sample and to find that percentage. Jones and Berard wrote, "When a raw material is heated in air, it loses weight as a result of driving off volatilities. In general, any material whose oxide formula contains H_2O, CO_2, SO_2 or NO_2 loses weight if heated to a sufficiently high temperature."[120] This high temperature causes vitrification of the material which results in shrinkage, along with decrease of porosity and increase of strength. This analytical method is conducted on brick and clay to create a common weight and common oxidized basis. From this point the material can be used for forming the pellets used in X-ray Fluorescence (XRF) analysis.

[119] These sands are silica dioxides, when fired which will change during heating and cooling cycles. J.T. Jones and M.F. Berard's book *Ceramics: Industrial Processing and Testing,* wrote "Since large silica grains remain relatively unreacted even at maturity, the probability of their going back through the polymorphic transformations during cooling must be considered. Generally, any cristobalite and tridymite formed will remain on cooling, but the majority of the silica grains in many ceramics never transform beyond the high quartz form." (75)

[120] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 116.

3.3.2 Methodology of Technique

To carry out the test a small section of the sample brick or dried clay is broken into pieces and placed into the puck mill to create a powder sample, which is collected in a plastic container for many analytical experiments. A crucible, or small boat shaped container that can handle the range of temperatures without chemical changes, is first weighed on a laboratory scale and recorded. Next the powder is added to the crucible. Once filled the surface is packed down and smoothed. The crucible and powder together is weighed and recorded, and the tier weight is subtracted to determine the sample weight. This process is repeated with each sample and the crucibles are identified. A documentary photograph of all the samples should be taken at this time. (Figure 3.7)

Once all the samples in the crucibles are completed, they are taken to the Lindberg/ Blue oven.[121] (Figure 3.8) This oven is set to 1000˚C and slowly heats over eight hours. This again simulates the slow heating process found in early brick kilns. This top temperature is held for one hour and then slowly cooled.

After the process is completed, the samples are removed and a photograph is taken. There is usually evidence of shrinkage. These crucibles and samples are then weighed on the scales and recorded. The difference of shrinkage depends of the elements and minerals present. This process must be conducted for the material samples that will be later analyzed under the X-ray Fluorescence instrument.

3.4- X-ray Fluorescence (XRF)

[121] The Blue M company makes industrial ovens for scientific purposes. Their website is: http://www.blue-m.com/default.aspx.

3.4.1 Description of Technique

X-ray Fluorescence (XRF) analysis is used for deducing the elements in raw and fired materials. XRF uses the radiation of X-rays to excite the inner electron shells of atoms, such as K, L and M shells, which are normally unaffected by outside oxidation processes. Thus the XRF bombards "a sample with radiation that exceeds the binding energy of the electrons in the atoms of which the material is composed of and [detects] the energy and number of resultant X-rays emitted from each element, it is possible to determine the composition and proportional concentrations of those elements."[122] To be able to read and analyze elements the XRF instrument consists of numerous wavelength dispersive spectrometers (WDS) and one energy dispersive spectrometer. The WDS collects these emitting X-rays and the EDS will "measure and categorize the energies of all x-rays emitted from sample."[123] All of the actions and parts are run and interpreted by computers. The samples under analysis can be small pieces of the larger materials, but the best results are from a powder form that has been pressed, or melted, into homogenous pellets. This is a result to the uneven distribution of particles in the material itself. This pellet gives a good example of the elements present in a sample material. After the machine has finished the analysis the results give the chemistry of the sample with percentages and part per million (ppm) of elements present. (Figure 3.9) This testing method, along with XRD, will be used in comparing the clay with the brick samples of the Ashley River. This machine must also be calibrated using a series of United States Geological Survey (USGS) and National Institute of Standards and Technology (NIST) reference materials and a copper disk for an energy calibration.

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[122] Bruce Kaiser. *Draft Bruker XRF Spectroscopy Use Guide: Spectral Interpretation and Sources of Interference.* 4.
[123] Dennis R. Dinger. *Characterization Techniques for Ceramists.* 96.

3.4.2Methodology of Technique

The first step in finding the chemistry of the brick samples is to create a pellet or disk for the XRF to analyze. To make the disks, a platinum bowl is used to mix three ingredients; sample powder that was heated during LOI testing, #2 and #3. The Platinum bowl is placed on the laboratory scale and zeroed. Next add exactly 6.0 grams of Lithium Borate. The appearance is spherical and can disseminate easily. After Lithium Borate is added, the scale is zeroed again and 0.75 grams of the powder sample is added. The sample powder should be added without any large chunks. Again zero the scale. The last ingredient to add is 1.0 grams of Ammonium Nitrate. Enter the exact measurement into the computer program. After this last step, mix the three ingredients together gently. Take this mixture and place it in the heating apparatus, known as the Claisse M4 Fluxer. This apparatus heats and turns the mixture into a red solution over twenty minutes. In the last five minutes, the liquid is dumped into disk shaped platinum containers. (Figure 3.10) These cool very quickly and can be touched with bare hands as soon as the Claisse M4 Fluxer is finished. To take the sample disks out of the containers use a suction cup. Label the disk with the sample name and weight calculated from the computer program. Repeat these steps for all the samples needed for XRF analysis. Take these disks to the XRF instrument. These disks create a common ground for analysis. “When compacted powder samples are analyzed, differences in compaction densities from sample to sample also cause inaccurate results.”[124]

[124] Dennis Dinger. 99. Small flat surfaces can be analyzed but these more homogenous disks give the best and most consistent results.

To prepare and calibrate the QuanX EC XRF, by Thermo Noran, a small copper disk is used.[125] Once the calibration is completed, the samples are entered into the computer program. This includes the name, and weight of each sample, which came from the pre-heating process. The computer program is also set up with the correct filters and setting in working with ceramics. Each sample has a separate location in the XRF instrument. (Figure 3.11) Once the top is shut and the start button pressed, the collection of data begins. The entire process for five samples takes around thirty minutes.

After the readings are completed the results are listed in their oxidized state. Each element is listed as a percentage or parts per million (ppm) present in the sample material. These results can be used individually or as supporting data for other chemical and elemental analysis on the sample brick.

3.5- Polished Thin Section

3.5.1 Description of Technique

Polished thin section microscopy is the visual study of grains and particles in the sample. Very thin sections, around 30µm thick, are cut and polished for viewing under a microscope with polarized light. The study uses a simple microscope, under which the materials can be characterized and inorganic particles may be identified. This analytical method has been used in the classification of rocks, soils, and sands, along with some provenance studies of early

[125] Thermo Scientific, http://www.thermoscientific.com/wps/portal/ts/HOME, produces this XRF instrument.

brick and terra cottas. For this project the thin section microscopy analysis was carried out in a lab located in Texas that specializes in this type of examination.[126]

3.5.2 Methodology of Technique

Although this testing is conducted in a separate lab that specializes in thin section analysis, the methodology remains the same. A very thin section of the sample brick is roughly cut from the larger mass. This thin sheet is affixed to a glass slide using an epoxy resin.[127] Once the sample is firmly attached, the exposed side is ground to a uniform thickness of 30µm. After the preferred thickness is achieved the side is polished to rid the surface of scratch marks. This polishing is "usually conducted on a wax or cloth covered wheel using a paste containing very fine diamond chips or alumina powder."[128] To keep this surface clear a cover slip can be added, but is not necessary, to protect from staining or future scratching.

The section is then analyzed under a microscope with a polarized light. Chandra Reedy, a professor at University of Delaware with a specialization in the study and documentation of traditional materials and technology, suggests that the microscopes do not have to be the most expensive but must cover "magnifications ranging from 16x to 400x."[129] Highly trained and experienced researchers should conduct this testing to obtain the best results for the physical

[126] This lab is the National Petrographic Lab in Houston, Texas.

[127] Chandra L. Reedy. *Thin-Section Petrography in Studies of Cultural Materials.* 1994. "the sample is mounted on a glass slide using an epoxy resin with a refractive index (1.54-1.55) essentially the same as that of quartz." Pg 2

[128] J.T. Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing.* 131. This polishing step is usually repeated many times with successively finer and finer grains. The better the polish the fewer the amount of scratches to see through the microscope.

[129] Chandra Reedy. : Reedy states in her article that "One advantage of thin-section petrography is that the necessary equipment (a polarizing microscope) is relatively inexpensive, making the technique potentially available to almost any laboratory as a routine method of analysis." Pg 2

investigation.[130] Researchers can study characteristics of color, opaqueness, and isotropism versus anisotropsim.[131] They are also able to see the minerals, textures and percentage of various other constituents present in materials. These analytical methods have been used for creating classifications and confirming materials present in the material sample. Thin section analysis will clarify the particles and minerals found in the other forms of examination.

3.6- Mercury Intrusion Porosimetry

3.6.1 Description of Technique

Mercury Intrusion method determines the porosity, pore size distribution and the nature of the open pores in the brick sample. The instrument used is the Quantachrome Poremaster. (Figure 3.12) Once the instrument has been calibrated, through manufacturer's supplied standards, a small piece of the sample brick is placed in the tube and exposed to low and high pressures, up to 60,000 psia (pounds per square inch absolute). These pressures are forcing the mercury into the sample and into the small pores.[132] Dennis Dinger notes that "the force that must be applied to the mercury increases as pore diameters decrease."[133] This test then compares the sample without mercury and one with the mercury. Dinger further states that "The greater the porosity of a sample, the more likely will be the penetration of liquids and

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[130] Chandra Reedy. "Although a significant investment in training and experience is required to use this technique to full advantage, thin-section analysis is still a very efficient way to obtain crucial information about many inorganic materials." Pg 2

[131] Isotropism means the material is identical is all directions while Anisotropism means the material differs in different directions of the material.

[132] Mercury is the preferred substance due to its property as a non-wetting liquid. Jones and Berard's book, *Ceramics: Industrial Processing and Testing,* states "The first, intrusion porosimetry, uses the fact that a nonwetting liquid will not penetrate into a small pore unless an external pressure is applied. Mercury is the liquid most commonly used, and higher and higher pressures are needed to force it into smaller and smaller pores." (110)

[133] Dennis R. Dinger. *Characterization Techniques for Ceramists.* 53.

vapors into the material, and usually such penetration is accomplished by potential structural damage to the material."[134] The data is given in a graph of pore size and percentages. These can be compared with other brick in the area to see if they were made in the same batch of brick or even how early the brick were made. This is just one tool in understanding brick and one step in the comparison of brick of the same region.

Before any samples can be examined the instrument, produced by Quantachrome PoreMaster, must be calibrated to the correct pressures, cleaned from any last testing, and new mercury added if needed.[135] Small pieces of the sample brick are weighed and placed in the larger end of the capillary tube. (Figure 3.13) Again, measure the weight of the sample and tube together on the laboratory scale. Once this is finished, seal the top of the capillary tube. The tube with the sample is placed in the low pressure cylinder; this valve only runs to 50 psi. After twenty minutes, remove the capillary tube and place sample in the high pressure cylinder. This test allows up to 30,000 psi to be forced on the mercury. The top of the high pressure valve must be screwed tight because of the amount of pressure being applied and to prevent a large mess if the sample explodes. This section of the analysis runs for ten minutes. After the testing is completed, the tube with the sample and mercury are weighed, all the data is given to the computer and the results are read in listed data and schematic graphs. (Figure 3.14)

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[134] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 109.
[135] Quantachrome Instruments produced the instrument used. There are several types of mercury intrusion porosimetry readers, and the website explains them in more detail. http://www.quantachrome.com/mercury_p/poremaster.html.

3.7- Thermal Gradient Firing

3.7.1 Description of Technique

Thermal gradient firing tests are used to observe how different temperatures affect the development of colors in brick clays on firing. The physical color is also determined by several other factors, but temperature is a major factor. This analysis method is executed by a furnace that can produce varied temperatures. (Figure 3.15) The highest heat is located in the back of the furnace, with temperatures descending towards the front. Temperatures are controlled by a computer, which allows this type of testing to be completed with more precision. Each sample was fired individually during older testing processes, but due to technological advances, ten samples can now be fired simultaneously. Also, through computerization, the heating process can control the time for each firing. To simulate the firing in kilns the furnace warms slowly to the high temperature and then holds that temperature for a selected time. Although the total time is much shorter than that of historical brick firing, researchers "can observe and measure body properties as a function of firing temperature achieved at each position in the gradient furnace."[136]

3.7.2 Methodology of Technique

This type of testing is only performed on the clay samples in an unfired state. The first step is to prepare clay sample disks for firing, which must be almost fully dried. To obtain this state the clay sample should sit in an oven for at least twenty-four hours. Next the sample is

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[136] Denis R. Dinger. *Characterization Techniques for Ceramists.* (Kearney, NE: Morris Publishing, 2005), 85.

placed in a mortar and pestle to make a paste-like consistency. (Figure 3.16) If the clay is too dry and tends to crumble, mist with water. Take the paste and place it into a mold for creating small disks, fifteen grams in size. (Figure 3.17) To form a preferred sized disk, use a clamp for appropriate compression, slowly removing to maintain the untouched condition. (Figure 3.18) This procedure is repeated to create ten samples.

After the ten disks are finished the firing process begins. (Figure 3.19) The Orton Thermal Gradient Furnace is a cylindrical furnace that is attached to a computer.[137] This allows for control of gradual differences in temperature over the short interior space. Once the computer is set for the gradual heating, over twelve hours, the furnace sits at this highest temperature for four hours. The highest temperature in the furnace is located at the rear at 1200˚C. The front temperature can be around 200˚C difference. This process simulates the heating patterns of a kiln and colors that form. Place the ten samples on the thin strip and photograph. The sample is then slid into the furnace and the door is closed. After the full heating sequence experiment remove the samples and take another photograph for documentation. The difference in colors should be evident. (Figure 3.20)

3.8 Archimedian Density and Porosity

3.8.1 Description of Technique

A regular test performed on brick is the Archimedian Porosity and Density method. Archimedes' principal, as written by Jones and Berard, simply states:

[137] Orton is an American company that specializes in research equipment for art and industrial uses. More information on the instrument used for this study is at: http://www.ortonceramic.com/instruments/05bGTF.shtml.

> "An object placed in a fluid suffers a loss in weight equal to the weight of the fluid which the object displaces. Thus, if the object is completely submerged in the fluid, it will lose an amount of weight equal to its volume multiplied by the density of the fluid."[138]

This process, unlike the Mercury Intrusion method, uses atmospheric pressure to calculate Bulk Density, Apparent Density and Percent Apparent Porosity.[139] John Sanders, a research Associate Professor at Clemson, wrote that the two methods "should give similar result, but they won't be identical."[140] To achieve these measurements four weight measurements must be performed and recorded in this order: the measurement of the sample dry, after twenty-four hours in cold water, after sitting in boiling water and on a suspended scale.

3.8.2 Methodology of Technique

The first step is to use a wet tile saw and cut five one inch cubes of each sample brick. The samples will be wet and must be placed in a dryer for twenty-four hours. (Figure 3.21) Once the cubes are fully dried, they are removed and measured on lab scales. Record all the measurements. Next, the samples are placed in cold water for twenty-four hours. After the time is complete, the samples are removed and measurements recorded. The samples will still be wet, but continue to the next step. The five sample cubes are then placed in a pot of boiling water for five hours. (Figure 3.22) After the selected time, the cubes are removed and measured. The final measurement is with a suspended scale. Record the weight into the

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[138] J.T. Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing.* 105.
[139] Material Science and Technology Online (http://mst-online.nsu.edu) defines Bulk Density as "a ceramic's density, and it includes the material's porosity and the fact that most ceramics contain both a crystalline and a noncrystalline phase." Apparent density, by Jones and Berard (107), "is defined as the weight per unit volume." Percent pore volume, also known as open pore volume, can be directly measured. Jones and Berard write, "When this volume is expressed as a percentage of the bulk volume of the sample, it is called either the percent apparent porosity or most often simply the porosity." (109)
[140] Dr. John P. Sanders. Email correspondence with author. 9 February, 2011.

computer program and it will calculate the bulk density, apparent density, percent apparent porosity, and the average of all the five samples in each category.

3.9 Moisture Content

3.9.1 Description of Technique

One of the initial tests on the clay sample is the moisture content. The process is very similar to the Loss of Ignition (LOI) analysis that is performed on fired brick samples; both find the amount of water present in the sample. To find this figure, the clay sample is placed in a heat proof container and dried to temperatures around 1000˚C. When the clay is heated to this temperature, Jones and Berard state, "water of hydration, i.e. molecular water such as that in borax, is lost gradually with heating. And carbonaceous material present combines with oxygen from the air to form volatile oxides which are also carried away."[141] After several hours of heating, the samples are removed and shrinkage is seen. (Figure 3.23) This test is usually conducted when clay is made into brick and the moisture added must be adjusted in the process.

3.9.2 Methodology of Technique

This measurement of the water content of the clay sample is very similar to the Loss of Ignition (LOI) test. A crucible, a container not affected by high heat, is weighed on a lab scale and the weight is recorded. The sample clay is then filled into the crucible and the surface is flush. The sample in the crucible is weighed and recorded. This step is repeated for the number of clay samples taken. Take a photograph of the samples before the heat.

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[141] J.T. Jones and M.F. Berar. *Ceramics: Industrial Processing and Testing.* (Ames, Iowa: University of Iowa Press, 1972), 116.

Place all the clay samples in the drier. The heat, for this experiment, will warm to 1100˚C over a span of eight hours. Once the top temperature is reached, the drier will hold that heat for one hour. After the sample has cooled, a photo and weight measurement is taken and recorded. Once all the measurements have been recorded in the computer program, the percent of moisture is calculated and reported.

3.10 Colorimetry

3.10.1 Description of Technique

Color identification is another analytical method used commonly in brick studies. Color determination has always been an issue of individual perception and interpretation. To combat this, in 1905, the Munsell Color system was developed.[142] (Figure 3.24) In recent decades, a new system was developed that depends less on individual perception and more on computer identification, the colorimeter. Current colorimeters consist of a handheld device with a measuring head and a separate data processer. This process is utilized consistently in industrial fields, including the food industry.

Colorimeters, such as the Minolta brand, use the "Lab" color system to identify the materials color. Minolta states that "In 1976, the CIE developed the Lab System which is the most used system in the world and the most popular system in industry. It is a three

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[142] Konica Minolta. *Clemson University: Understanding and Controlling Color.* http://www.konicaminolta.com/sensingusa/application_notes/Color-Measurement/Clemson-University-Understanding-and-Controlling-Color. (Accessed February 2011.): This article states, "To overcome these [discrepancies in the past] problems, various systems have been developed in the past in an attempt to quantify color and express it numerically. The first of these was the Munsell System developed in 1905 by an American artist, A. H. Munsell. His method utilized a large number of paper color chips of various hues, lightness, and saturations. A specimen color was visually compared to these standards, and the color was described in terms of the standards."

dimensional system where the L axis indicates lightness, and the a and b axes indicate chromaticity or color. The a axis refers to red in the positive x direction and green in the negative x direction. The b axis refers to yellow in the positive y direction and blue in the negative y direction."[143] This three-dimensional color chart allows for precise colors that would not be decipherable by visual inspection.

3.10.2 Methodology of Technique

Identifying the color of the brick is a simple process. The larger sample of the brick is first cleared of any dirt or mortar on the surface. Using the measuring head of the Minolta CR-210 colorimeter, place the detector down on the surface of the brick and press start. Wait until the device beeps three times, this should take no more than five seconds, and remove the detector. On the data processer, three numbers should appear. They will be following letters L, a, and b. This is the Lab color identification system. Compare these numbers to the three-dimensional color chart. (Figure 3.25) Repeat this on each brick sample and record each set of color identification numbers.

[143] Konica Minolta. *Clemson University: Understanding and Controlling Color.* http://www.konicaminolta.com/sensingusa/application_notes/Color-Measurement/Clemson-University-Understanding-and-Controlling-Color.

Figure 3.1: X-ray Diffraction Instrument; XGEN-4000 made by Scintag. (Lanphear)

Figure 3.2: Puck Mill. (Lanphear)

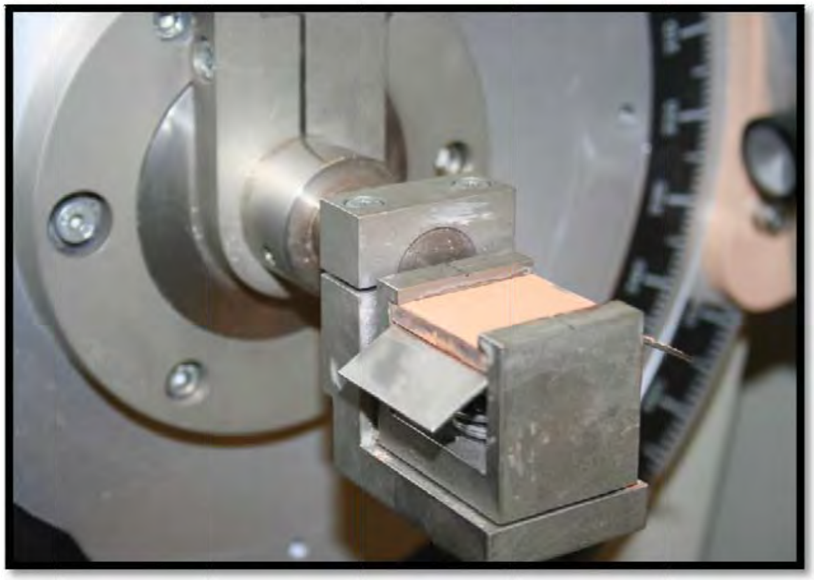

Figure 3.3: Close up of view of sample in XRD instrument. The microscope moves around the sample over a prescribed degree range. (Lanphear)

Figure 3.4:Thermal Expansion Instrument/ Dilatometer. Netzsch DIL 402 C Dilatometer. (Lanphear)

Figure 3.5: Cutting brick samples with the tile cutter.
(Lanphear)

Figure 3.6: Close up view of the sample in the Dilatometer.
(Lanphear)

Figure 3.7: Five of the brick samples in the oven for the Loss of Ignition test. (1) Lord Ashley, (2) Dorchester 1091, (3) Dorchester 1067, (4) Dorchester 1428, & (5) Drayton Hall 1118. (Lanphear)

Figure 3.8: Small electric kiln for heating in Loss of Ignition test. Lindberg/ Blue oven. (Lanphear)

Figure 3.9: X-ray Fluorescence Instrument; QuanX EC XRF, by Thermo Noran. (Lanphear)

Figure 3.10: After the powdered form of the brick sample is mixed with Lithium Borate and Ammonium Nitrate the mixture is heated in the Claisse M4 Fluxer. This liquid form is then poured into a mold that gives the disk like shape. (Lanphear)

Figure 3.11: Five samples in the XRF instrument. This XRF can read ten samples in a short time. The elements are then reported through the computer program. (Lanphear)

Figure 3.12: Mercury Intrusion Porosimeter. Produced by Quantachrome PoreMaster. (Lanphear)

Figure 3.13: Small samples before the Mercury Intrusion test.

Figure 3.14: Weighing the sample after the mercury intrusion test. The entire tube is filled with mercury and the sample. (Lanphear)

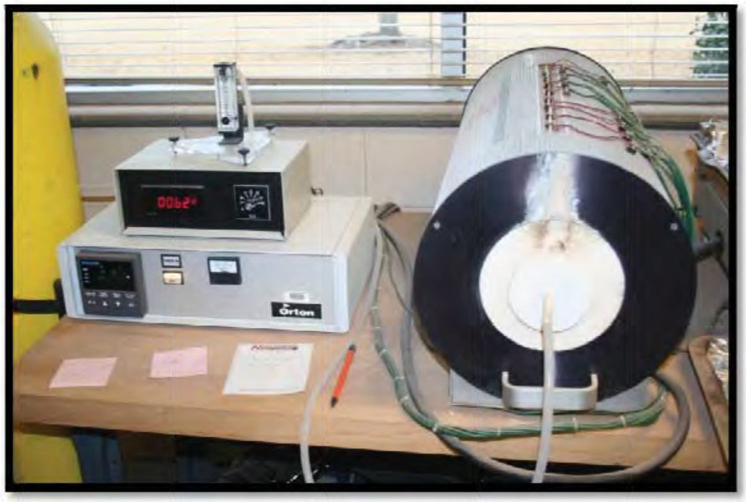

Figure 3.15: Thermal Gradient Furnace. Produced by Orton, an American scientific instrument company. (Lanphear)

Figure 3.16: The clay sample was mixed with a little water to form a paste. A mortar and pestle are used. (Lanphear)

Figure 3.17: The mold that created the disks for the thermal gradient firing. (Lanphear)

Figure 3.18: Example of two disks from Church Creek clay sample. Ten disks are made for each clay sample. The color is examined before and after the firing. (Lanphear)

Figure 3.19: Clay sample disks before thermal gradient firing. (Lanphear)

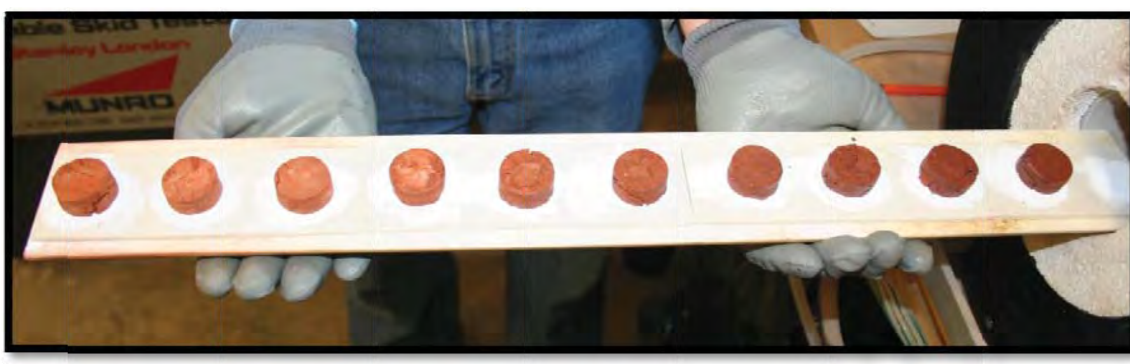

Figure 3.20: The Church Creek clay disks after firing. Color difference is noted. (Lanphear)

Figure 3.21: The three samples were cut into five one-inch cubes. (Lanphear)

Figure 3.22: The pots used for the hot water tests in Archimedian testing. (Lanphear)

Figure 3.23: Dryer used for moisture content testing. Scientific Product: Gold Series. (Lanphear)

Figure 3.24: Colorimeter Instrument. Manufactured by Minolta. (Michael Mason)

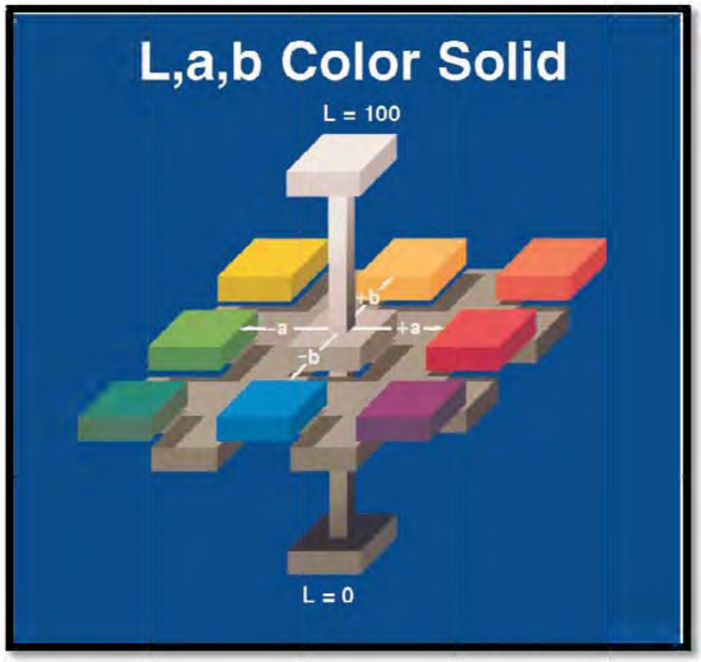

Figure 3.25: The colorimeter three-dimensional color chart.
(Image from Hunter Lab, color specialists. Hunterlab.com)

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Results

The Ashley River's brick and clay results are from two major testing periods, the last week of January and the middle of February, 2011. All the tests were conducted at the National Brick Research Center, in conjunction with Clemson University, located near Anderson, South Carolina with the guidance of Dr. Denis Brosnan. The author did assist in most of the early stages of the preparation and testing process. The brick of the first testing period received the entire series analysis but because of time and funding available, the second set received only the chemical analysis. These analytical methods were designed to determine the chemical and physical characteristics of brick and clay from the Ashley River in the Low Country of South Carolina.

4.1.1 Brick

There were, in total, eight brick tested over the period of the study. Three brick were available from the site at Dorchester, one from the Lord Ashley Site and four from Drayton Hall. Although this is a small sampling of the brick from the Ashley River area it is the beginning of the identification of a unique brick family for the river region. As stated earlier, not all the tests were able to be conducted on each brick sample, although a good indication of the average of each test was able to be found.

4.1.1.1 X-ray Fluorescence

The chemistry of the brick was found by the XRF. The same instrument was used on all the tests for this study. The results are seen in two forms, the major constituents, oroxidized form, which is the form found in the earth, and the minor constituents. Both forms present Al2O3 (Aluminum Oxides), SiO2 (Silica), CaO (Calcium Oxides, or Lime), and Fe2O3 (Iron Oxide, or as seen in nature, Hemitite). These elements are common in brick and most earth made materials. Two brick, Drayton Hall's 1118 and Dorchester's 1091, have a much larger amount of Calcium that could be due to mortar seeping into the brick over time or the calcium content of the area where the brick was dug. (Tables 4.1 and 4.2)

Table 4.1: Chemistry of the Brick Sample Major Constituents, in Oxidized Form

		Dorchester			Lord Ashley	Drayton Hall			
		1067	1091	1428	Lord Ashley	1118	Pre-Drayton	Attic	North Flanker
Major Constituents									
Al2O3	%	12.98	11.27	12.13	11.94	9.16	11.24	8.08	10.37
SiO2	%	78.33	80.85	79.5	81.19	83.78	81.12	85.44	82.25
Na2O	%	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
K2O	%	0.92	0.9	1.17	0.5	0.81	1.35	0.80	0.69
MgO	%	0.32	<0.2	0.28	<0.2	<0.2	0.21	0.27	0.21
CaO	%	<0.01	0.74	<0.01	<0.01	0.8	0.33	0.44	0.66
TiO2	%	1.15	1.03	0.96	0.89	0.97	1.13	0.71	1.02
MnO	%	0.02	0.02	0.02	0.01	0.04	0.04	0.03	0.03
Fe2O3	%	5.82	4.6	5.46	4.92	3.57	3.99	3.45	4.06
P2O5	%	0.05	0.05	0.05	0.05	0.17	0.12	0.34	0.28
S	%	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sum of Major Constituents	%	99.59	99.46	99.57	99.5	99.3	99.52	99.56	99.57

Table 4.2: Chemistry of the Brick Sample Minor Constituents

sites		Dorchester			Lord Ashley	Drayton Hall			
		1067	1091	1428	Lord Ashley	1118	Pre-Drayton	Attic	North Flanker
Minor Constituents									
Cl	ppm	<250	<250	<250	<250	<250	<250	<250	<250
V	ppm	<150	<150	<150	<150	<150	<150	<150	<150
Cr	ppm	89	54	<50	75	<50	91	<50	102
Ni	ppm	<10	<10	<10	<10	<10	<10	<10	<10
Cu	ppm	66	44	49	43	55	45	32	29
Zn	ppm	<20	<20	<20	<20	<20	<20	<20	<20
As	ppm	<20	<20	<20	27	26	<20	26	<20
Rb	ppm	<30	<30	<30	<30	<30	<30	<30	<30
Sr	ppm	93	81	131	67	152	109	181	125
Zr	ppm	275	390	230	209	265	473	347	292
Ba	ppm	400	440	480	370	430	560	320	350
Pb	ppm	<50	<50	<50	<50	<50	84	<50	<50

4.1.1.2 X-ray Diffraction

Additional chemical characteristics of the brick were found with XRD. The results are viewed in a graph. The minerals present are Quartz, Cristoballite, Hematite, Sillimanite and Tridymite. Quartz, or ordinary sand, is a form of silica. Professors J.T. Jones and M.F. Berard write that "The role of the silica grains in a vitrifying ceramic is a critical one. Silica undergoes several changes in crystal structure during heating and cooling."[144] These changes cause different forms of Quartz, as in Cristoballite and Tridymite.[145]

In the sample, Drayton Hall 1118, a mineral was present not seen in any other brick samples. This was the mineral anorthite. Anorthite derives from high amounts of a form of calcium in the raw materials, not the mortar.[146] The results are seen in Graph 4.1.

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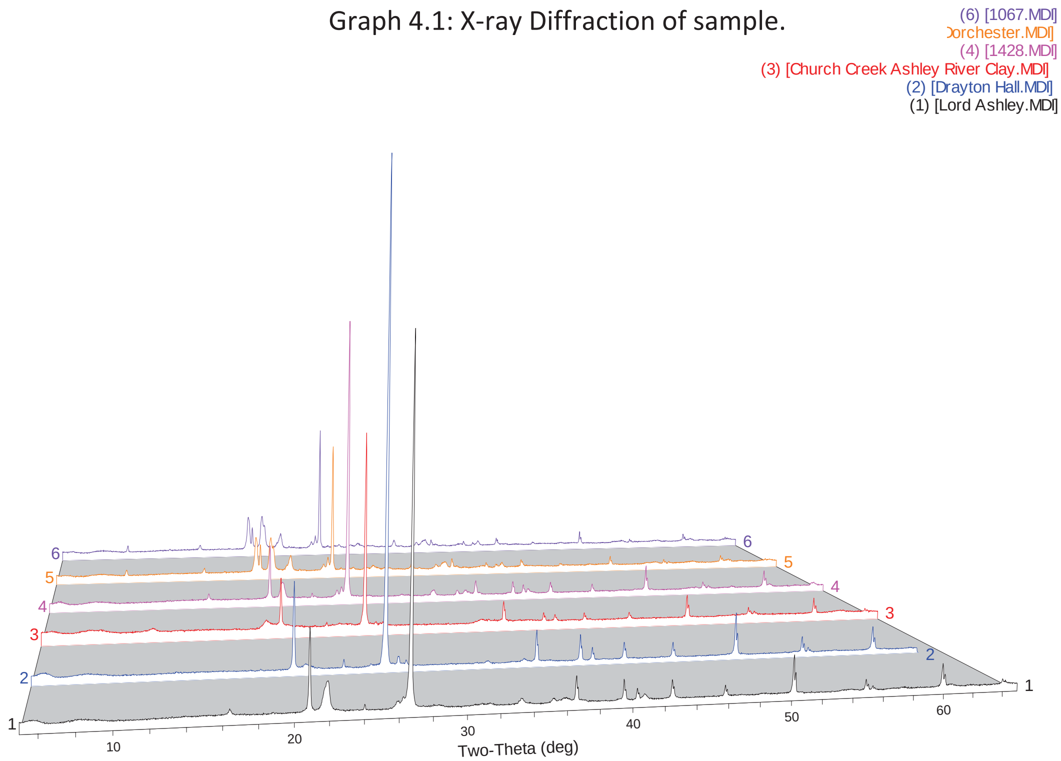
[144] J.T. Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing.* (Ames, IA: The Iowa State University Press, 1972), 73.
[145] J.T. Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing.* 75. Jones and Berard stated that "When liquid is present, the high quartz can very slowly transform into other forms on further heating: to tridymite above 867˚C and to cristobalite above 1470˚C. Some cristobalite is often found in ceramics that have been fired to high temperatures."
[146] Dr. Denis Brosnan. Personal interview with author. (January 2011)

Graph 4.1: X-ray Diffraction of sample.



4.1.1.3 Loss of Ignition

Discovering the amount of weight lost during heating, or the Loss of Ignition, is a straight forward process. Jones and Berard's book states that "In general any material whose oxide formula contains H_2O, CO_2, SO_2, or NO_2 loses weight if heated to a sufficiently high temperature."[147] All the brick were subjected to this process. The range of results has Dorchester 1091 with the largest loss of weight at 1.84% and the least percentage of loss is seen in the Drayton Hall brick from the attic, at 0.34%. (Table 4.3) There are many factors that contribute to the brick's weight, such as the atmosphere in the location and the size of pores in the sample brick.

Table 4.3: Loss of Ignition results

sites	Dorchester			Lord Ashley	Drayton Hall			
	1067	1091	1428	Lord Ashley	1118	Pre-Drayton	Attic	North Flanker
Loss %	0.36%	1.84%	0.40%	0.78%	0.81%	1.20%	0.34%	0.81%

[147] [147] J.T. Jones and M.F. Berard. *Ceramics: Industrial Processing and Testing.* 116. Thus most of the loss of weight is water weight.

4.1.1.4 Mercury Intrusion Porosity

This analysis was completed on five samples over the course of three days. The small samples used were only a representation of the entire material. This test, as seen in the table below, produces the median pore diameter of the pores and the porosity percentage of the sample, along with the Bulk and Apparent Density. The median pore diameter varied drastically, from 7.7 microns to 22.25 microns, although, the tests found porosity of all the samples are around 30%. (Table 4.4)

Table 4.4: Mercury Intrusion Porosimetry Results

Sites		Dorchester			Lord Ashley	Drayton Hall
		1067	1091	1428	Lord Ashley	1118
Property	Unit					
Total Intrusion Volume	ml/g	0.16	0.17	0.2	0.16	0.19
Median Pore Diameter	microns	19.06	11.21	22.25	9.52	7.7
Bulk Density	g/cc	1.74	1.7	1.63	1.93	1.72
Apparent Density	g/cc	2.17	1.94	2.15	2.2	1.84
Porosity	%	28.22	29.19	33.44	31.25	32.49
Pores >3 Microns	%	0	68.05	93.17	66.06	70.99
Maage Index		19.74	181.93	239.24	178.33	187.27
Pores >10 Microns	%	0	52.71	80.06	48.93	39.7
Pores 10-1 Microns	%	0	21.37	17.57	26.75	44.48
Pores <1 Microns	%	100	25.92	2.37	24.32	15.82

4.1.1.5 Archimedian Density and Porosity

This investigational method also attains the Bulk Density, Apparent Density and Percent Apparent Porosity. Only four sample brick underwent the testing, due to cost constraints and size, the Lord Ashley sample was too small to use. Each brick had five small cubes which were combined for an average of the sample brick. The results, as seen in the tables below, are concurrent with the results found in the Mercury Intrusion testing. Bulk Density measurements were averaging around 1.7 g/cc. Apparent Density averaged around 2.6 g/cc. And the porosity averaged 32%. (Table 4.5)

Table 4.5: Archimedian Porosimetry and Density for sample Dorchester 1067

Sites	Dorchester: 1067						
	1	2	3	4	5	Average	Std Dev
Dry Weight (g)	21.1604	22.7383	21.3098	24.2194	22.3677		
24hr Cold Weight (g)	23.5353	25.415	23.6205	26.9432	24.6752		
5hr Boiled Weight (g)	24.8759	27.0457	25.256	28.7674	26.3047		
Suspended Weight (g)	12.7996	13.7936	12.9434	14.7032	13.5396		
CWA (%)	11.22	11.77	10.84	11.25	10.32	11.08	0.54
BWA (%)	17.56	18.81	18.52	17.78	17.6	18.25	0.63
C/B	0.64	0.63	0.59	0.6	0.59	0.61	0.02
Bulk Density	1.75	1.72	1.73	1.72	1.75	1.74	0.02
Apparent Density	2.53	2.53	2.55	2.55	2.53	2.54	0.01
% Apparent Porosity	30.77	32.35	32.05	32.34	30.84	31.67	0.8

Table 4.6: Archimedian Porosimetry and Density for sample Dorchester 1091

Sites	Dorchester: 1091						
	1	2	3	4	5	Average	Std Dev
Dry Weight (g)	23.3846	26.2335	24.1217	24.9823	23.8657		
24hr Cold Weight (g)	26.7965	30.1312	27.6796	28.3658	27.2905		
5hr Boiled Weight (g)	27.9835	31.503	29.1492	29.7452	28.7049		
Suspended Weight (g)	14.4181	16.1214	14.964	15.4355	14.7909		
CWA (%)	14.59	14.86	14.75	13.54	14.35	14.42	0.52
BWA (%)	19.67	20.09	20.84	19.07	20.28	19.99	0.67
C/B	0.74	0.74	0.71	0.71	0.71	0.72	0.02
Bulk Density	1.72	1.71	1.75	1.75	1.72	1.72	0.02
Apparent Density	2.61	2.59	2.63	2.62	2.63	2.62	0.02
% Apparent Porosity	33.9	34.26	35.44	33.28	34.78	34.33	0.82

Table 4.7: Archimedian Porosimetry and Density for sample Dorchester 1428

Sites	Dorchester: 1428						
	1	2	3	4	5	Average	Std Dev
Dry Weight (g)	17.1916	16.7902	19.5916	17.3443	16.1727		
24hr Cold Weight (g)	20.0351	19.6166	22.6182	20.1655	18.8396		
5hr Boiled Weight (g)	20.994	20.4243	23.5962	21.0193	19.8239		
Suspended Weight (g)	10.6112	10.2683	11.9278	10.652	10.0308		
CWA (%)	16.54	16.83	15.45	16.27	16.49	16.32	0.53
BWA (%)	22.12	21.64	20.44	21.19	22.58	21.59	0.83
C/B	0.75	0.78	0.76	0.77	0.73	0.76	0.02
Bulk Density	1.66	1.65	1.68	1.67	1.65	1.66	0.01
Apparent Density	2.61	2.57	2.56	2.59	2.63	2.59	0.03
% Apparent Porosity	36.62	35.78	34.32	35.45	37.28	35.89	1.13

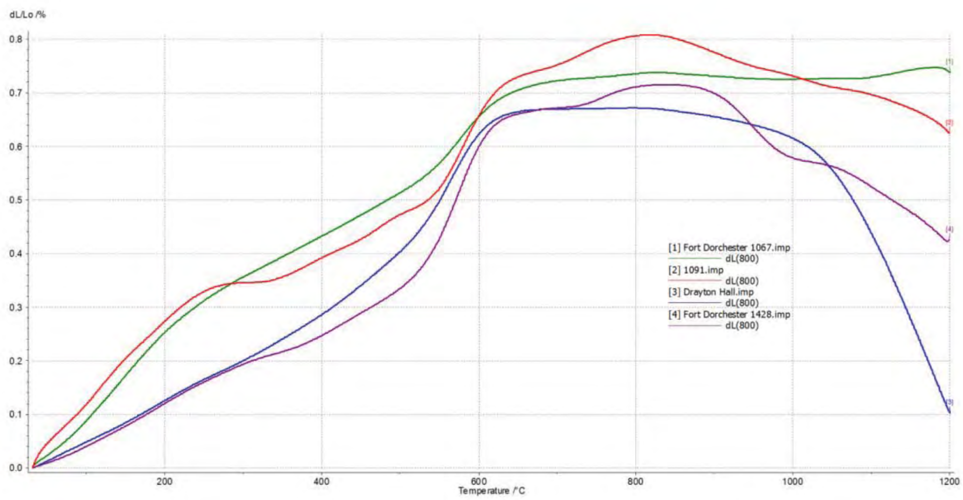
Table 4.8: Archimedian Porosimetry and Density for sample Drayton Hall 1118

Sites	Drayton Hall: 1118						
	1	2	3	4	5	Average	Std Dev
Dry Weight (g)	20.7851	26.158	24.7729	19.3052	26.4517		
24hr Cold Weight (g)	23.524	29.7264	28.2268	21.9605	29.9923		
5hr Boiled Weight (g)	24.6093	31.0485	29.6569	22.8892	31.3842		
Suspended Weight (g)	12.6624	16.1704	15.2153	11.976	16.1548		
CWA (%)	13.18	13.64	13.94	13.75	13.39	13.58	0.3
BWA (%)	18.4	18.7	19.72	18.56	18.65	18.8	0.52
C/B	0.72	0.73	0.71	0.74	0.72	0.72	0.01
Bulk Density	1.74	1.76	1.72	1.75	1.74	1.74	0.02
Apparent Density	2.56	2.62	2.59	2.6	2.57	2.59	0.02
% Apparent Porosity	32.01	32.87	33.82	32.54	32.39	32.73	0.68

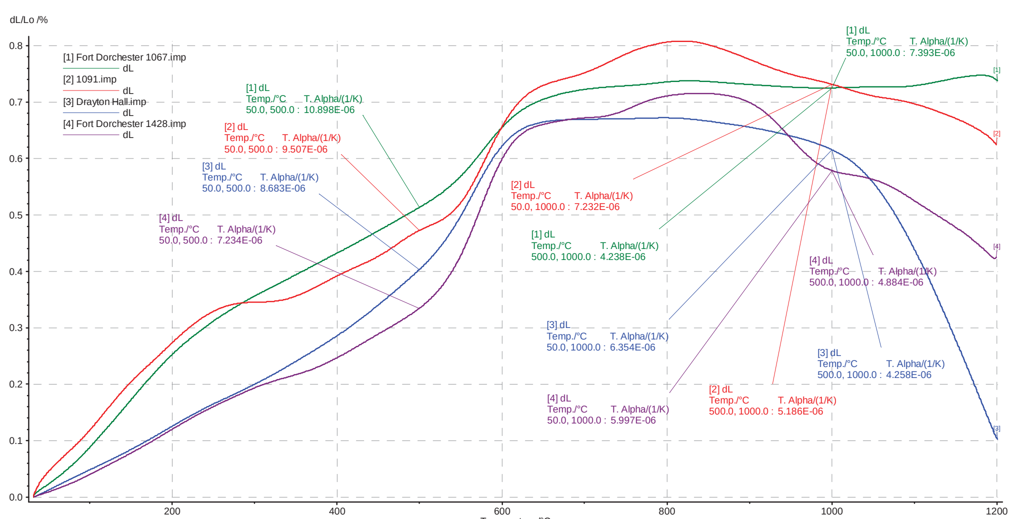
4.1.1.6 Thermal Expansion/ Dilatometer Testing

Only four brick underwent the dilatometer testing. They included Drayton Hall 1118 (identified in the graph as Drayton Hall), and the three Fort Dorchester brick: 1067, 1091, and 1428. The dilatometer heats up the sample brick rods to find their original firing temperature. The four brick were all over the normal, 950˚C, range. Two of the brick, Dorchester 1091 and 1428, were close in range. Dorchester 1091 differed greatly to the other tested samples. The movement of the graph also shows the evidence, as also indicated in the XRD testing of quartz, and, in a lesser extent, cristobalite. The quartz evidence is seen in the spike of all four brick at 600˚C. The smaller peak, around 250˚, is the cristobalite presence. (Graph 4.2) The Drayton Hall 1118 sample has a different decrease than the other samples. The sample has two small peaks that indicate the anorthite present in the brick, as found in the chemistry. The average firing temperature of all the brick is over 1000˚C. The dilatometer testing also determines the thermal expansion coefficient. This coefficient averaged 5.69 x 10-6. (Graph 4.3)

Graph 4.2: Thermal Expansion for samples Drayton Hall 1118, Dorchester 1091, Dorchester 1067, Dorchester 1428



Graph 4.3: Thermal Expansion Coefficients for samples Drayton Hall 1118, Dorchester 1091, Dorchester 1067, Dorchester 1428



4.1.1.7 Colorimeter Testing

The Minolta Colorimeter tested four sample brick. Each brick had three locations on the surface and interior tested. The average results from each brick varied greatly. The L-value, a-value and b-value readings differed by ten to almost twenty points. (Figure 4.9) When averaged out, the Ashley River brick has a colorimeter reading with the L-value at 41.9175, a-value at 13.9975 and b-value at 20.4325. These all range in the red section of the colorimeter three-dimensional color chart.

Table 4.9: Minolta Colorimeter Average Results

Sample	L-value	a-value	b-value
Dorchester 1067	37.44	10	11.97
Dorchester 1091	42.64	15.33	22.41
Dorchester 1428	39.05	20.15	17.93
Drayton Hall 1118	48.54	22.21	29.42
Average	41.9175	13.9975	20.4325

4.1.1.8 Standard Petrographic Thin Section

A total of six brick were analyzed during this testing; Lord Ashley, Dorchester 1067, Dorchester 1091, Dorchester 1428, Drayton 1118 and Pre-Drayton. Each of the thin sections was examined under 100x magnification and with a reflected polarized light. At this level the larger pores (the larger gray matter in the images), the quarts or sand particles (the white and lighter gray coarse particles) and the vitrified clay (the reddish color areas) can be seen. The vitrified clay has several colors blended together, from shades of yellow-red to light red-brown. (seen in figures 4.1 To 4.6) This color range is seen in all the brick samples. This vitrified clay region also has small pores present, better seen at higher magnifications. The thin section examination also found grog particles, which are the presence of reused brick scrap. Grog does not fully blend with the clay which causes larger voids surrounding the area. Grog was added to reuse material and to control the shrinking and drying process, a common process seen in the area. The results, as seen in the images below, all have a common look in the vitrified clay, only the amount of sand differs. (Figures 4.1 through 4.6)

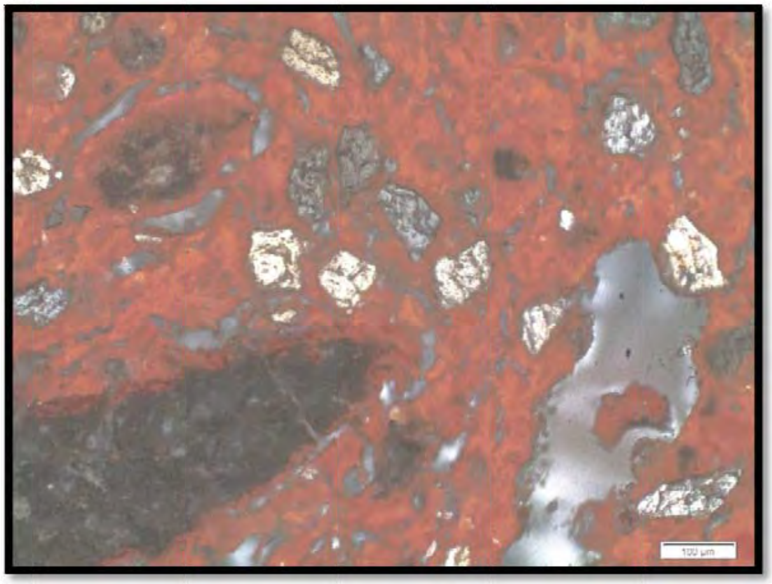


Figure 4.1: Dorchester 1067 sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

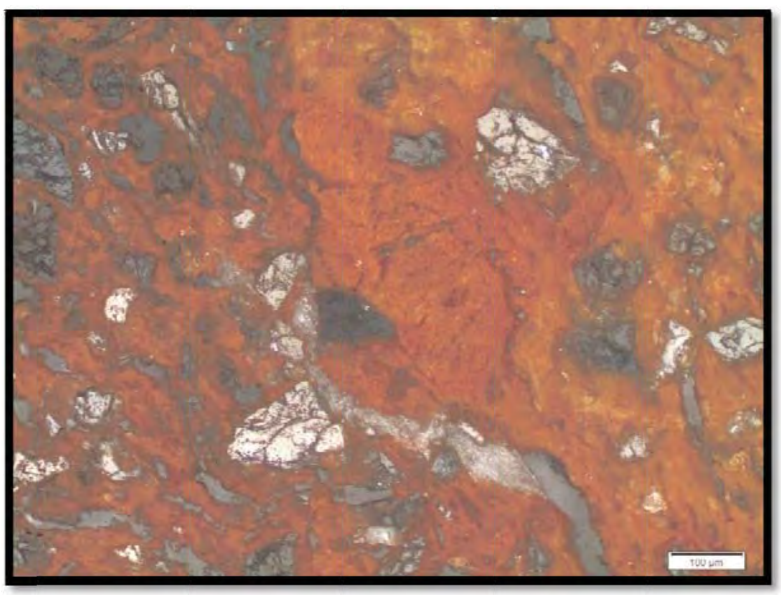


Figure 4.2: Dorchester 1091 sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

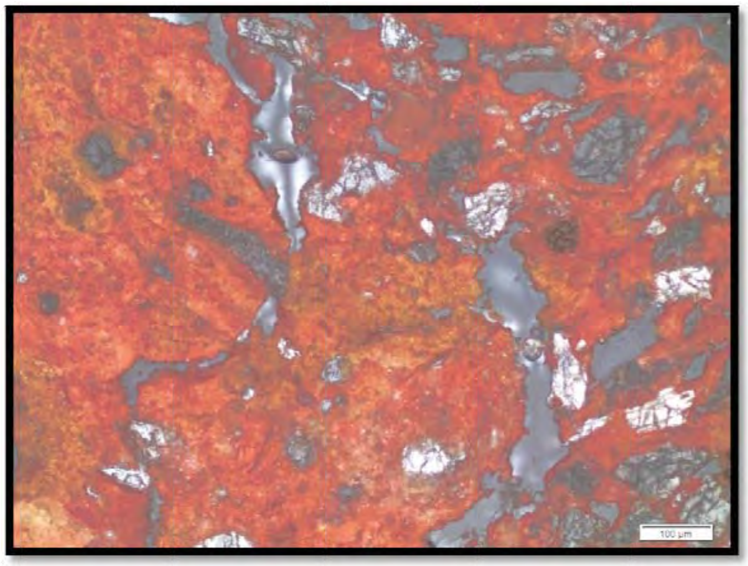


Figure 4.3: Dorchester 1428 sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

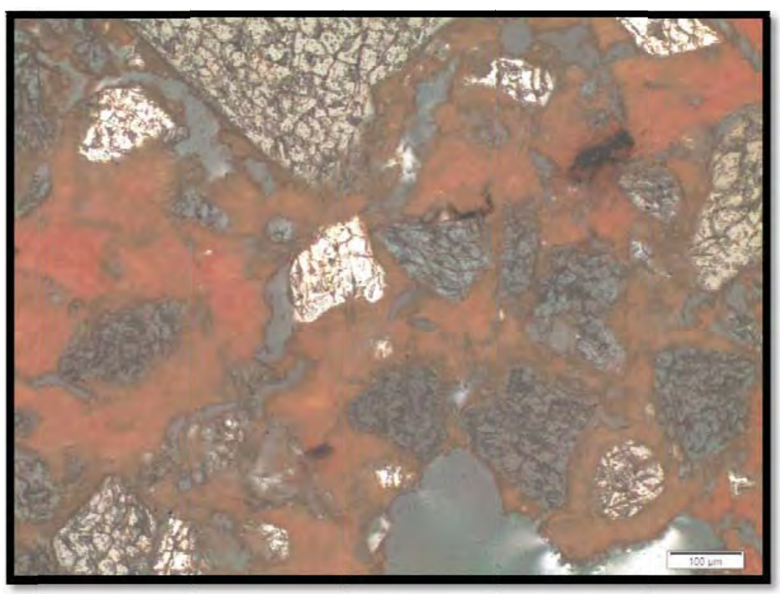


Figure 4.4: Lord Ashley sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

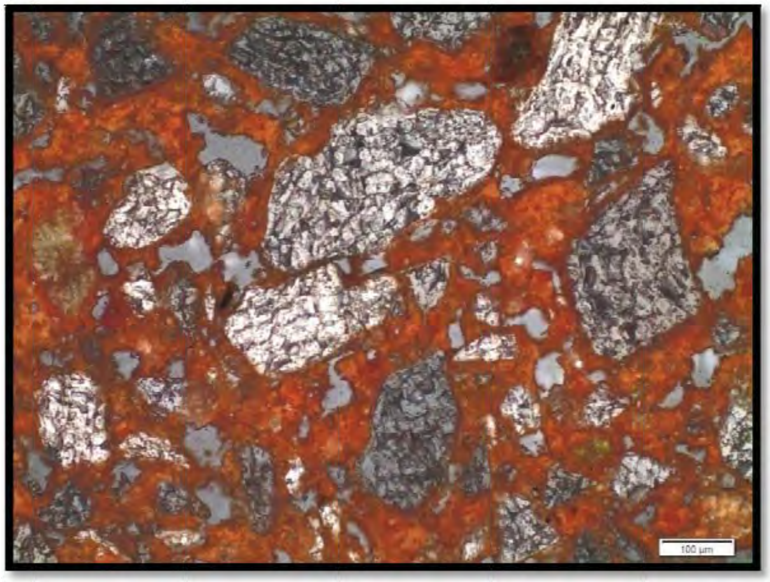


Figure 4.5: Drayton Hall 1118 sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

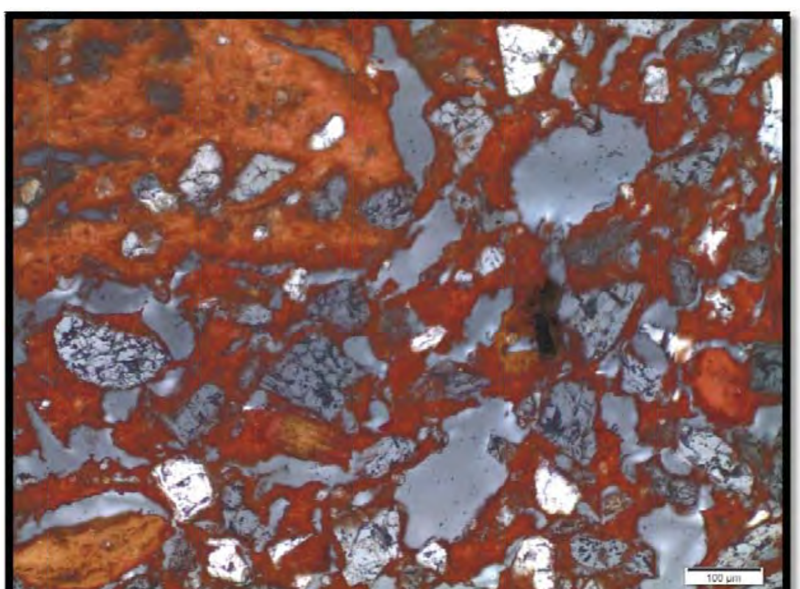


Figure 4.6: Pre-Drayton Hall sample Standard Petrographic Thin Section. 100 x magnification. (Dr. Denis Brosnan)

4.1.2 Clay

Two locations were selected for the raw clay samples, one at Colonial Dorchester State Park and the other further downstream at Church Creek. The first location was around a quarter of a mile from the river, while the second was from a creek off the Ashley River. These tests were all conducted on the unfired state of the clay or fired during one of the tests. As stated earlier, not all of the tests were able to be performed on both of the clay samples.

4.1.2.1 X-ray Fluorescence

The XRF results reported the chemistry of the raw materials in the oxidized and un-oxidized forms. The oxidized form, as they would be found in the earth, has Aluminum Oxide, Silica, and Iron Oxide (also known as Hematite). When comparing the two samples, Church Creek has higher amounts of Aluminum Oxide and Potassium Oxide. This sample also has a noticeable difference in the Silica, with only 71.76% to Dorchester's 84.37%. (Tables 4.10 and 4.11) The aluminum oxide content suggests the clay contains kaolin which is useful in brick clays and is always present in brick and earthenware materials.

Table 4.10: Chemistry of the Clay, Sample Major Constituents, in Oxidized Form

site		Dorchester Clay	Church Creek Clay
Major Constituents			
Al2O3	%	9.06	17.04
SiO2	%	84.37	71.76
Na2O	%	<0.5	0.62
K2O	%	0.23	1.16
MgO	%	<0.2	0.79
CaO	%	<0.01	0.23
TiO2	%	0.75	1.2
MnO	%	0.01	0.03
Fe2O3	%	5.05	6.97
P2O5	%	0.05	0.05
S	%	<0.05	<0.05
Sum of Major Constituents	%	99.53	99.85

Table 4.11: Chemistry of the Clay, Sample Minor Constituents

site		Dorchester Clay	Church Creek Clay
Minor Constituents			
Cl	ppm	<250	<250
V	ppm	<150	<150
Cr	ppm	79	161
Ni	ppm	<10	19
Cu	ppm	<25	<25
Zn	ppm	<20	51
As	ppm	20	<20
Rb	ppm	<30	<30
Sr	ppm	33	117
Zr	ppm	199	276
Ba	ppm	<200	410
Pb	ppm	<50	<50

4.1.2.2 Moisture Content

The moisture content of the clay was taken shortly after the samples were brought to the lab. This test is similar to the LOI test conducted on the brick samples. The state the raw materials were dug allowed for most water to be present in the clays. Church Creek clay had a higher percentage of water present, at 7.82%. This was almost double Dorchester's clay sample. (Table 4.12)

Table 4.12: Moisture Content of clay samples

site	Dorchester Clay	Church Creek Clay
Percentage	4.63%	7.82%

4.1.2.3 Thermal Gradient Firing

Only one test was performed for the raw materials in Thermal Gradient Firing. The ten samples taken from the Church Creek sample were fired together in the same thermal gradient furnace. Each sample was placed two inches apart and began the same diameter. The results show that the difference in temperature on the same type of disk can produce difference in color, size and weight of the clay. The largest change in diameter was around 1.22mm at 1970˚F, or about 1077˚C, this caused a 4.51% shrinkage. The least amount of shrinkage, at 1.33% was found at the lowest temperature. The average amount of shrinkage was 3.261%. (Table 4.13) All the sample weights decreased by nearly one gram.

Table 4.13: Thermal Gradient Firing of Church Creek Clay

site	Church Creek Clay									
sample	1	2	3	4	5	6	7	8	9	10
Green Weight (g)	11.1581	10.6327	10.9095	10.7604	11.4959	11.5583	11.1838	11.477	11.8762	11.5664
Green Diameter (mm)	25.83	25.72	25.57	25.8	26.78	27.07	26.5	26.09	26.89	26.5
Position in oven (in)	5	7	9	11	13	15	17	19	21	23
Temp (°F)	1800	1830	1868	1901	1943	1970	2010	2056	2100	2100
Fired Diameter (mm)	25.51	24.9	24.74	24.66	25.96	25.85	25.81	25.33	25.87	25.56
Fired Weight (g)	10.2	9.8	10	9.8	10.5	10.5	10.2	10.5	10.8	10.6
Size Shrinkage (%)	1.33	3.19	3.25	4.42	3.06	4.51	2.6	2.91	3.79	3.55

4.2 Analysis

The tests evaluated the chemical and physical properties of brick and clay from along the Ashley River. All of these tests were conducted at the National Brick Research Center in Anderson, South Carolina. The eight brick and two clay samples did not receive all the methods of analysis; for example the XRF experiment was conducted on all the brick and clay samples while the thermal gradient firing was only performed on one clay sample. This short investigation, as stated by Allan Gilbert, Garman Harbottle and Daniel deNoyelles, focuses on a specific type of artifact and "can afford to minimize costs by analyzing enough specimens to see variability level off and stabilize."[148] Certain tests were also limited due to cost constraints.

Past tests have been performed in the Ashley River and surrounding areas by Dr. Denis Brosnan, thus a small precedent was set as a comparison in this study's findings. Dr. Brosnan's previous studies included Middleton Place plantation, Colonial Dorchester and Fort Sumter.[149] The data from this current study was first assessed independently and later in conjunction with Dr. Brosnan's prior results. This study, although limited, is an important initial step in identifying an Ashley River brick family. Future studies can build on these eight initial samples, which will minimize the error ratio and create more definitive culmination.

4.2.1 Visual Assessment

To trace a brick to its original location a visual assessment must be made. Many methods can be used; size, texture and surface features. This study concentrated on the color of

[148] Allan S. Gilbert, Garman Harbottle, and Daniel deNoyelles. *A Ceramic Chemistry for New Netherland/New York.* (Society for Historical Archaeology, Historical Archaeology, Vol. 27, No. 3, 1993). 20.l

[149] Fort Sumter Historic Structures Report, and two individual studies by Dr. Denis Brosnan, not yet published.

the brick itself. Color, as stated earlier, is created through several factors; including the minerals present in the material, such as iron, and the firing temperature. Even due to these factors, color can serve as a key identifying feature.

The results show a large variance in the four brick analyzed. From the initial visual inspection, the fired brick had seemingly dramatic color differences. (Figures 2.3 through 2.5 and Figure 2.11) Further investigation displayed two types of colors; an orange-red coloring and an orange-brown color. These colors were also seen in the raw clay samples which displayed bands of color similar to that found in the brick samples. During the colonial process of making brick, human or animal power mixed the clays. This, however, does not force all the clay to blend evenly. The lack of blending causes this difference in the visual and colorimeter readings. (Table 4.9) These colors differ from those found on the Wando River which have a purplish tone, and what are known as "Charleston Gray" brick. This test alone cannot be the sole basis of the identification of brick but serve as an early indication of a regional characteristic. This visual analysis works best in conjunction with the other methods to identify a true connection.

4.2.2 Chemical Composition of the Clay and Brick

Once a similarity is found through color, the chemical makeup of the brick and clay can be assessed. The main methods are through XRF and XRD analysis. These chemical experiments find the fingerprint of each brick for comparison purposes. The XRF data was completed for both the clay and brick, unlike the XRD, which was only applied to the brick. The data show that the main elements are the same in brick and clay, with Silica having the highest percentage in the XRF results. This amount of silica is later affirmed in the XRD results with a large percentage of quartz and polymorphic forms of quarts, such as cristobalite and tridymite. The presence of quartz is normal for the area as a result of the location near the ocean and the high amount of silica on the earth's surface.[150]

When comparing all the chemical data, Lord Ashley, Dorchester 1067 and 1428, and Drayton Hall samples Attic, Pre-Drayton and North Flanker all have similar chemistries. This similarity is also shared with the clay sample from Dorchester. Differences were seen in Dorchester 1091, and Drayton Hall 1118 and North Flanker with extremely high percentages of CaO(calcium oxide).(Table 4.1) Other samples at Drayton, such as the Attic and Pre-Drayton samples, had higher amounts of calcium but not to the extremes seen in sample 1118. Dr. Brosnan stated that most clay, raw or fired, have CaO levels at 0.1 or 0.2. Levels of .7, or higher, calcium oxide lead researchers to search for the lime source.

Calcium or lime can enter the brick in two ways, either through the lime mortar, made from Oyster shells in the Low Country that seeps into the brick, or the location of the clay pits near limestone supplies. Lime is produced through the calcination of limestone or the burning of oysters.[151] Limestone is more prevalent in the mid-west of the United States, but smaller pockets can be found in South Carolina. An area along the Santee River, in the middle of South Carolina, has larger deposits of limestone.[152] This limestone creates run off that seeps into the Cooper and Wando River. The Ashley River has recorded lower levels of calcium than the Wando.

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[150] Jones and Berard wrote, in *Ceramics: Industrial Processing and Testing,* that "Quartz is the most common mineral in the earth's crust, but is usually found mixed with other minerals in granite and other rocks." (18)

[151] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 19.

[152] Dr. Denis Brosnan. Correspondence with author. (January 2011).

The four brick with higher levels of lime all underwent XRD analysis. Three of the brick had graphs similar to Dr. Brosnan's previous study of the area with results shows the presence of quartz, cristobalite, tridymite and hematite. These minerals suggests that it is likely that the higher lime content is from mortar seeping into the brick over several years of exposure to moisture. The fourth brick, Drayton Hall 1118, had another mineral present, anorthite. Anorthite, according to Dr. Brosnan, is a form of calcium that is from the clay itself. Most likely the locale where the clay was dug had higher levels of calcium. Marl clays, along the Cooper River, have higher amounts of anorthite in the brick. Marl clays have a yellow color and need higher temperatures to vitrify during the firing process. Drayton Hall 1118 has chemical characteristics that match brick found in Fort Sumter, which were fired along the Wando River and its tributaries.[153] Because of this difference the brick shows signs of being made elsewhere in Charleston. But more testing must be conducted to assure these results. (Graph 4.1)

Calcium levels are also higher in the clay from Church Creek. Due to this fact, and by comparing this sample to the other brick from Drayton Hall, it appears that lime content increases nearer the mouth of the Ashley River. At this point the calcium content does not go below 0.3 percent. Further testing would have to be done to confirm these findings.

The clay from Church Creek did not match the clay makeup found in the other brick and clay from the Ashley River. (Table 4.10) This is likely because of the location of the clay sample site. The location was very close to the creek which could skew results. Another sample from

[153] Dr. Brosnan, and his participation in the Fort Sumter Historic Structures Report, has found the chemical and physical characteristics of brick in the fort. The bricks in Fort Sumter were purchased from plantations owned by people such as Dr. Graves, Dr. Prilous, Graves, Stoney, Dr. Tenant, Sanders, and Parkers in the 1850s. Their plantations were located along the Wando and Cooper Rivers. This list of brick purchases, in 1855, are part of the National Park Service, at Fort Moultrie, under the guidance of Rick Dorrance. (Obtained October 2010).

further inland along the Ashley could produce a different result. Near this site, brick manufacture occurred in the eighteenth century. The St. Andrew's parish church, first built in 1706, had a kiln on site. This kiln is now located under the 1723 extension of the church and was found during historic restoration, completed in 2005.[154] The results from the chemical testing showed that Church Creek clay has a different makeup than other local clay deposits. Dr. Brosnan observed that "The Church Creek clay is very high in kaolinite and related minerals making its aluminum oxide content (Al_2O_3) appear as higher than that of the bricks. It does not look directly related to the brick [Dorchester 1067, 1091, 1428, Lord Ashley, and Drayton Hall Pre-Drayton, Attic and North Flanker]."[155] This presence of kaolinite is evidence of the decomposition of granite, which is in all clays and is useful in brick firing. Dr. Brosnan further stated that "if the brick maker added sand to the clay (and they certainly did), it would dilute the aluminum oxide content."[156] Thus, the clay could have been used but with the addition of high amounts of sand, or quartz. This would the correlate to the high amounts of quarts in the brick chemistry for the area.

Thermal expansion testing was used to assure the minerals being found on the XRD are present in the brick. The dilatometer not only found the firing temperature but the results confirmed the presence of quartz (by the peak around 570˚C) and cristobalite (by the peak near 280˚C).[157] This test was conducted on two brick samples and a single clay sample. This is a small

[154] The restoration was completed by Richard Marks Restoration Inc. The Kiln was found by the company and recorded. This beehive kiln is similar to those found in Virginia at the beginning of the eighteenth century.
[155] Dr. Denis Brosnan. Personal correspondence by email. (January 29, 2011). The listing of the bricks was added by the author.
[156] Dr. Denis Brosnan. Personal correspondence by email. (January 29, 2011).
[157] Dr. Denis Brosnan. Personal correspondence with author. (March 2011)

amount to determine a typology for all historic brick of the Ashley River, but it is a starting point that can expand on as money for testing becomes available.

The two brick samples had different results. Both illustrated that the firing temperature of brick in this area is much higher than typical brick today. The two Dorchester brick were fired with averaging temperatures higher than 1050˚C, which is seen by the onset of shrinkage above this temperature. These findings match the brick tested from Fort Sumter. During the pre-Civil War era of brick making in Charleston, brick was being fired with fuel that could burn at high temperature for long periods of time.[158] The Church Creek clay sample had a lower temperature reading than the brick samples. This could be because of the raw state of the clay which does not include the extra sand or other minerals which are added during the production stage. The readings are around 950˚C. (Graph 4.2)

Definitive chemical characteristics for Ashley River brick have yet to be determined, but future tests could solidify these findings and the creation of the Ashley River brick family. Since most from the brick of this area carries similar findings from XRF and XRD testing, it is safe to say that the Ashley River does exhibit different elements compared to the Wando River. The variance of clay along the Ashley River is low although the lime content seems to increase downriver. In Gilbert, Harbottle and deNoyelles' study of brick around New York, they note that "The standard deviation for a series of concentrations determined for a single element in a

[158] Marie Ferrara Hollings. Brickwork of Charlestown to 1780. 9. " Locally, oak and pine were used in brick manufacture."

single clay source can be from 2 percent to 20 percent of the mean."[159] More tests will confirm these results and eliminate the extreme samples.

4.2.3 Microscopy Analysis

A third approach to identify similarities in brick is through microscopy; this study used standard petrographic thin section analysis. The results confirmed a connection of the brick and clay samples to the Ashley River region. The commonality is seen in the range of swirling colors present in the vitrified clay. As stated earlier, the raw clay collected along the river had bands of colors; yellows, browns and reds. The colorimeter found these unblended colors while the thin section analysis confirmed it visually. This analysis also confirmed the Drayton Hall 1118 sample brick as being made in the river region even with the presence of anorthite.[160] The colors present match those seen at Dorchester and Lord Ashley, not to those seen in analysis conducted on Wando River brick.[161] The Wando River brick has consistent colored vitrified clay with a different pore structure. This is because of the absence of color bands in the region's clay and the different form of silica, which cause Wando brick to expand more. Thin section analysis comparison proves this difference.

This analysis method also found that the brick from Colonial Dorchester contained many grog particles. The used of grog particles, or scrap brick pieces, was due to not wasting materials and the effect on the drying process of brick. They are seen in the thin section analysis as large

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[159] Allan S. Gilbert, Garman Harbottle, and Daniel deNoyelles. *A Ceramic Chemistry for the New Netherland/New York.* (Society for Historical Archaeology; Historical Archaeology, Vol. 27, No.3, 1993), 20.
[160] The previous research showed the brick differed chemically. Results showed anorthite present in the brick. This could be due to several factors, such as more sand being used during production, or the brick sample could be a fluke. This points out the reason for further study and more samples to be tested.
[161] Rick Dorrance. Fort Sumter Historic Structures Report. National Park Service. (In editing stage, 2010). And through personal conversations with Dr. Denis Brosnan.

sections of vitrified clay with little pores present. Grog particles were not seen as abundantly in the other samples but that is likely due to their location of production and the scrap materials present in a larger settlement, such as Dorchester.

4.2.4 Other properties related to sourcing

Once the other tests have been completed the porosity, water content, and firing temperatures can further reassure the regional commonality. This study used two different methods to find the porosity characteristics of the sample brick from the Ashley River; mercury intrusion porosimetry and Archimedean porosity and density. As stated earlier, both tests are able to determine the bulk density, apparent density and percent apparent porosity of ceramics. In addition, the mercury intrusion testing is also able to calculate the size and percentage of the size of pores in the material. The readings of both tests are very similar but not exactly the same. This is due, as also stated earlier, to the fact that mercury intrusion uses high amounts of pressure to fill the open pores while the Archimedean method uses atmospheric pressure.

The densities found were similar in both tests, the average bulk density found in the mercury intrusion method being 1.7g/cc while the Archimedean method was 1.75 g/cc. The similarities are due to the similar weight and volume of the handmade brick, from hand packing and the similarity of the clay material. The apparent density was more varied. The mercury intrusion method averaged 2.06 g/cc. The Archimedean method was averaging at 2.59 g/cc. This slight difference is likely due to the different types of pressures used to measure the samples. (Table 4.5 through 4.8)

The porosity of the brick was also similar in both tests. All five brick had porosity at thirty percent or more. This is a high percentage; considering that the more pores in a ceramic, the less durable it is considered. Current machine-made brick have porosity levels near zero. The number of pores can also determine the strength and water absorbency of the brick. The more pores present, the less dense the brick, which then compromises the overall strength. These pores also allow more water to move through the brick. The percentage of pores is from the pressure applied in packing the brick.

Human power, which was the case before the Civil War along the Ashley River, cannot remove all the pores in brick. Machines developed in the later nineteenth century compact the clay admixture more tightly than hand packing allows, and the pore size shrunk and the porosity decreased. The mercury intrusion method also finds the percentage of pores of different sizes. Four of the five brick analyzed had forty percent or more of their pores larger than ten microns in size. The fifth brick, Dorchester 1067, had no pores in this range. One hundred percent of its pores were less than one micron in size. This brick, therefore, was likely made at a later date then the other sample brick. Mr. Joseph Ioor Waring's comments in 1895 about brick being made at the location of Colonial Dorchester could indicate that this brick was made during this later period.[162]

Since all the brick have thirty percent porosity, there are many crevices in the brick that can store water and other minerals. (Table 4.4) The Loss of Ignition test uses high heat to rid the samples of H_2O, CO_2 and NO_2. All eight of the samples were evaluated and the loss percentage was varied. The lowest percentage, Drayton Hall Attic brick, was 0.34% and the highest,

[162] Joseph Ioor Waring wrote on November 17th, 1895 an article, *A Shrine of the Past,* in The Sunday News (Charleston, South Carolina).

Dorchester 1091, was 1.84%. (Table 4.3) In most cases the location of the brick, either in the elements or in collections storage, will determine the amount of water present. This test did not show any difference due to brick storing location. It must be noted brick in this study came from varied locations; Drayton Hall's North Flanker brick were still buried in the ground, while Dorchester 1067, 1091, 1428, and Drayton Hall 1118 were part of the Charleston Museum's collection.

The amount of moisture in the clay was also analyzed. Clay, either in a paste or dry state, contains some amount of water. This may be due to presence of kaolinite. The chemical description of kaolinite is hydrated aluminum silicate, $Al_2Si_2O_5(OH)_4$.[163] Jones and Berard state that "Excellent deposits of kaolins are found in the southeastern United States, the most important locations being in the Carolinas, Georgia, and northern Florida."[164] Thus moisture is present in the clay found in the Charleston region. Since the Church Creek clay sample has very noticeable amounts of kaolin, as seen in the XRD results, the moisture content was the higher of the two, at 7.82%. (Table 4.12) The clay from Colonial Dorchester did not undergo the XRD testing, but kaolin clay is likely to have been present since both are clays. The lower percentage of moisture is likely due to the location of digging further from the river. Also both clay samples had a paste-like consistency when brought to the lab, indicating some level of moisture.[165]

The study also found the firing temperatures of the original brick and raw clay samples. From several readings on the Dilatometer, the instrument for thermal expansion readings, the

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[163] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 15
[164] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 15
[165] The plastic, or paste like consistency, that is formed by clay when water is added makes the formation of brick easier. The more water added the more plastic the clay becomes. Jones and Berard state that "Additions of water to a kaolin cause it to become plastic, i.e., the resulting paste can be deformed and molded, and it will hold its new shape."(15)

firing temperature for a sample brick was around 1100˚C. (Graph 4.2) This temperature is very high for brick firing, but due to the minerals present necessitates the higher temperature. Chemistry evidence of high amounts of lime requires temperatures around 1250˚C to start the vitrification process.[166] This number can drop due to other components, fluxes, added during the brick making process.[167] Jones and Berard noted "Many inorganic materials exhibit some fluxing tendency, but the most important fluxes for ceramics are those that contain alkalies (Li, Na, K, Rb, Cs), alkaline earths (Ca, Mg, Sr, Ba), boric oxide, and the lead oxides."[168] The test also created a thermal expansion coefficient. The coefficient from the Ashley River averaged around 5.69 x 10-6, which falls in the range of most clay brick. This number is much smaller than the average for the brick along the Wando River; at 11 x 10-6. This difference is notable in that the Wando made brick expands more in higher heat, which indicates a difference the make-up of the brick. (Graph 4.3)

The firing temperatures where then used during the thermal gradient test on ten samples from Church Creek. When the firing was completed, the sample disks were visually analyzed. All had cracks, due to not being fully dried before heating, but the middle sample disks were closer in color than the outside disks. In reviewing the data, measurements show middle disks tend to have the greatest shrinkage. At the temperature 1970˚F, or 1076.67˚C, vitrification was the greatest at 4.51% shrinkage. (Table 4.13) After that point the disk shrinks at a slower

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[166] This number is seen in the graphs given by the dilatometer. When the curve drops during the thermal expansion test, it is at this temperature at which the vitrificaiton starts. From these numbers, Dr. Sanders, research assistant at the Brick Institute of America, suggested that the thermal gradient furnace be set.
[167] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 16. They noted that "Kaolins fire to a white or nearly white color. This property combined with their ability to be plasticized and fired into a dense, hard mass in the presence of fluxes (substances which lower the required firing temperature) makes kaolin a prime ingredient in many ceramic products."
[168] Jones and Berard. *Ceramics: Industrial Processing and Testing.* 16.

rate until the temperature 2100˚F for an extended amount of time. Many supplementary tests can be performed from these disks, but were not conducted for this study.

CHAPTER 5: CONCLUSION

5.1 Summary

Brick making has occurred in Charleston since the first decade of English settlement. These locally fired brick have previously been studied in regards to their size, shape, location of production, and the people who made them. This study advances the process of identifying an individual brick, in a given building, from the Ashley River region. Utilizing chemical and physical characteristics under the assistance of the National Brick Research Center in combination with existing historical context, nine different analytical methods were performed on two raw clay samples and eight fired brick samples. They were: Archimedean porosity and density, thermal gradient firing, thermal expansion, moisture content, loss of ignition, thin section microscopy, x-ray fluorescence, and x-ray diffraction.

Based on the experiments and historical research, the Ashley River clays do have a common derivative of physical and chemical characteristics. The visual aspects of the samples that were assessed, such as color, had similar tones (with the exception of the Dorchester samples, which varied greatly). The brick from structures along the Ashley River displayed a similar chemical make-up (except Drayton Hall 1118) as seen in the range of silica and its poly-forms, such as quartz, cristobalite, and tridymite. The amount of calcium oxide was also low, although the few that were high most likely came from lime mortar seeping into the brick over time. Only, Drayton Hall 1118 differed from the other samples due to the high calcium oxide content that came from anorthite which is found in the clay source itself. The two clay test results showed that the Dorchester sample was in the range of brick from the region, but the Church Creek clay had very high calcium amounts. This increase in calcium oxide did appear in small amounts downriver and could have been changed in the fired state during historic processing. These findings were reaffirmed through standard petrographic thin section analysis. The banded color found in the raw clay was also seen in the vitrified clay under 100 x magnifications. This unblended color is not seen in previous studies in the area.

Further testing found even more distinct characteristics of brick made on the Ashley River. Porosity of these brick was around thirty percent, with a majority of pores larger than ten microns. This number of pores is characteristic of brick made by hand. One of the brick measured had similar porosity, and density readings but, as seen in the Mercury Intrusion Method, one hundred percent of those pores were smaller than one micron. These results point towards a probable machine-made brick from the later nineteenth century along the Ashley River. Density readings were low, due to the high porosity, and averaged 1.7g/cc (grams per cubic centimeter). Porosity and Density results were found through the Archimedean porosity and density and mercury intrusion methods. Testing included loss of ignition in the brick samples and percent moisture of the clay. The brick all had fewer than two percent loss of ignition while the clay lost four to seven percent moisture. The last test re-examined the color of the clay along the Ashley River, but in comparison to the firing temperatures found in thermal expansion tests. Thermal gravimetric firing displayed color similar in tone of color found in the historic brick samples around the firing temperature of 1970˚F, or 1076.67˚C.

All the tests performed were completed over a month and a half period. Sampling and descriptions along with test settings were determined by Dr. Brosnan, of the National Brick Research Center. Both chemical and physical characteristic testing where used for a more comprehensive comparison of the building material than has previously been conducted. This study revealed that three main steps are needed to established brick characteristics; they are visual, chemical and thin section analysis. One testing method for each of the three must be done to create a clear identity of a specific brick. This should also be done on the clay samples for best comparison.

Best use of this data in the field would be in conjunction with physical appearance of the brick; including color, size, and location. The color ranges identified in this study, such as the orange-red and orange-brown color, along with colorimeter readings, likely indicate brick made along the Ashley River. Once the color has been identified lab work must be conducted to confirm this initial connection. The study also expressed that not just one analysis method can be used for identifying brick but at least three; as in the case of the Drayton Hall 1118 sample. Physical and chemical characterizations of a material cannot alone prove a brick's provenance.

This creation of the brick profile from the Ashley River will someday aid in the identification of these brick in structures in any Low Country region. There may even be ways to connect brick to specific plantation brickyards, particularly with written records that have yet to be uncovered.

5.2 Future Research

Future researchers can build on this study in a number of ways. The first step would be to complete all the analytical methods on each sample from this study. As a result of cost constraints, some tests were cut short and results could not be supported or adjusted. The next phase would be to develop the Ashley River study with additional sites and several brick from each site. These sites could include brick from the first house and flankers of Middleton

Plantation, St. Andrews Episcopal Church and Archdale Plantation. This would decrease any errors or extreme results that can occur during initial chemical and physical characterization testing. Continual documentary research on historic brickyards on the Ashley and surrounding rivers would enhance the study and might allow a connection of brick to a specific location, not just a river region.

Future research could also expand the study parameters to surrounding rivers, such as the Cooper, Wando and even Edisto Rivers. These rivers all had brick making plantations before the Civil War, and some locations were even providing brick for large projects in downtown Charleston during the colonial period. The Cooper and Wando Rivers have had some previous historical research completed, but no chemical and physical characterization tests have been conducted as a whole.[169] By completing all the major rivers in the Charleston area a database could be generated to use for comparisons of the brick in structures, both downtown and in surrounding areas.

[169] Dr. Brosnan has conducted some testing of brick from Fort Sumter, for the Fort Sumter Historic Structures Report (written 2010), but did not compare raw materials or conduct an area study.

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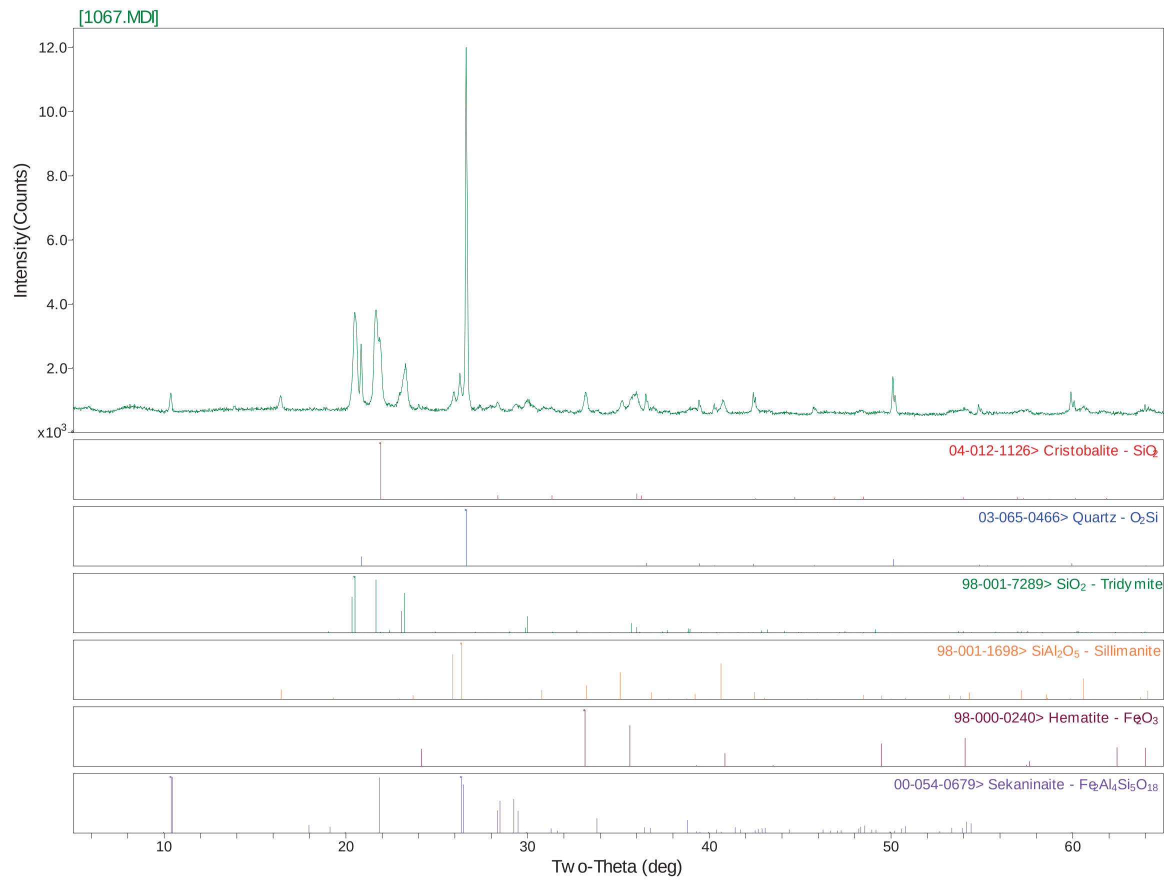
Appendices

Appendix A: Dorchester 1067 Results



XRD results for Dorchester 1067 sample. The minerals present are listed under the graph. The lab work was compiled at the National Brick Research Center.

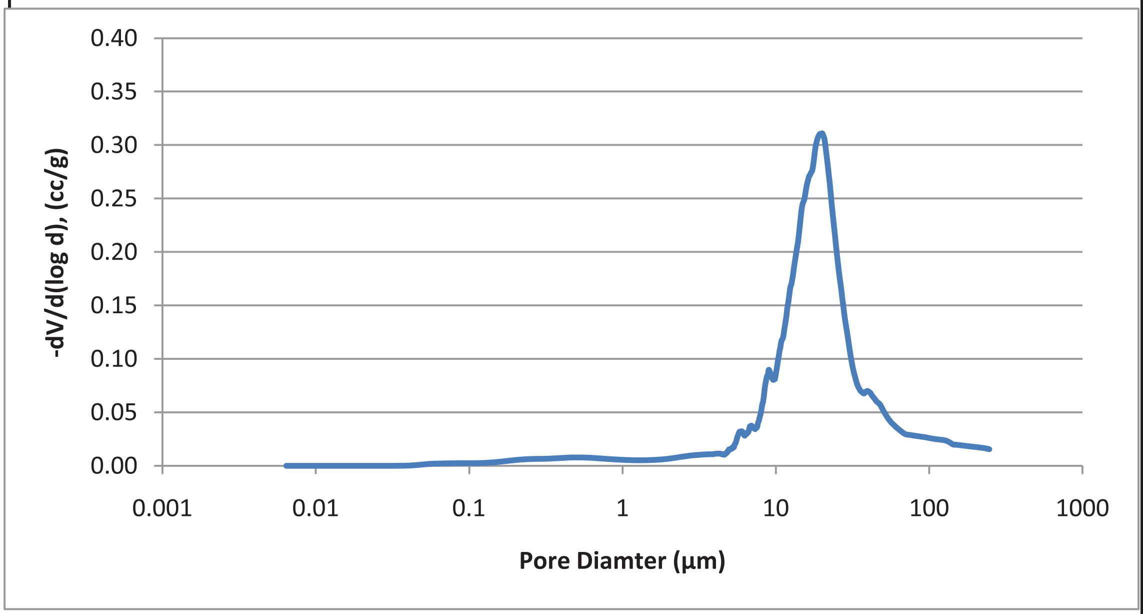
LOI	0.36	%

Chemisry (Oxidized Basis)		
Major Constituents		1067- Fort Dorchester
Al_2O_3	%	12.98
SiO_2	%	78.33
Na_2O	%	<0.5
K_2O	%	0.92
MgO	%	0.32
CaO	%	<0.01
TiO_2	%	1.15
MnO	%	0.02
Fe_2O_3	%	5.82
P_2O_5	%	0.05
S	%	<0.05
Sum of Major Constituents	%	99.59
Minor Constituents		
Cl	ppm	<250
V	ppm	<150
Cr	ppm	89
Ni	ppm	<10
Cu	ppm	66
Zn	ppm	<20
As	ppm	<20
Rb	ppm	<30
Sr	ppm	93
Zr	ppm	275
Ba	ppm	400
Pb	ppm	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI		

Chemistry/ XRF and Loss of Ignition results for Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center

Poresize Data

Property	Unit	
Total Intrusion Volume	ml/g	0.16
Median Pore Diameter	microns	19.06
Bulk Density	g/cc	1.74
Apparent Density	g/cc	2.17
Porosity	%	28.22
Pores >3 Microns	%	0.00
Maage Index		19.74
Pores >10 Microns	%	0.00
Pores 10-1 Microns	%	0.00
Pores <1 Microns	%	100.00



Mercury Intrusion results for Drayton Hall 1118 sample. (Following table is the raw pore size data) The lab work was compiled at the National Brick Research Center.

Raw Pore Size Data		
Pore Diameter	Volume Intruded	Delta Volume
2.47E+02	0.0004	1.55E-02
2.26E+02	0.0007	1.67E-02
1.93E+02	0.0021	1.79E-02
1.68E+02	0.0033	1.89E-02
1.53E+02	0.0042	1.96E-02
1.44E+02	0.0048	2.00E-02
1.35E+02	0.0055	2.23E-02
1.27E+02	0.0062	2.38E-02
1.19E+02	0.0069	2.44E-02
1.12E+02	0.0076	2.49E-02
1.06E+02	0.0082	2.54E-02
9.98E+01	0.0088	2.60E-02
9.45E+01	0.0094	2.67E-02
8.97E+01	0.01	2.71E-02
8.53E+01	0.0106	2.77E-02
8.14E+01	0.0111	2.80E-02
7.77E+01	0.0117	2.85E-02
7.41E+01	0.0124	2.90E-02
7.06E+01	0.013	2.94E-02
6.75E+01	0.0137	3.10E-02
6.47E+01	0.0142	3.30E-02
6.24E+01	0.0147	3.49E-02
6.04E+01	0.0151	3.66E-02

5.87E+01	0.0155	3.84E-02
5.70E+01	0.016	4.01E-02
5.53E+01	0.0166	4.23E-02
5.35E+01	0.0173	4.51E-02
5.16E+01	0.0181	4.89E-02
4.98E+01	0.0189	5.27E-02
4.81E+01	0.0196	5.67E-02
4.68E+01	0.0203	5.87E-02
4.56E+01	0.021	6.00E-02
4.45E+01	0.0217	6.19E-02
4.34E+01	0.0225	6.39E-02
4.23E+01	0.0233	6.58E-02
4.13E+01	0.024	6.83E-02
4.04E+01	0.0246	6.92E-02
3.97E+01	0.0252	7.00E-02
3.90E+01	0.0257	6.96E-02
3.83E+01	0.0263	6.88E-02
3.77E+01	0.0268	6.77E-02
3.71E+01	0.0273	6.79E-02
3.65E+01	0.0278	6.91E-02
3.58E+01	0.0283	6.98E-02
3.51E+01	0.0289	7.18E-02
3.43E+01	0.0295	7.44E-02
3.36E+01	0.0301	7.84E-02
3.28E+01	0.0309	8.39E-02
3.21E+01	0.0316	8.92E-02
3.14E+01	0.0325	9.58E-02

3.07E+01	0.0335	1.04E-01
2.99E+01	0.0348	1.14E-01
2.92E+01	0.0362	1.25E-01
2.84E+01	0.0377	1.35E-01
2.77E+01	0.0392	1.47E-01
2.71E+01	0.0406	1.57E-01
2.66E+01	0.0422	1.68E-01
2.60E+01	0.0438	1.77E-01
2.55E+01	0.0456	1.89E-01
2.49E+01	0.0477	2.02E-01
2.43E+01	0.0498	2.16E-01
2.38E+01	0.0518	2.28E-01
2.33E+01	0.0537	2.40E-01
2.29E+01	0.0556	2.51E-01
2.25E+01	0.0578	2.63E-01
2.21E+01	0.0602	2.74E-01
2.16E+01	0.0629	2.86E-01
2.12E+01	0.0656	2.96E-01
2.08E+01	0.0682	3.05E-01
2.04E+01	0.0706	3.09E-01
2.01E+01	0.0729	3.11E-01
1.98E+01	0.0753	3.10E-01
1.94E+01	0.0778	3.10E-01
1.91E+01	0.0804	3.09E-01
1.87E+01	0.0828	3.06E-01
1.84E+01	0.085	3.02E-01
1.81E+01	0.087	2.97E-01

1.78E+01	0.0889	2.90E-01
1.76E+01	0.0908	2.82E-01
1.73E+01	0.0927	2.76E-01
1.70E+01	0.0948	2.74E-01
1.67E+01	0.0968	2.72E-01
1.64E+01	0.0986	2.70E-01
1.62E+01	0.1001	2.67E-01
1.60E+01	0.1016	2.63E-01
1.58E+01	0.1031	2.59E-01
1.56E+01	0.1046	2.55E-01
1.54E+01	0.106	2.50E-01
1.52E+01	0.1074	2.47E-01
1.50E+01	0.1088	2.45E-01
1.48E+01	0.11	2.42E-01
1.46E+01	0.1113	2.36E-01
1.45E+01	0.1124	2.29E-01
1.43E+01	0.1136	2.22E-01
1.41E+01	0.1148	2.15E-01
1.39E+01	0.116	2.09E-01
1.38E+01	0.1172	2.04E-01
1.36E+01	0.1182	1.99E-01
1.34E+01	0.1193	1.94E-01
1.33E+01	0.1202	1.89E-01
1.31E+01	0.1211	1.84E-01
1.30E+01	0.1219	1.79E-01
1.28E+01	0.1227	1.75E-01
1.27E+01	0.1234	1.71E-01

1.26E+01	0.1241	1.69E-01
1.25E+01	0.1249	1.67E-01
1.23E+01	0.1256	1.63E-01
1.22E+01	0.1263	1.58E-01
1.21E+01	0.1269	1.54E-01
1.20E+01	0.1276	1.50E-01
1.19E+01	0.1282	1.47E-01
1.18E+01	0.1288	1.41E-01
1.16E+01	0.1293	1.37E-01
1.15E+01	0.1298	1.33E-01
1.14E+01	0.1303	1.30E-01
1.13E+01	0.1309	1.26E-01
1.12E+01	0.1314	1.22E-01
1.11E+01	0.1318	1.19E-01
1.10E+01	0.1323	1.18E-01
1.09E+01	0.1327	1.17E-01
1.08E+01	0.1332	1.14E-01
1.07E+01	0.1337	1.11E-01
1.06E+01	0.1341	1.08E-01
1.05E+01	0.1346	1.05E-01
1.04E+01	0.135	1.01E-01
1.03E+01	0.1354	9.83E-02
1.02E+01	0.1357	9.42E-02
1.01E+01	0.1361	9.05E-02
1.01E+01	0.1364	8.74E-02
9.96E+00	0.1367	8.42E-02
9.87E+00	0.137	8.11E-02

9.78E+00	0.1373	8.08E-02
9.70E+00	0.1376	8.10E-02
9.62E+00	0.1379	8.03E-02
9.53E+00	0.1381	8.12E-02
9.45E+00	0.1384	8.20E-02
9.37E+00	0.1388	8.29E-02
9.29E+00	0.1391	8.38E-02
9.21E+00	0.1394	8.61E-02
9.14E+00	0.1397	8.79E-02
9.06E+00	0.1401	8.94E-02
8.99E+00	0.1404	8.97E-02
8.91E+00	0.1407	8.66E-02
8.84E+00	0.141	8.47E-02
8.77E+00	0.1414	8.39E-02
8.70E+00	0.1417	8.20E-02
8.63E+00	0.1419	7.97E-02
8.57E+00	0.1422	7.69E-02
8.50E+00	0.1424	7.43E-02
8.44E+00	0.1426	7.03E-02
8.37E+00	0.1428	6.61E-02
8.31E+00	0.1431	6.24E-02
8.25E+00	0.1433	5.93E-02
8.19E+00	0.1434	5.82E-02
8.13E+00	0.1436	5.57E-02
8.06E+00	0.1438	5.29E-02
8.00E+00	0.1439	5.01E-02
7.95E+00	0.1441	4.80E-02

7.89E+00	0.1442	4.65E-02
7.83E+00	0.1444	4.48E-02
7.78E+00	0.1445	4.28E-02
7.72E+00	0.1446	4.15E-02
7.66E+00	0.1448	4.02E-02
7.61E+00	0.1449	3.84E-02
7.56E+00	0.145	3.65E-02
7.50E+00	0.1451	3.56E-02
7.45E+00	0.1452	3.56E-02
7.40E+00	0.1453	3.56E-02
7.35E+00	0.1454	3.44E-02
7.29E+00	0.1455	3.44E-02
7.24E+00	0.1456	3.49E-02
7.19E+00	0.1457	3.59E-02
7.14E+00	0.1458	3.58E-02
7.09E+00	0.1459	3.56E-02
7.03E+00	0.1461	3.63E-02
6.98E+00	0.1462	3.72E-02
6.93E+00	0.1463	3.75E-02
6.88E+00	0.1465	3.62E-02
6.83E+00	0.1466	3.61E-02
6.78E+00	0.1467	3.69E-02
6.73E+00	0.1468	3.52E-02
6.68E+00	0.1469	3.35E-02
6.63E+00	0.147	3.18E-02
6.58E+00	0.1471	3.11E-02
6.54E+00	0.1472	3.08E-02

6.49E+00	0.1473	3.03E-02
6.44E+00	0.1474	2.98E-02
6.40E+00	0.1474	2.96E-02
6.36E+00	0.1475	3.07E-02
6.31E+00	0.1476	2.95E-02
6.27E+00	0.1477	2.82E-02
6.23E+00	0.1478	2.87E-02
6.19E+00	0.1479	2.92E-02
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6.04E+00	0.1482	3.20E-02
6.00E+00	0.1483	3.23E-02
5.96E+00	0.1484	3.23E-02
5.92E+00	0.1485	3.10E-02
5.87E+00	0.1486	3.13E-02
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5.78E+00	0.1489	3.12E-02
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5.50E+00	0.1494	2.24E-02
5.46E+00	0.1495	2.09E-02
5.41E+00	0.1495	2.04E-02
5.37E+00	0.1496	1.93E-02

5.33E+00	0.1497	1.74E-02
5.29E+00	0.1497	1.71E-02
5.25E+00	0.1498	1.70E-02
5.22E+00	0.1498	1.73E-02
5.18E+00	0.1499	1.63E-02
5.15E+00	0.1499	1.62E-02
5.11E+00	0.1499	1.58E-02
5.08E+00	0.15	1.57E-02
5.05E+00	0.1501	1.55E-02
5.01E+00	0.1501	1.52E-02
4.98E+00	0.1501	1.52E-02
4.95E+00	0.1502	1.54E-02
4.92E+00	0.1502	1.47E-02
4.89E+00	0.1502	1.39E-02
4.85E+00	0.1503	1.31E-02
4.82E+00	0.1503	1.30E-02
4.79E+00	0.1504	1.22E-02
4.75E+00	0.1504	1.21E-02
4.72E+00	0.1504	1.14E-02
4.69E+00	0.1505	1.10E-02
4.65E+00	0.1505	1.07E-02
4.62E+00	0.1505	1.04E-02
4.59E+00	0.1506	1.05E-02
4.56E+00	0.1506	1.05E-02
4.53E+00	0.1506	1.06E-02
4.49E+00	0.1506	1.06E-02
4.46E+00	0.1507	1.07E-02

4.44E+00	0.1507	1.11E-02
4.39E+00	0.1508	1.11E-02
4.33E+00	0.1508	1.15E-02
4.25E+00	0.1509	1.14E-02
4.16E+00	0.151	1.14E-02
4.05E+00	0.1512	1.13E-02
3.92E+00	0.1513	1.09E-02
3.79E+00	0.1515	1.09E-02
3.65E+00	0.1516	1.08E-02
3.51E+00	0.1518	1.07E-02
3.36E+00	0.152	1.06E-02
3.21E+00	0.1522	1.04E-02
3.08E+00	0.1524	1.02E-02
2.94E+00	0.1526	9.94E-03
2.82E+00	0.1528	9.71E-03
2.71E+00	0.153	9.40E-03
2.60E+00	0.1532	9.03E-03
2.49E+00	0.1533	8.67E-03
2.39E+00	0.1535	8.28E-03
2.30E+00	0.1536	7.89E-03
2.20E+00	0.1537	7.46E-03
2.11E+00	0.1539	7.08E-03
2.02E+00	0.154	6.72E-03
1.93E+00	0.1541	6.40E-03
1.84E+00	0.1542	6.09E-03
1.75E+00	0.1544	5.85E-03
1.66E+00	0.1545	5.64E-03

1.58E+00	0.1546	5.49E-03
1.49E+00	0.1547	5.35E-03
1.41E+00	0.1548	5.25E-03
1.33E+00	0.155	5.20E-03
1.26E+00	0.1551	5.20E-03
1.18E+00	0.1552	5.25E-03
1.11E+00	0.1554	5.36E-03
1.04E+00	0.1555	5.50E-03
9.82E-01	0.1557	5.69E-03
9.23E-01	0.1558	5.88E-03
8.68E-01	0.156	6.11E-03
8.18E-01	0.1561	6.33E-03
7.72E-01	0.1563	6.58E-03
7.29E-01	0.1565	6.84E-03
6.91E-01	0.1566	7.07E-03
6.56E-01	0.1568	7.29E-03
6.24E-01	0.157	7.48E-03
5.95E-01	0.1571	7.62E-03
5.69E-01	0.1573	7.73E-03
5.45E-01	0.1574	7.77E-03
5.24E-01	0.1576	7.82E-03
5.04E-01	0.1577	7.83E-03
4.85E-01	0.1578	7.83E-03
4.68E-01	0.158	7.81E-03
4.51E-01	0.1581	7.73E-03
4.36E-01	0.1582	7.65E-03
4.22E-01	0.1583	7.52E-03

4.08E-01	0.1584	7.39E-03
3.94E-01	0.1585	7.28E-03
3.81E-01	0.1586	7.15E-03
3.69E-01	0.1587	7.07E-03
3.57E-01	0.1588	6.95E-03
3.45E-01	0.1589	6.85E-03
3.34E-01	0.159	6.75E-03
3.23E-01	0.1591	6.65E-03
3.12E-01	0.1592	6.58E-03
3.01E-01	0.1593	6.53E-03
2.91E-01	0.1594	6.52E-03
2.81E-01	0.1595	6.50E-03
2.72E-01	0.1596	6.45E-03
2.62E-01	0.1597	6.42E-03
2.53E-01	0.1598	6.35E-03
2.44E-01	0.1599	6.28E-03
2.36E-01	0.16	6.18E-03
2.28E-01	0.1601	6.03E-03
2.20E-01	0.1602	5.88E-03
2.13E-01	0.1603	5.73E-03
2.05E-01	0.1604	5.53E-03
1.98E-01	0.1604	5.31E-03
1.92E-01	0.1605	5.10E-03
1.85E-01	0.1606	4.89E-03
1.79E-01	0.1607	4.65E-03
1.73E-01	0.1607	4.40E-03
1.68E-01	0.1608	4.15E-03

1.62E-01	0.1608	3.93E-03
1.57E-01	0.1609	3.75E-03
1.51E-01	0.1609	3.55E-03
1.46E-01	0.161	3.33E-03
1.41E-01	0.161	3.18E-03
1.37E-01	0.1611	3.04E-03
1.32E-01	0.1611	2.88E-03
1.27E-01	0.1612	2.74E-03
1.23E-01	0.1612	2.66E-03
1.19E-01	0.1612	2.60E-03
1.15E-01	0.1613	2.55E-03
1.11E-01	0.1613	2.53E-03
1.07E-01	0.1613	2.50E-03
1.04E-01	0.1614	2.48E-03
1.00E-01	0.1614	2.52E-03
9.67E-02	0.1615	2.51E-03
9.36E-02	0.1615	2.51E-03
9.05E-02	0.1615	2.51E-03
8.76E-02	0.1616	2.52E-03
8.48E-02	0.1616	2.47E-03
8.21E-02	0.1616	2.44E-03
7.96E-02	0.1617	2.42E-03
7.71E-02	0.1617	2.36E-03
7.48E-02	0.1617	2.34E-03
7.25E-02	0.1618	2.35E-03
7.03E-02	0.1618	2.30E-03
6.83E-02	0.1618	2.26E-03

6.62E-02	0.1619	2.20E-03
6.43E-02	0.1619	2.16E-03
6.25E-02	0.1619	2.10E-03
6.07E-02	0.1619	2.07E-03
5.90E-02	0.162	2.01E-03
5.73E-02	0.162	1.92E-03
5.57E-02	0.162	1.84E-03
5.42E-02	0.162	1.73E-03
5.27E-02	0.1621	1.55E-03
5.12E-02	0.1621	1.39E-03
4.98E-02	0.1621	1.22E-03
4.85E-02	0.1621	1.07E-03
4.72E-02	0.1621	9.06E-04
4.59E-02	0.1621	7.68E-04
4.47E-02	0.1621	6.29E-04
4.36E-02	0.1621	5.11E-04
4.24E-02	0.1621	3.99E-04
4.13E-02	0.1621	3.01E-04
4.03E-02	0.1621	2.10E-04
3.93E-02	0.1621	1.65E-04
3.83E-02	0.1621	1.26E-04
3.73E-02	0.1621	1.03E-04
3.64E-02	0.1621	7.96E-05
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3.38E-02	0.1621	3.22E-05
3.29E-02	0.1621	1.63E-05

3.22E-02	0.1621	8.04E-06
3.14E-02	0.1621	0.00E+00
3.06E-02	0.1621	0.00E+00
2.99E-02	0.1621	0.00E+00
2.92E-02	0.1621	0.00E+00
2.85E-02	0.1621	0.00E+00
2.79E-02	0.1621	0.00E+00
2.72E-02	0.1621	0.00E+00
2.66E-02	0.1621	0.00E+00
2.60E-02	0.1621	0.00E+00
2.54E-02	0.1621	0.00E+00
2.49E-02	0.1621	0.00E+00
2.43E-02	0.1621	0.00E+00
2.38E-02	0.1621	0.00E+00
2.33E-02	0.1621	0.00E+00
2.28E-02	0.1621	0.00E+00
2.23E-02	0.1621	0.00E+00
2.19E-02	0.1621	0.00E+00
2.14E-02	0.1621	0.00E+00
2.10E-02	0.1621	0.00E+00
2.06E-02	0.1621	0.00E+00
2.02E-02	0.1621	0.00E+00
1.98E-02	0.1621	0.00E+00
1.94E-02	0.1621	0.00E+00
1.91E-02	0.1621	0.00E+00
1.87E-02	0.1621	0.00E+00
1.84E-02	0.1621	0.00E+00

1.80E-02	0.1621	0.00E+00
1.77E-02	0.1621	0.00E+00
1.74E-02	0.1621	0.00E+00
1.71E-02	0.1621	0.00E+00
1.68E-02	0.1621	0.00E+00
1.65E-02	0.1621	0.00E+00
1.62E-02	0.1621	0.00E+00
1.60E-02	0.1621	0.00E+00
1.57E-02	0.1621	0.00E+00
1.55E-02	0.1621	0.00E+00
1.52E-02	0.1621	0.00E+00
1.50E-02	0.1621	0.00E+00
1.47E-02	0.1621	0.00E+00
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1.41E-02	0.1621	0.00E+00
1.39E-02	0.1621	0.00E+00
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1.33E-02	0.1621	0.00E+00
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1.27E-02	0.1621	0.00E+00
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1.24E-02	0.1621	0.00E+00
1.22E-02	0.1621	0.00E+00
1.20E-02	0.1621	0.00E+00

1.19E-02	0.1621	0.00E+00
1.17E-02	0.1621	0.00E+00
1.16E-02	0.1621	0.00E+00
1.14E-02	0.1621	0.00E+00
1.13E-02	0.1621	0.00E+00
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1.04E-02	0.1621	0.00E+00
1.03E-02	0.1621	0.00E+00
1.02E-02	0.1621	0.00E+00
1.01E-02	0.1621	0.00E+00
9.94E-03	0.1621	0.00E+00
9.82E-03	0.1621	0.00E+00
9.70E-03	0.1621	0.00E+00
9.59E-03	0.1621	0.00E+00
9.48E-03	0.1621	0.00E+00
9.37E-03	0.1621	0.00E+00
9.26E-03	0.1621	0.00E+00
9.16E-03	0.1621	0.00E+00
9.05E-03	0.1621	0.00E+00
8.95E-03	0.1621	0.00E+00
8.85E-03	0.1621	0.00E+00
8.75E-03	0.1621	0.00E+00
8.66E-03	0.1621	0.00E+00

8.56E-03	0.1621	0.00E+00
8.47E-03	0.1621	0.00E+00
8.38E-03	0.1621	0.00E+00
8.29E-03	0.1621	0.00E+00
8.20E-03	0.1621	0.00E+00
8.12E-03	0.1621	0.00E+00
8.03E-03	0.1621	0.00E+00
7.95E-03	0.1621	0.00E+00
7.87E-03	0.1621	0.00E+00
7.78E-03	0.1621	0.00E+00
7.71E-03	0.1621	0.00E+00
7.63E-03	0.1621	0.00E+00
7.55E-03	0.1621	0.00E+00
7.47E-03	0.1621	0.00E+00
7.40E-03	0.1621	0.00E+00
7.33E-03	0.1621	0.00E+00
7.26E-03	0.1621	0.00E+00
7.18E-03	0.1621	0.00E+00
7.11E-03	0.1621	0.00E+00
7.05E-03	0.1621	0.00E+00
6.98E-03	0.1621	0.00E+00
6.91E-03	0.1621	0.00E+00
6.85E-03	0.1621	0.00E+00
6.78E-03	0.1621	0.00E+00
6.71E-03	0.1621	0.00E+00
6.65E-03	0.1621	0.00E+00
6.59E-03	0.1621	0.00E+00

6.52E-03	0.1621	0.00E+00
6.42E-03	0.1621	0.00E+00

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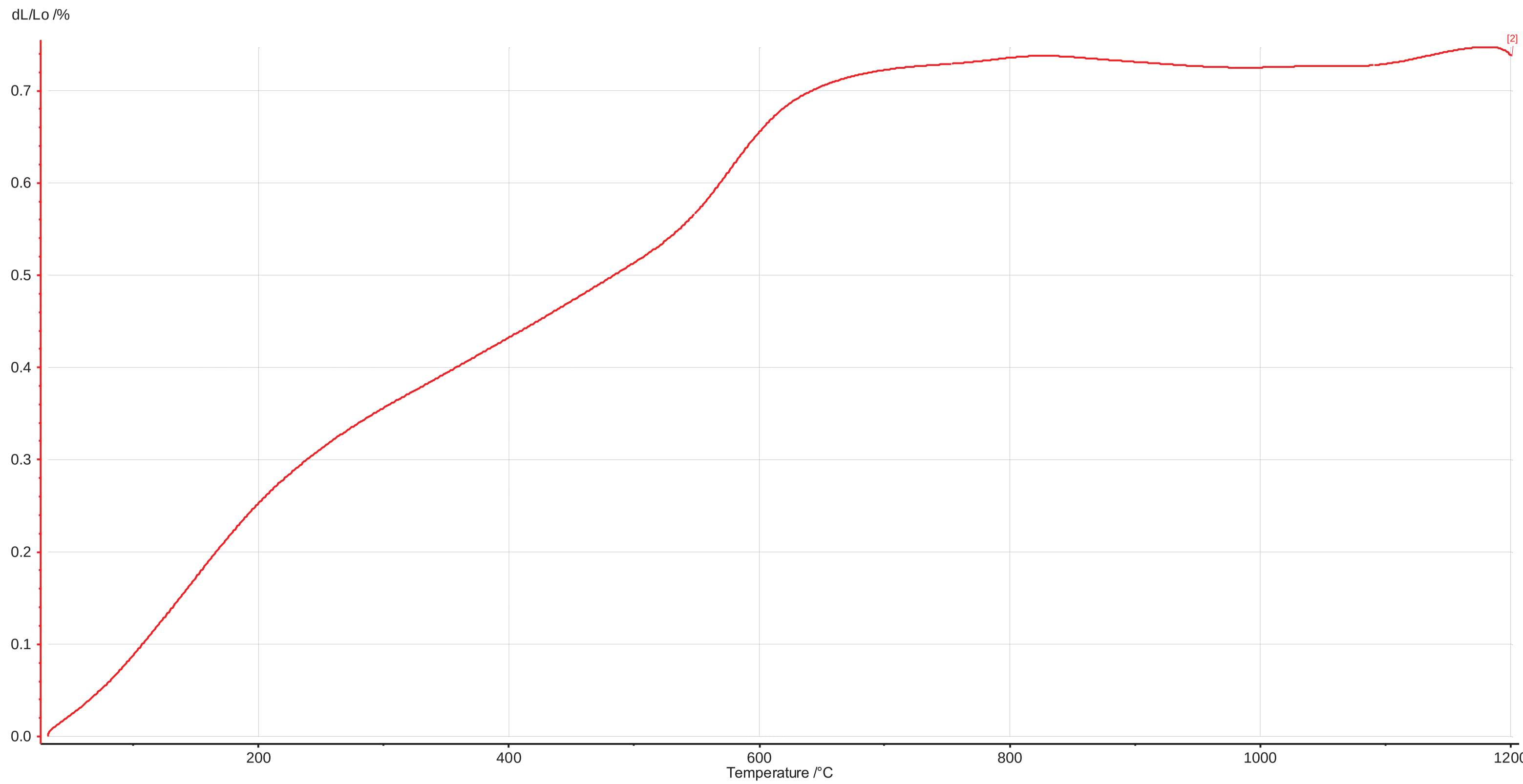
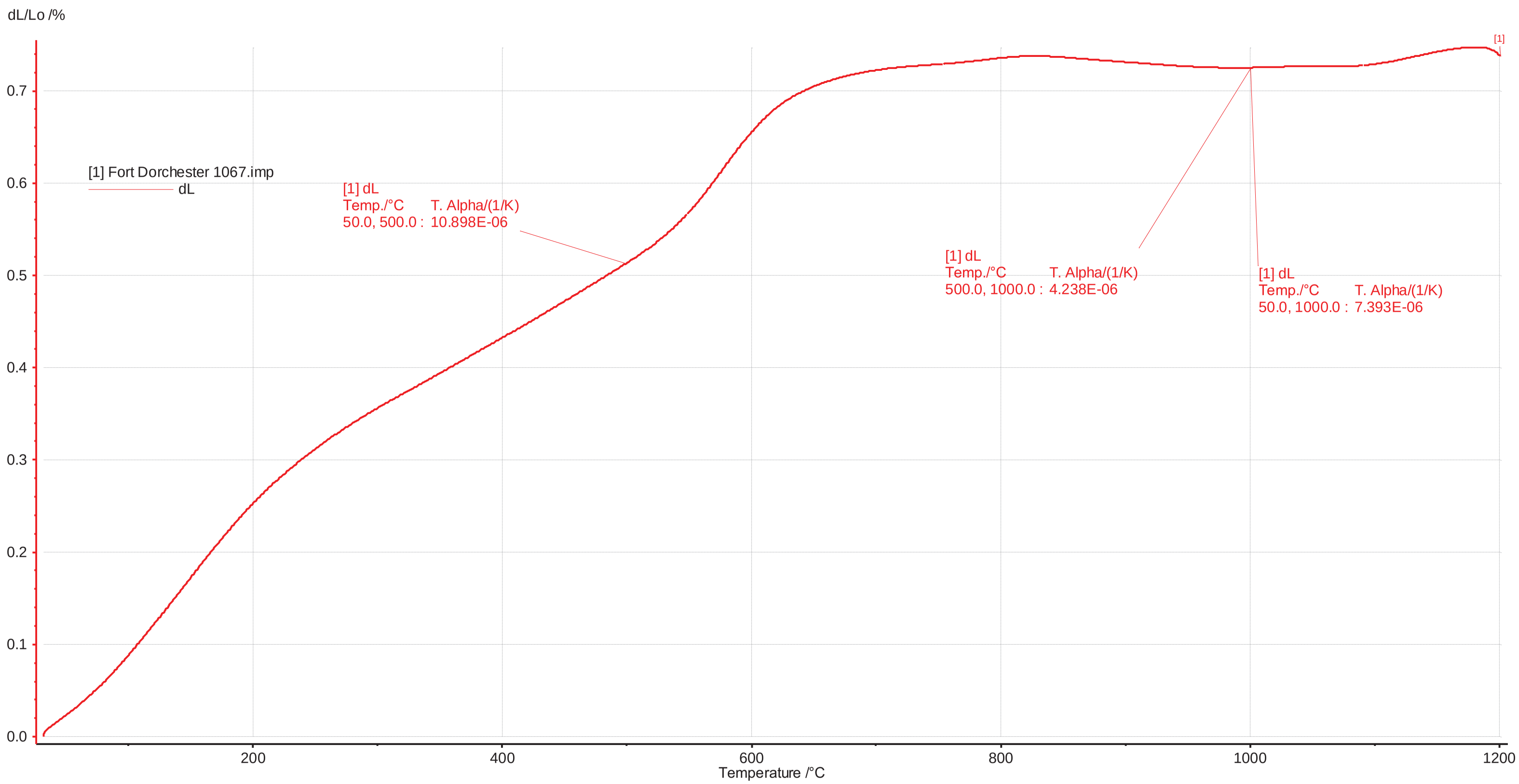


Thermal Expansion curve from the Dilatometer for the Dorchester 1067 sample. The lab work was compiled at the National Brick Research Center

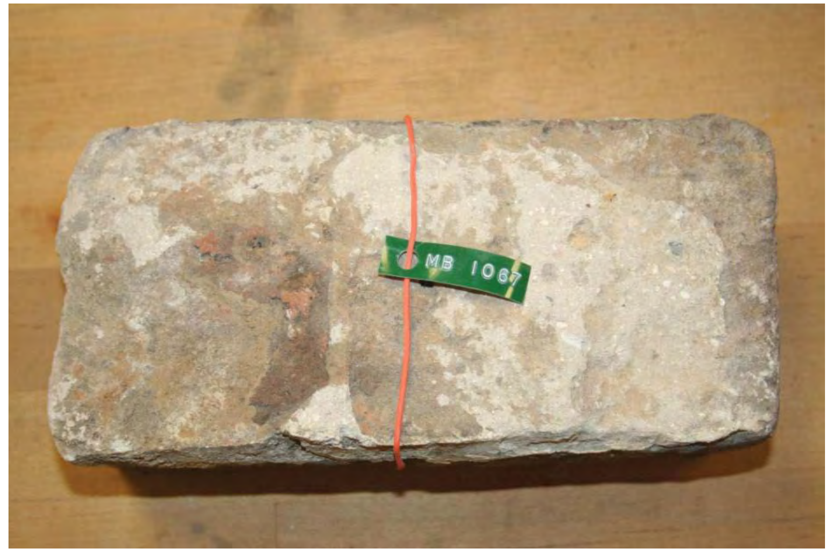


Thermal Expansion Coefficient from the Dilatometer for the Dorchester 1067 sample. The lab work was compiled at the National Brick Research Center.

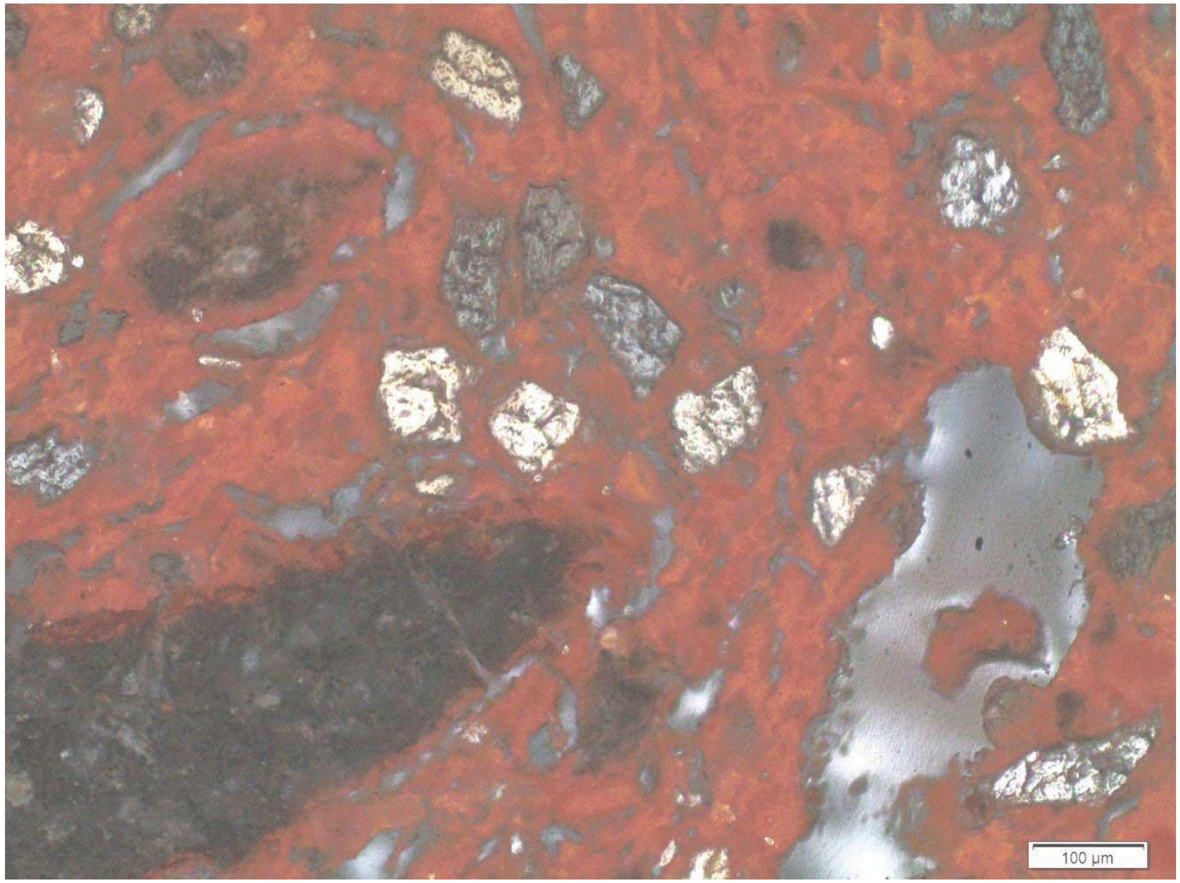
Sample #	Dry Weight (g)	24hr Cold Weight (g)	Boiled Weight	Suspended Weight	CWA (%)	BWA (%)	C/B	Bulk Density	Apparent Density	% Apparent Porosity
1	21.1604	23.5353	24.8759	12.7996	11.22	17.56	0.64	1.75	2.53	30.77
2	22.7383	25.415	27.0157	13.7936	11.77	18.81	0.63	1.72	2.54	32.35
3	21.3098	23.6205	25.256	12.9434	10.84	18.52	0.59	1.73	2.55	32.05
4	24.2194	26.9432	28.7674	14.7032	11.25	18.78	0.60	1.72	2.55	32.34
5	22.3677	24.6752	26.3047	13.5396	10.32	17.60	0.59	1.75	2.53	30.84
				Average	11.08	18.25	0.61	1.74	2.54	31.67
				Std Dev	0.54	0.63	0.02	0.02	0.01	0.80

Archimedian Density and Porosity results for Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center

Run	L-value	a-value	b-value
1	36.64	11.07	13.36
2	38.43	9.84	11.94
3	37.24	9.09	10.62
Average	37.436667	10	11.97333
St Dev	0.9110617	0.99965	1.370304

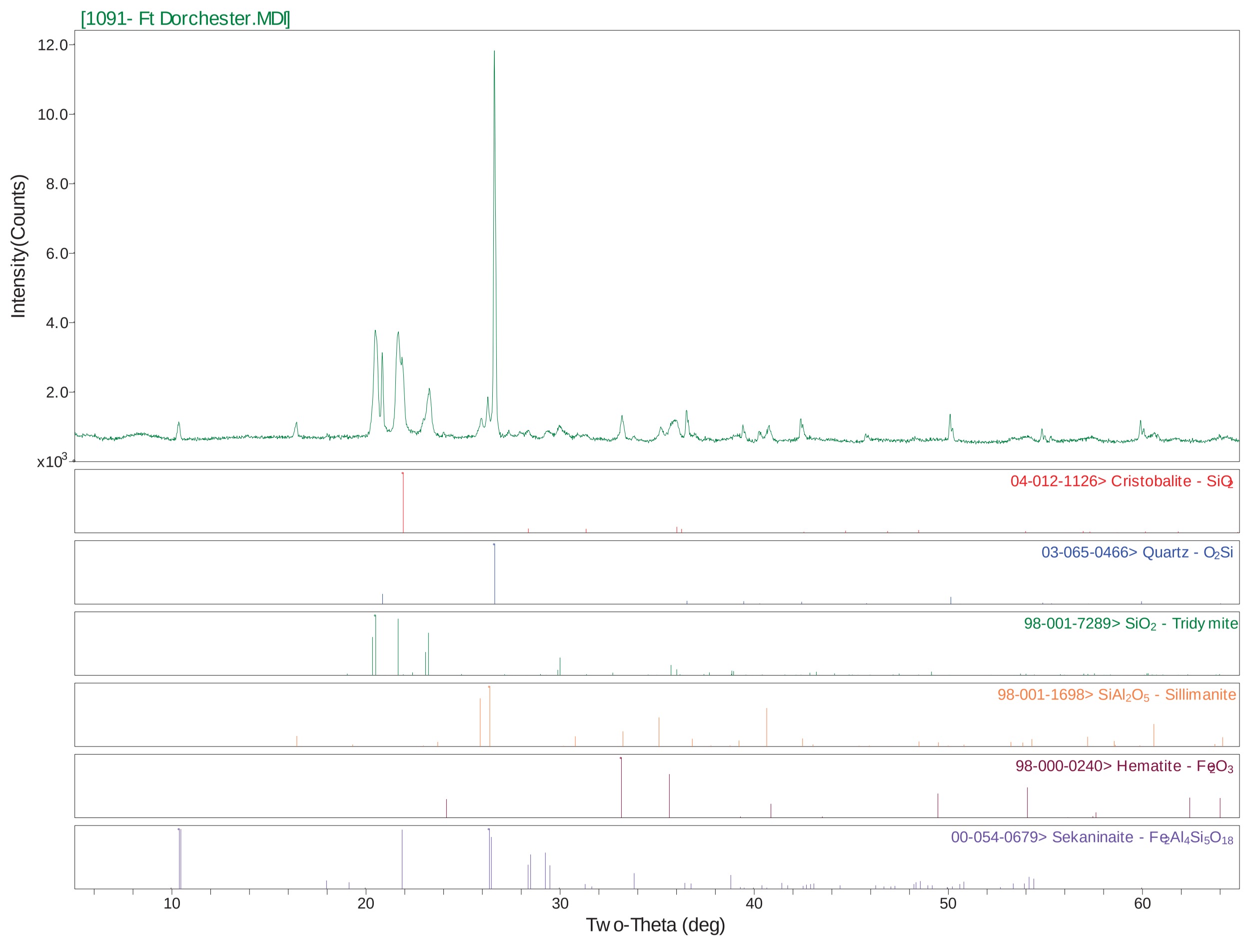


Colorimeter results for Dorchester 1067 sample. Numbers can be compared to three-dimensional color chart. The lab work was compiled at the National Brick Research Center.



Standard Petrographic Thin Section result for Dorchester 1067 sample. Lab work was compiled at the National Petrographic Lab.

Appendix B- Dorchester 1091 Results



XRD results for Dorchester 1091 sample. The minerals present are listed under the graph. The lab work was compiled at the National Brick Research Center.

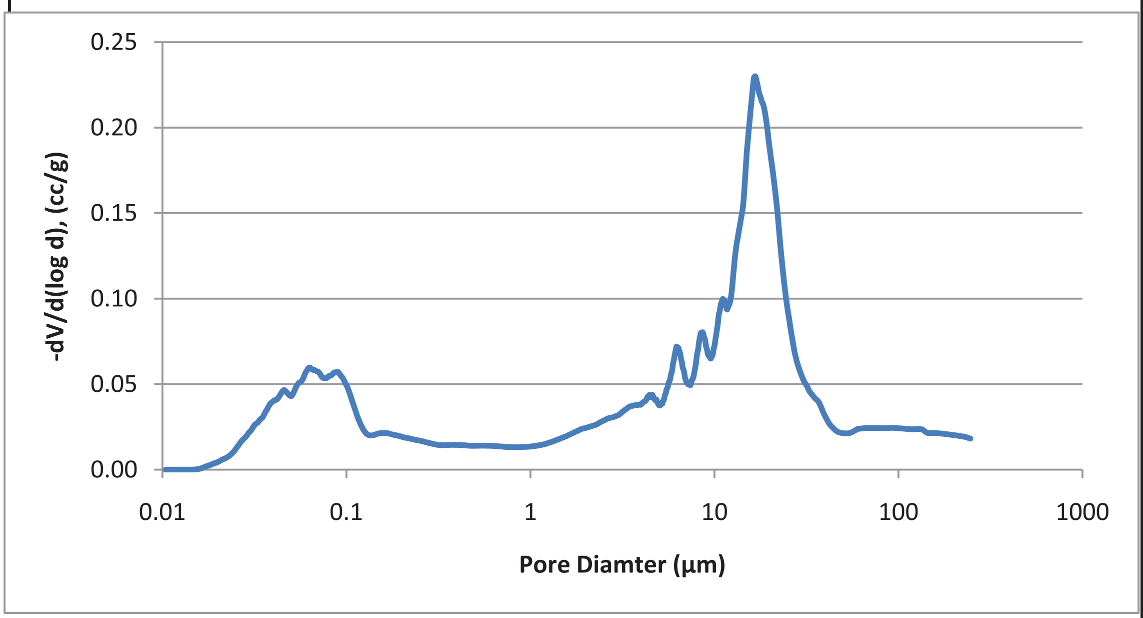
LOI	1.84	%

Chemisry (Oxidized Basis)		
Major Constituents		1091- Fort Dorchester
Al2O3	%	11.27
SiO2	%	80.85
Na2O	%	<0.5
K2O	%	0.90
MgO	%	<0.2
CaO	%	0.74
TiO2	%	1.03
MnO	%	0.02
Fe2O3	%	4.60
P2O5	%	0.05
S	%	<0.05
Sum of Major Constituents	%	99.46
Minor Constituents		
Cl	ppm	<250
V	ppm	<150
Cr	ppm	54
Ni	ppm	<10
Cu	ppm	44
Zn	ppm	<20
As	ppm	<20
Rb	ppm	<30
Sr	ppm	81
Zr	ppm	390
Ba	ppm	440
Pb	ppm	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI		

Chemistry/ XRF and Loss of Ignition results for Dorchester 1091 sample. The lab work was compiled at the National Brick Research Center.

Poresize Data

Property	Unit	
Total Intrusion Volume	ml/g	0.17
Median Pore Diameter	microns	11.21
Bulk Density	g/cc	1.70
Apparent Density	g/cc	1.94
Porosity	%	29.19
Pores >3 Microns	%	68.05
Maage Index		181.93
Pores >10 Microns	%	52.71
Pores 10-1 Microns	%	21.37
Pores <1 Microns	%	25.92



Mercury Intrusion results for Dorchester 1091 sample. (Following table is the raw pore size data) The lab work was compiled at the National Brick Research Center.

Raw Pore Size Data		
Pore Diameter	Volume Intruded	Delta Volume
2.47E+02	0.0003	1.81E-02
2.26E+02	0.001	1.93E-02
1.93E+02	0.0027	2.04E-02
1.68E+02	0.004	2.12E-02
1.53E+02	0.0048	2.15E-02
1.44E+02	0.0054	2.15E-02
1.35E+02	0.0062	2.35E-02
1.27E+02	0.0069	2.37E-02
1.19E+02	0.0077	2.36E-02
1.12E+02	0.0083	2.38E-02
1.06E+02	0.0089	2.40E-02
9.98E+01	0.0094	2.42E-02
9.45E+01	0.0099	2.44E-02
8.97E+01	0.0104	2.44E-02
8.53E+01	0.0109	2.42E-02
8.14E+01	0.0114	2.43E-02
7.77E+01	0.0119	2.43E-02
7.41E+01	0.0125	2.44E-02
7.06E+01	0.0131	2.43E-02
6.75E+01	0.0136	2.44E-02
6.47E+01	0.014	2.42E-02
6.24E+01	0.0144	2.40E-02
6.04E+01	0.0147	2.39E-02

5.87E+01	0.015	2.31E-02
5.70E+01	0.0153	2.24E-02
5.53E+01	0.0156	2.17E-02
5.35E+01	0.0159	2.12E-02
5.16E+01	0.0162	2.12E-02
4.98E+01	0.0166	2.13E-02
4.81E+01	0.0168	2.17E-02
4.68E+01	0.0171	2.22E-02
4.56E+01	0.0173	2.30E-02
4.45E+01	0.0175	2.41E-02
4.34E+01	0.0178	2.52E-02
4.23E+01	0.0181	2.66E-02
4.13E+01	0.0184	2.84E-02
4.04E+01	0.0186	3.04E-02
3.97E+01	0.0189	3.21E-02
3.90E+01	0.0192	3.39E-02
3.83E+01	0.0195	3.59E-02
3.77E+01	0.0197	3.76E-02
3.71E+01	0.02	3.91E-02
3.65E+01	0.0203	4.03E-02
3.58E+01	0.0206	4.10E-02
3.51E+01	0.021	4.20E-02
3.43E+01	0.0214	4.32E-02
3.36E+01	0.0219	4.46E-02
3.28E+01	0.0223	4.61E-02
3.21E+01	0.0227	4.84E-02
3.14E+01	0.0232	5.01E-02

3.07E+01	0.0237	5.18E-02
2.99E+01	0.0242	5.46E-02
2.92E+01	0.0249	5.79E-02
2.84E+01	0.0256	6.16E-02
2.77E+01	0.0263	6.60E-02
2.71E+01	0.0269	7.06E-02
2.66E+01	0.0275	7.62E-02
2.60E+01	0.0283	8.19E-02
2.55E+01	0.0291	8.87E-02
2.49E+01	0.03	9.57E-02
2.43E+01	0.031	1.04E-01
2.38E+01	0.032	1.13E-01
2.33E+01	0.033	1.21E-01
2.29E+01	0.034	1.30E-01
2.25E+01	0.0351	1.39E-01
2.21E+01	0.0364	1.50E-01
2.16E+01	0.0378	1.59E-01
2.12E+01	0.0393	1.67E-01
2.08E+01	0.0408	1.75E-01
2.04E+01	0.0422	1.80E-01
2.01E+01	0.0436	1.86E-01
1.98E+01	0.0451	1.92E-01
1.94E+01	0.0466	1.99E-01
1.91E+01	0.0482	2.06E-01
1.87E+01	0.0498	2.11E-01
1.84E+01	0.0514	2.14E-01
1.81E+01	0.0528	2.15E-01

1.78E+01	0.0544	2.18E-01
1.76E+01	0.056	2.20E-01
1.73E+01	0.0576	2.23E-01
1.70E+01	0.0593	2.27E-01
1.67E+01	0.0609	2.30E-01
1.64E+01	0.0625	2.29E-01
1.62E+01	0.0639	2.23E-01
1.60E+01	0.0653	2.17E-01
1.58E+01	0.0666	2.11E-01
1.56E+01	0.0678	2.05E-01
1.54E+01	0.069	1.99E-01
1.52E+01	0.0699	1.91E-01
1.50E+01	0.0708	1.85E-01
1.48E+01	0.0717	1.76E-01
1.46E+01	0.0726	1.67E-01
1.45E+01	0.0734	1.59E-01
1.43E+01	0.0742	1.53E-01
1.41E+01	0.075	1.49E-01
1.39E+01	0.0757	1.46E-01
1.38E+01	0.0765	1.43E-01
1.36E+01	0.0773	1.39E-01
1.34E+01	0.0781	1.35E-01
1.33E+01	0.0788	1.33E-01
1.31E+01	0.0795	1.29E-01
1.30E+01	0.0801	1.25E-01
1.28E+01	0.0806	1.19E-01
1.27E+01	0.0811	1.15E-01

1.26E+01	0.0816	1.09E-01
1.25E+01	0.082	1.05E-01
1.23E+01	0.0824	1.01E-01
1.22E+01	0.0828	9.88E-02
1.21E+01	0.0832	9.69E-02
1.20E+01	0.0835	9.59E-02
1.19E+01	0.0839	9.48E-02
1.18E+01	0.0843	9.36E-02
1.16E+01	0.0847	9.43E-02
1.15E+01	0.0851	9.63E-02
1.14E+01	0.0855	9.75E-02
1.13E+01	0.0859	9.89E-02
1.12E+01	0.0863	9.95E-02
1.11E+01	0.0867	9.97E-02
1.10E+01	0.0871	9.82E-02
1.09E+01	0.0875	9.73E-02
1.08E+01	0.0879	9.55E-02
1.07E+01	0.0883	9.26E-02
1.06E+01	0.0887	9.12E-02
1.05E+01	0.089	8.81E-02
1.04E+01	0.0894	8.42E-02
1.03E+01	0.0897	8.14E-02
1.02E+01	0.09	7.85E-02
1.01E+01	0.0903	7.57E-02
1.01E+01	0.0906	7.30E-02
9.96E+00	0.0908	7.14E-02
9.87E+00	0.0911	6.92E-02

9.78E+00	0.0913	6.67E-02
9.70E+00	0.0916	6.64E-02
9.62E+00	0.0918	6.53E-02
9.53E+00	0.0921	6.49E-02
9.45E+00	0.0923	6.57E-02
9.37E+00	0.0925	6.62E-02
9.29E+00	0.0928	6.68E-02
9.21E+00	0.093	6.76E-02
9.14E+00	0.0932	7.01E-02
9.06E+00	0.0935	7.13E-02
8.99E+00	0.0938	7.31E-02
8.91E+00	0.094	7.59E-02
8.84E+00	0.0943	7.68E-02
8.77E+00	0.0946	7.80E-02
8.70E+00	0.0949	7.95E-02
8.63E+00	0.0951	8.04E-02
8.57E+00	0.0954	7.98E-02
8.50E+00	0.0957	7.97E-02
8.44E+00	0.096	7.98E-02
8.37E+00	0.0962	7.78E-02
8.31E+00	0.0965	7.62E-02
8.25E+00	0.0967	7.41E-02
8.19E+00	0.097	7.09E-02
8.13E+00	0.0972	6.93E-02
8.06E+00	0.0974	6.76E-02
8.00E+00	0.0976	6.52E-02
7.95E+00	0.0978	6.20E-02

7.89E+00	0.098	6.03E-02
7.83E+00	0.0982	5.82E-02
7.78E+00	0.0984	5.64E-02
7.72E+00	0.0986	5.46E-02
7.66E+00	0.0987	5.37E-02
7.61E+00	0.0988	5.27E-02
7.56E+00	0.099	5.24E-02
7.50E+00	0.0992	5.13E-02
7.45E+00	0.0993	5.00E-02
7.40E+00	0.0995	4.93E-02
7.35E+00	0.0996	5.00E-02
7.29E+00	0.0998	5.04E-02
7.24E+00	0.0999	5.02E-02
7.19E+00	0.1001	4.99E-02
7.14E+00	0.1002	5.07E-02
7.09E+00	0.1004	5.08E-02
7.03E+00	0.1006	5.16E-02
6.98E+00	0.1007	5.29E-02
6.93E+00	0.1009	5.36E-02
6.88E+00	0.1011	5.62E-02
6.83E+00	0.1012	5.77E-02
6.78E+00	0.1014	5.89E-02
6.73E+00	0.1016	5.95E-02
6.68E+00	0.1018	6.22E-02
6.63E+00	0.102	6.37E-02
6.58E+00	0.1023	6.52E-02
6.54E+00	0.1025	6.73E-02

6.49E+00	0.1027	6.87E-02
6.44E+00	0.1029	6.93E-02
6.40E+00	0.1031	7.10E-02
6.36E+00	0.1033	7.11E-02
6.31E+00	0.1035	7.15E-02
6.27E+00	0.1037	7.12E-02
6.23E+00	0.1039	7.20E-02
6.19E+00	0.1041	7.06E-02
6.16E+00	0.1043	6.98E-02
6.12E+00	0.1045	6.78E-02
6.08E+00	0.1047	6.66E-02
6.04E+00	0.1049	6.45E-02
6.00E+00	0.1051	6.31E-02
5.96E+00	0.1053	6.17E-02
5.92E+00	0.1054	5.90E-02
5.87E+00	0.1056	5.68E-02
5.82E+00	0.1058	5.61E-02
5.78E+00	0.106	5.40E-02
5.73E+00	0.1062	5.22E-02
5.68E+00	0.1064	5.13E-02
5.63E+00	0.1065	5.05E-02
5.59E+00	0.1067	4.84E-02
5.54E+00	0.1069	4.76E-02
5.50E+00	0.1071	4.69E-02
5.46E+00	0.1072	4.49E-02
5.41E+00	0.1074	4.40E-02
5.37E+00	0.1075	4.30E-02

5.33E+00	0.1076	4.14E-02
5.29E+00	0.1078	4.04E-02
5.25E+00	0.1079	3.99E-02
5.22E+00	0.108	3.85E-02
5.18E+00	0.1081	3.85E-02
5.15E+00	0.1082	3.88E-02
5.11E+00	0.1083	3.84E-02
5.08E+00	0.1084	3.75E-02
5.05E+00	0.1085	3.75E-02
5.01E+00	0.1086	3.76E-02
4.98E+00	0.1088	3.79E-02
4.95E+00	0.1089	3.85E-02
4.92E+00	0.109	3.90E-02
4.89E+00	0.1091	3.98E-02
4.85E+00	0.1092	4.09E-02
4.82E+00	0.1093	4.05E-02
4.79E+00	0.1094	4.05E-02
4.75E+00	0.1096	4.12E-02
4.72E+00	0.1097	4.14E-02
4.69E+00	0.1098	4.17E-02
4.65E+00	0.11	4.27E-02
4.62E+00	0.1101	4.36E-02
4.59E+00	0.1102	4.35E-02
4.56E+00	0.1103	4.36E-02
4.53E+00	0.1105	4.29E-02
4.49E+00	0.1106	4.25E-02
4.46E+00	0.1108	4.30E-02

4.44E+00	0.1109	4.37E-02
4.41E+00	0.111	4.28E-02
4.38E+00	0.1111	4.26E-02
4.34E+00	0.1113	4.27E-02
4.31E+00	0.1114	4.18E-02
4.27E+00	0.1116	4.07E-02
4.23E+00	0.1118	4.03E-02
4.18E+00	0.1119	3.97E-02
4.14E+00	0.1121	3.96E-02
4.09E+00	0.1123	3.93E-02
4.04E+00	0.1125	3.87E-02
3.99E+00	0.1127	3.79E-02
3.94E+00	0.1129	3.80E-02
3.89E+00	0.1131	3.80E-02
3.84E+00	0.1133	3.77E-02
3.79E+00	0.1136	3.77E-02
3.74E+00	0.1138	3.76E-02
3.69E+00	0.114	3.76E-02
3.65E+00	0.1142	3.75E-02
3.60E+00	0.1144	3.74E-02
3.56E+00	0.1146	3.72E-02
3.51E+00	0.1148	3.70E-02
3.47E+00	0.115	3.69E-02
3.43E+00	0.1152	3.65E-02
3.38E+00	0.1154	3.61E-02
3.34E+00	0.1156	3.57E-02
3.30E+00	0.1158	3.53E-02

3.27E+00	0.1159	3.49E-02
3.23E+00	0.1161	3.45E-02
3.19E+00	0.1163	3.40E-02
3.15E+00	0.1165	3.36E-02
3.11E+00	0.1166	3.31E-02
3.08E+00	0.1168	3.26E-02
3.04E+00	0.117	3.22E-02
3.00E+00	0.1171	3.19E-02
2.97E+00	0.1173	3.16E-02
2.93E+00	0.1175	3.14E-02
2.90E+00	0.1176	3.12E-02
2.86E+00	0.1178	3.09E-02
2.82E+00	0.118	3.07E-02
2.79E+00	0.1181	3.05E-02
2.75E+00	0.1183	3.04E-02
2.71E+00	0.1185	3.03E-02
2.68E+00	0.1187	3.01E-02
2.64E+00	0.1188	2.99E-02
2.61E+00	0.119	2.96E-02
2.57E+00	0.1192	2.93E-02
2.54E+00	0.1194	2.90E-02
2.50E+00	0.1196	2.87E-02
2.46E+00	0.1197	2.83E-02
2.43E+00	0.1199	2.80E-02
2.39E+00	0.1201	2.77E-02
2.36E+00	0.1202	2.72E-02
2.32E+00	0.1204	2.68E-02

2.29E+00	0.1206	2.64E-02
2.25E+00	0.1208	2.61E-02
2.22E+00	0.1209	2.59E-02
2.19E+00	0.1211	2.57E-02
2.15E+00	0.1213	2.54E-02
2.12E+00	0.1215	2.52E-02
2.08E+00	0.1216	2.50E-02
2.05E+00	0.1218	2.47E-02
2.02E+00	0.122	2.45E-02
1.99E+00	0.1221	2.43E-02
1.95E+00	0.1223	2.41E-02
1.92E+00	0.1225	2.40E-02
1.89E+00	0.1226	2.37E-02
1.86E+00	0.1228	2.34E-02
1.83E+00	0.123	2.30E-02
1.80E+00	0.1231	2.27E-02
1.77E+00	0.1233	2.23E-02
1.74E+00	0.1235	2.20E-02
1.72E+00	0.1236	2.16E-02
1.69E+00	0.1238	2.12E-02
1.66E+00	0.1239	2.08E-02
1.63E+00	0.1241	2.05E-02
1.60E+00	0.1242	2.00E-02
1.57E+00	0.1244	1.96E-02
1.54E+00	0.1245	1.93E-02
1.52E+00	0.1247	1.90E-02
1.49E+00	0.1248	1.86E-02

1.46E+00	0.125	1.83E-02
1.44E+00	0.1251	1.79E-02
1.41E+00	0.1253	1.76E-02
1.38E+00	0.1254	1.72E-02
1.35E+00	0.1256	1.69E-02
1.33E+00	0.1257	1.65E-02
1.30E+00	0.1258	1.62E-02
1.27E+00	0.126	1.58E-02
1.24E+00	0.1261	1.55E-02
1.22E+00	0.1263	1.51E-02
1.19E+00	0.1264	1.48E-02
1.16E+00	0.1266	1.46E-02
1.13E+00	0.1267	1.44E-02
1.11E+00	0.1269	1.42E-02
1.08E+00	0.127	1.39E-02
1.05E+00	0.1272	1.38E-02
1.03E+00	0.1273	1.36E-02
9.98E-01	0.1275	1.35E-02
9.72E-01	0.1276	1.34E-02
9.46E-01	0.1278	1.33E-02
9.21E-01	0.1279	1.33E-02
8.96E-01	0.1281	1.33E-02
8.72E-01	0.1283	1.32E-02
8.48E-01	0.1284	1.31E-02
8.25E-01	0.1286	1.31E-02
8.02E-01	0.1287	1.31E-02
7.80E-01	0.1289	1.32E-02

7.58E-01	0.1291	1.32E-02
7.37E-01	0.1292	1.33E-02
7.17E-01	0.1294	1.34E-02
6.98E-01	0.1295	1.35E-02
6.79E-01	0.1297	1.36E-02
6.60E-01	0.1299	1.37E-02
6.43E-01	0.13	1.38E-02
6.26E-01	0.1302	1.39E-02
6.09E-01	0.1303	1.40E-02
5.93E-01	0.1305	1.40E-02
5.78E-01	0.1307	1.40E-02
5.63E-01	0.1308	1.40E-02
5.49E-01	0.131	1.40E-02
5.35E-01	0.1311	1.40E-02
5.22E-01	0.1313	1.40E-02
5.09E-01	0.1314	1.40E-02
4.96E-01	0.1316	1.39E-02
4.84E-01	0.1318	1.40E-02
4.71E-01	0.1319	1.40E-02
4.60E-01	0.1321	1.40E-02
4.48E-01	0.1322	1.42E-02
4.37E-01	0.1324	1.43E-02
4.26E-01	0.1325	1.43E-02
4.15E-01	0.1327	1.44E-02
4.05E-01	0.1328	1.45E-02
3.95E-01	0.133	1.45E-02
3.85E-01	0.1332	1.45E-02

3.76E-01	0.1333	1.45E-02
3.67E-01	0.1335	1.45E-02
3.59E-01	0.1336	1.44E-02
3.51E-01	0.1338	1.44E-02
3.43E-01	0.1339	1.43E-02
3.35E-01	0.134	1.43E-02
3.28E-01	0.1342	1.43E-02
3.21E-01	0.1343	1.44E-02
3.13E-01	0.1344	1.45E-02
3.07E-01	0.1346	1.47E-02
3.00E-01	0.1347	1.49E-02
2.93E-01	0.1349	1.51E-02
2.87E-01	0.135	1.54E-02
2.80E-01	0.1352	1.56E-02
2.74E-01	0.1353	1.59E-02
2.68E-01	0.1355	1.62E-02
2.62E-01	0.1356	1.65E-02
2.57E-01	0.1358	1.67E-02
2.51E-01	0.136	1.69E-02
2.46E-01	0.1361	1.71E-02
2.41E-01	0.1363	1.73E-02
2.36E-01	0.1364	1.75E-02
2.31E-01	0.1366	1.77E-02
2.26E-01	0.1368	1.79E-02
2.22E-01	0.1369	1.82E-02
2.17E-01	0.1371	1.84E-02
2.13E-01	0.1372	1.85E-02

2.09E-01	0.1374	1.87E-02
2.05E-01	0.1375	1.89E-02
2.01E-01	0.1377	1.92E-02
1.97E-01	0.1379	1.94E-02
1.93E-01	0.138	1.97E-02
1.90E-01	0.1382	1.99E-02
1.86E-01	0.1384	2.01E-02
1.83E-01	0.1385	2.03E-02
1.79E-01	0.1387	2.05E-02
1.76E-01	0.1389	2.07E-02
1.72E-01	0.1391	2.10E-02
1.69E-01	0.1392	2.12E-02
1.66E-01	0.1394	2.14E-02
1.63E-01	0.1396	2.14E-02
1.60E-01	0.1398	2.15E-02
1.57E-01	0.14	2.15E-02
1.54E-01	0.1401	2.14E-02
1.51E-01	0.1403	2.12E-02
1.48E-01	0.1405	2.11E-02
1.46E-01	0.1406	2.08E-02
1.43E-01	0.1408	2.05E-02
1.41E-01	0.1409	2.03E-02
1.39E-01	0.1411	2.01E-02
1.36E-01	0.1412	2.00E-02
1.34E-01	0.1414	2.01E-02
1.32E-01	0.1415	2.03E-02
1.30E-01	0.1416	2.07E-02

1.28E-01	0.1418	2.15E-02
1.25E-01	0.1419	2.24E-02
1.23E-01	0.1421	2.36E-02
1.21E-01	0.1422	2.49E-02
1.19E-01	0.1424	2.66E-02
1.18E-01	0.1426	2.82E-02
1.16E-01	0.1428	3.00E-02
1.14E-01	0.143	3.20E-02
1.12E-01	0.1432	3.40E-02
1.11E-01	0.1435	3.60E-02
1.09E-01	0.1437	3.79E-02
1.08E-01	0.1439	3.96E-02
1.07E-01	0.1441	4.13E-02
1.05E-01	0.1444	4.30E-02
1.04E-01	0.1446	4.45E-02
1.03E-01	0.1448	4.59E-02
1.02E-01	0.145	4.72E-02
1.01E-01	0.1452	4.84E-02
1.00E-01	0.1454	4.93E-02
9.92E-02	0.1456	5.01E-02
9.83E-02	0.1458	5.10E-02
9.74E-02	0.146	5.18E-02
9.65E-02	0.1462	5.27E-02
9.57E-02	0.1464	5.35E-02
9.49E-02	0.1466	5.40E-02
9.41E-02	0.1468	5.45E-02
9.33E-02	0.147	5.49E-02

9.26E-02	0.1472	5.55E-02
9.18E-02	0.1474	5.60E-02
9.11E-02	0.1476	5.65E-02
9.04E-02	0.1478	5.70E-02
8.97E-02	0.148	5.72E-02
8.90E-02	0.1482	5.71E-02
8.83E-02	0.1484	5.70E-02
8.77E-02	0.1486	5.68E-02
8.70E-02	0.1488	5.68E-02
8.63E-02	0.149	5.68E-02
8.56E-02	0.1492	5.68E-02
8.50E-02	0.1494	5.64E-02
8.43E-02	0.1495	5.60E-02
8.36E-02	0.1497	5.56E-02
8.30E-02	0.1499	5.53E-02
8.23E-02	0.1501	5.50E-02
8.17E-02	0.1503	5.49E-02
8.10E-02	0.1505	5.49E-02
8.04E-02	0.1507	5.48E-02
7.97E-02	0.1509	5.44E-02
7.91E-02	0.1511	5.40E-02
7.85E-02	0.1513	5.36E-02
7.78E-02	0.1514	5.35E-02
7.72E-02	0.1516	5.34E-02
7.66E-02	0.1518	5.34E-02
7.61E-02	0.152	5.35E-02
7.55E-02	0.1521	5.36E-02

7.49E-02	0.1523	5.36E-02
7.43E-02	0.1525	5.38E-02
7.37E-02	0.1527	5.41E-02
7.32E-02	0.1529	5.46E-02
7.26E-02	0.1531	5.51E-02
7.20E-02	0.1532	5.58E-02
7.15E-02	0.1534	5.64E-02
7.09E-02	0.1536	5.68E-02
7.04E-02	0.1538	5.72E-02
6.98E-02	0.154	5.73E-02
6.93E-02	0.1542	5.74E-02
6.87E-02	0.1544	5.76E-02
6.82E-02	0.1546	5.78E-02
6.77E-02	0.1548	5.80E-02
6.72E-02	0.155	5.81E-02
6.67E-02	0.1552	5.84E-02
6.62E-02	0.1554	5.84E-02
6.57E-02	0.1555	5.83E-02
6.52E-02	0.1557	5.86E-02
6.47E-02	0.1559	5.87E-02
6.42E-02	0.1561	5.91E-02
6.37E-02	0.1563	5.95E-02
6.32E-02	0.1565	5.97E-02
6.27E-02	0.1568	5.96E-02
6.22E-02	0.157	5.93E-02
6.17E-02	0.1572	5.89E-02
6.12E-02	0.1574	5.82E-02

6.07E-02	0.1576	5.77E-02
6.02E-02	0.1578	5.70E-02
5.97E-02	0.158	5.62E-02
5.93E-02	0.1582	5.54E-02
5.88E-02	0.1584	5.45E-02
5.83E-02	0.1585	5.36E-02
5.79E-02	0.1587	5.28E-02
5.75E-02	0.1589	5.22E-02
5.70E-02	0.1591	5.18E-02
5.66E-02	0.1592	5.15E-02
5.62E-02	0.1594	5.12E-02
5.58E-02	0.1596	5.10E-02
5.53E-02	0.1597	5.08E-02
5.49E-02	0.1599	5.05E-02
5.45E-02	0.1601	5.01E-02
5.41E-02	0.1602	4.96E-02
5.37E-02	0.1604	4.90E-02
5.33E-02	0.1605	4.83E-02
5.29E-02	0.1607	4.76E-02
5.25E-02	0.1609	4.68E-02
5.21E-02	0.161	4.60E-02
5.17E-02	0.1611	4.53E-02
5.13E-02	0.1613	4.45E-02
5.09E-02	0.1614	4.39E-02
5.05E-02	0.1616	4.33E-02
5.02E-02	0.1617	4.30E-02
4.98E-02	0.1619	4.30E-02

4.94E-02	0.162	4.33E-02
4.90E-02	0.1622	4.35E-02
4.86E-02	0.1623	4.38E-02
4.82E-02	0.1624	4.43E-02
4.78E-02	0.1626	4.46E-02
4.75E-02	0.1628	4.51E-02
4.71E-02	0.1629	4.56E-02
4.67E-02	0.1631	4.59E-02
4.64E-02	0.1632	4.63E-02
4.60E-02	0.1634	4.65E-02
4.57E-02	0.1635	4.65E-02
4.53E-02	0.1637	4.62E-02
4.50E-02	0.1638	4.58E-02
4.47E-02	0.164	4.55E-02
4.44E-02	0.1641	4.49E-02
4.41E-02	0.1643	4.44E-02
4.38E-02	0.1644	4.39E-02
4.34E-02	0.1645	4.32E-02
4.31E-02	0.1647	4.29E-02
4.28E-02	0.1648	4.23E-02
4.25E-02	0.1649	4.18E-02
4.22E-02	0.1651	4.13E-02
4.19E-02	0.1652	4.11E-02
4.15E-02	0.1653	4.09E-02
4.12E-02	0.1655	4.06E-02
4.09E-02	0.1656	4.06E-02
4.06E-02	0.1657	4.04E-02

4.02E-02	0.1659	4.02E-02
3.99E-02	0.166	4.00E-02
3.96E-02	0.1662	3.96E-02
3.92E-02	0.1663	3.92E-02
3.89E-02	0.1665	3.89E-02
3.86E-02	0.1666	3.85E-02
3.82E-02	0.1668	3.79E-02
3.79E-02	0.1669	3.72E-02
3.76E-02	0.167	3.66E-02
3.73E-02	0.1672	3.57E-02
3.69E-02	0.1673	3.50E-02
3.66E-02	0.1674	3.44E-02
3.63E-02	0.1676	3.37E-02
3.60E-02	0.1677	3.29E-02
3.57E-02	0.1678	3.21E-02
3.54E-02	0.1679	3.13E-02
3.50E-02	0.1681	3.06E-02
3.47E-02	0.1682	3.01E-02
3.44E-02	0.1683	2.98E-02
3.41E-02	0.1684	2.94E-02
3.38E-02	0.1685	2.90E-02
3.35E-02	0.1686	2.85E-02
3.31E-02	0.1687	2.78E-02
3.28E-02	0.1689	2.74E-02
3.25E-02	0.169	2.71E-02
3.22E-02	0.1691	2.67E-02
3.19E-02	0.1692	2.63E-02

3.15E-02	0.1693	2.58E-02
3.12E-02	0.1694	2.51E-02
3.09E-02	0.1695	2.43E-02
3.06E-02	0.1697	2.36E-02
3.03E-02	0.1698	2.29E-02
2.99E-02	0.1699	2.23E-02
2.96E-02	0.17	2.19E-02
2.93E-02	0.1701	2.12E-02
2.90E-02	0.1701	2.05E-02
2.87E-02	0.1702	1.98E-02
2.84E-02	0.1703	1.92E-02
2.80E-02	0.1704	1.86E-02
2.77E-02	0.1705	1.81E-02
2.74E-02	0.1706	1.76E-02
2.71E-02	0.1707	1.70E-02
2.68E-02	0.1708	1.64E-02
2.65E-02	0.1709	1.57E-02
2.61E-02	0.1709	1.48E-02
2.58E-02	0.171	1.41E-02
2.55E-02	0.1711	1.33E-02
2.52E-02	0.1712	1.26E-02
2.49E-02	0.1712	1.18E-02
2.46E-02	0.1713	1.10E-02
2.43E-02	0.1713	1.02E-02
2.40E-02	0.1714	9.66E-03
2.37E-02	0.1714	9.09E-03
2.34E-02	0.1715	8.54E-03

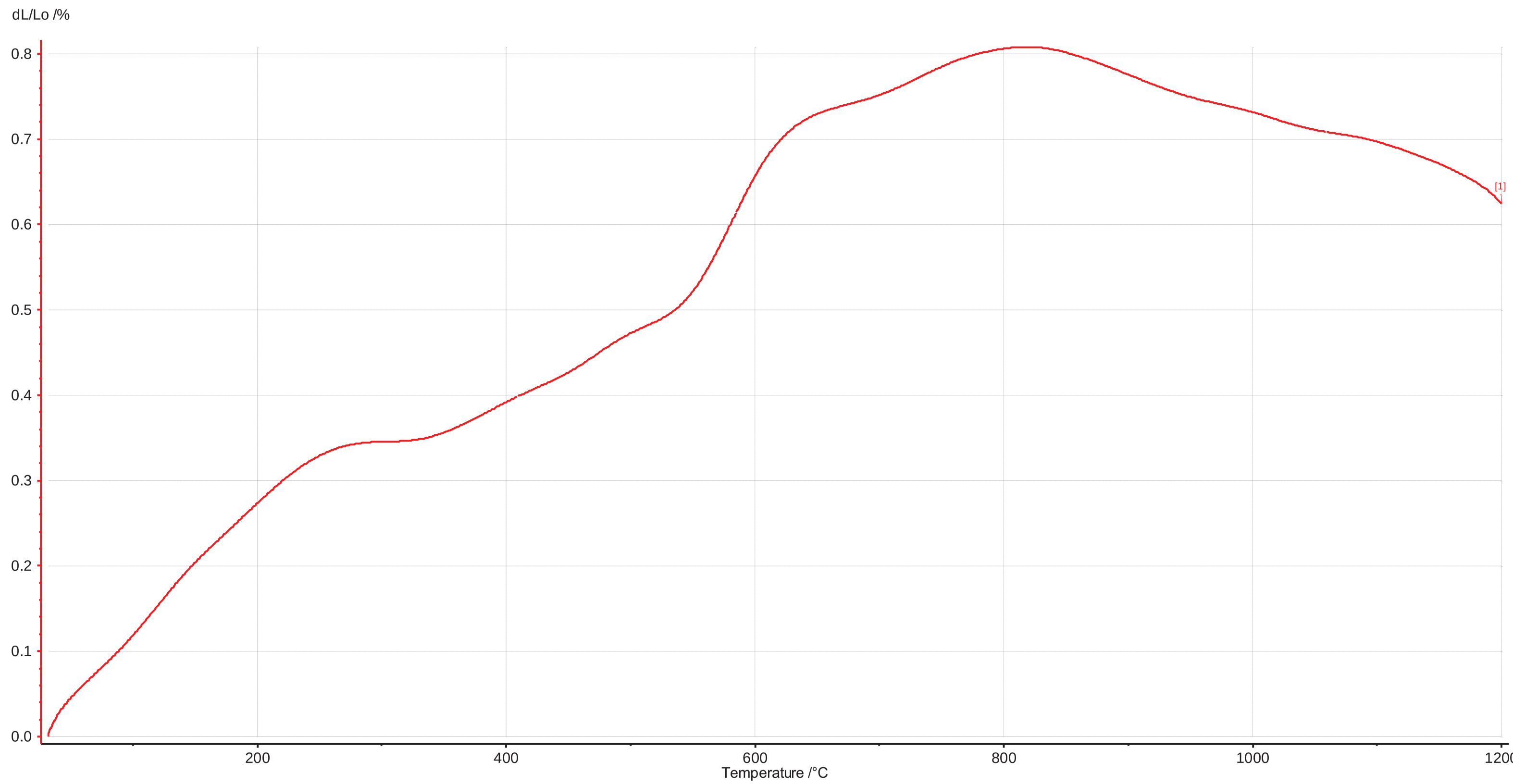
2.31E-02	0.1715	8.06E-03
2.28E-02	0.1715	7.64E-03
2.25E-02	0.1716	7.25E-03
2.22E-02	0.1716	6.88E-03
2.19E-02	0.1717	6.58E-03
2.16E-02	0.1717	6.30E-03
2.13E-02	0.1717	6.10E-03
2.11E-02	0.1718	5.82E-03
2.08E-02	0.1718	5.42E-03
2.05E-02	0.1718	5.05E-03
2.02E-02	0.1719	4.69E-03
1.99E-02	0.1719	4.39E-03
1.97E-02	0.1719	4.12E-03
1.94E-02	0.1719	3.92E-03
1.91E-02	0.172	3.74E-03
1.89E-02	0.172	3.48E-03
1.86E-02	0.172	3.23E-03
1.84E-02	0.172	2.91E-03
1.81E-02	0.172	2.64E-03
1.79E-02	0.1721	2.42E-03
1.76E-02	0.1721	2.21E-03
1.74E-02	0.1721	2.01E-03
1.71E-02	0.1721	1.76E-03
1.69E-02	0.1721	1.50E-03
1.66E-02	0.1721	1.20E-03
1.64E-02	0.1721	9.28E-04
1.62E-02	0.1721	7.19E-04

1.59E-02	0.1721	5.26E-04
1.57E-02	0.1721	3.98E-04
1.55E-02	0.1721	2.85E-04
1.53E-02	0.1721	1.89E-04
1.51E-02	0.1721	1.10E-04
1.48E-02	0.1721	4.71E-05
1.46E-02	0.1721	1.57E-05
1.44E-02	0.1721	0.00E+00
1.42E-02	0.1721	0.00E+00
1.40E-02	0.1721	0.00E+00
1.38E-02	0.1721	0.00E+00
1.36E-02	0.1721	0.00E+00
1.34E-02	0.1721	0.00E+00
1.32E-02	0.1721	0.00E+00
1.31E-02	0.1721	0.00E+00
1.29E-02	0.1721	0.00E+00
1.27E-02	0.1721	0.00E+00
1.25E-02	0.1721	0.00E+00
1.23E-02	0.1721	0.00E+00
1.22E-02	0.1721	0.00E+00
1.20E-02	0.1721	0.00E+00
1.18E-02	0.1721	0.00E+00
1.17E-02	0.1721	0.00E+00
1.15E-02	0.1721	0.00E+00
1.14E-02	0.1721	0.00E+00
1.12E-02	0.1721	0.00E+00
1.11E-02	0.1721	0.00E+00

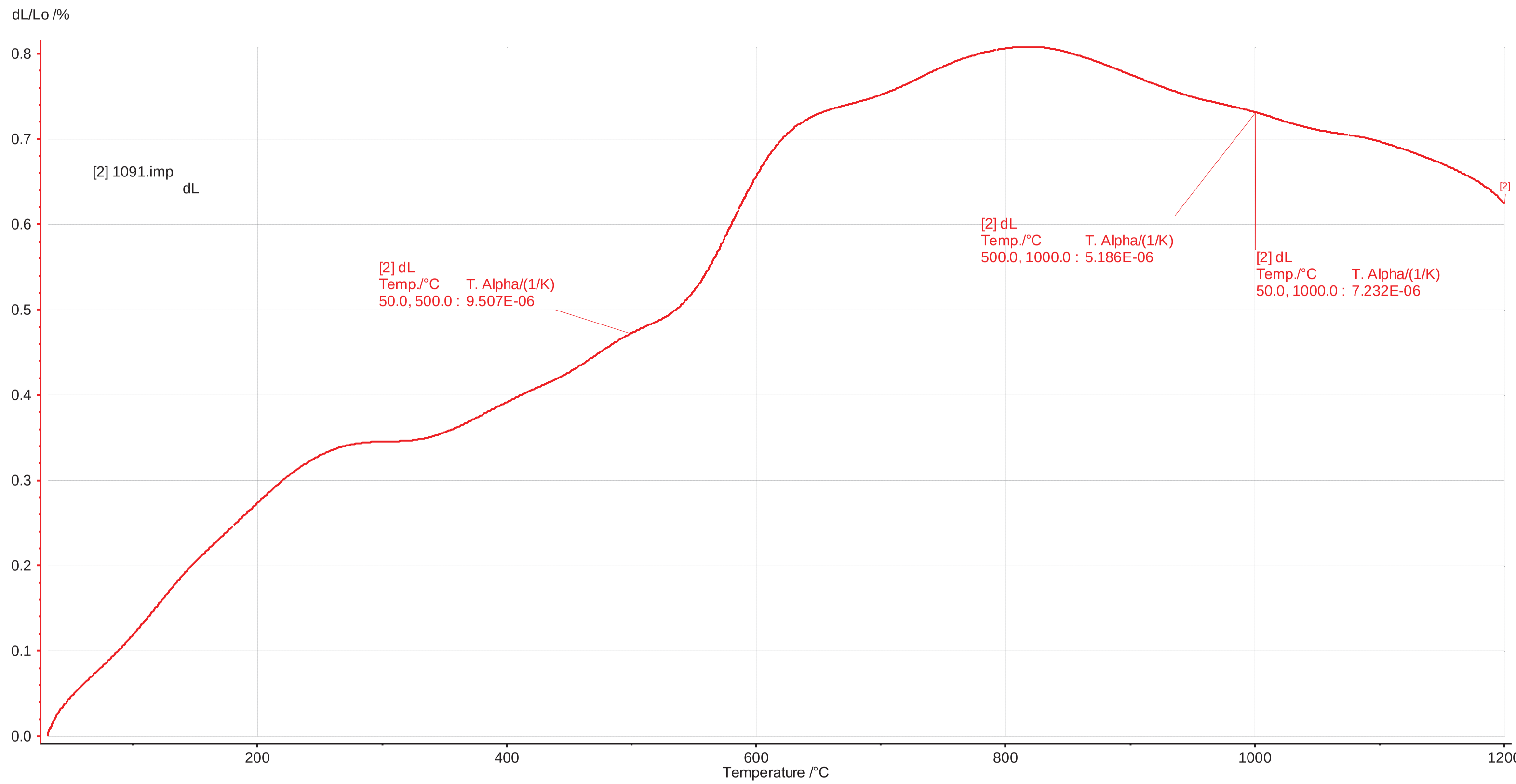
1.10E-02	0.1721	0.00E+00
1.08E-02	0.1721	0.00E+00
1.07E-02	0.1721	0.00E+00
1.05E-02	0.1721	0.00E+00
1.04E-02	0.1721	0.00E+00
1.03E-02	0.1721	0.00E+00
1.02E-02	0.1721	0.00E+00
1.00E-02	0.1721	0.00E+00
9.91E-03	0.1721	0.00E+00
9.80E-03	0.1721	0.00E+00
9.68E-03	0.1721	0.00E+00
9.57E-03	0.1721	0.00E+00
9.46E-03	0.1721	0.00E+00
9.35E-03	0.1721	0.00E+00
9.24E-03	0.1721	0.00E+00
9.14E-03	0.1721	0.00E+00
9.03E-03	0.1721	0.00E+00
8.93E-03	0.1721	0.00E+00
8.83E-03	0.1721	0.00E+00
8.73E-03	0.1721	0.00E+00
8.64E-03	0.1721	0.00E+00
8.54E-03	0.1721	0.00E+00
8.45E-03	0.1721	0.00E+00
8.36E-03	0.1721	0.00E+00
8.27E-03	0.1721	0.00E+00
8.18E-03	0.1721	0.00E+00
8.10E-03	0.1721	0.00E+00

8.01E-03	0.1721	0.00E+00
7.93E-03	0.1721	0.00E+00
7.85E-03	0.1721	0.00E+00
7.77E-03	0.1721	0.00E+00
7.69E-03	0.1721	0.00E+00
7.61E-03	0.1721	0.00E+00
7.53E-03	0.1721	0.00E+00
7.46E-03	0.1721	0.00E+00
7.38E-03	0.1721	0.00E+00
7.31E-03	0.1721	0.00E+00
7.24E-03	0.1721	0.00E+00
7.17E-03	0.1721	0.00E+00
7.10E-03	0.1721	0.00E+00
7.03E-03	0.1721	0.00E+00
6.96E-03	0.1721	0.00E+00
6.90E-03	0.1721	0.00E+00
6.83E-03	0.1721	0.00E+00
6.76E-03	0.1721	0.00E+00
6.70E-03	0.1721	0.00E+00
6.63E-03	0.1721	0.00E+00
6.56E-03	0.1721	0.00E+00
6.46E-03	0.1721	0.00E+00

10	0.0907
3	0.1171
1	0.1275



Thermal Expansion curve from the Dilatometer for the Dorchester 1091 sample. The lab work was compiled at the National Brick Research Center.

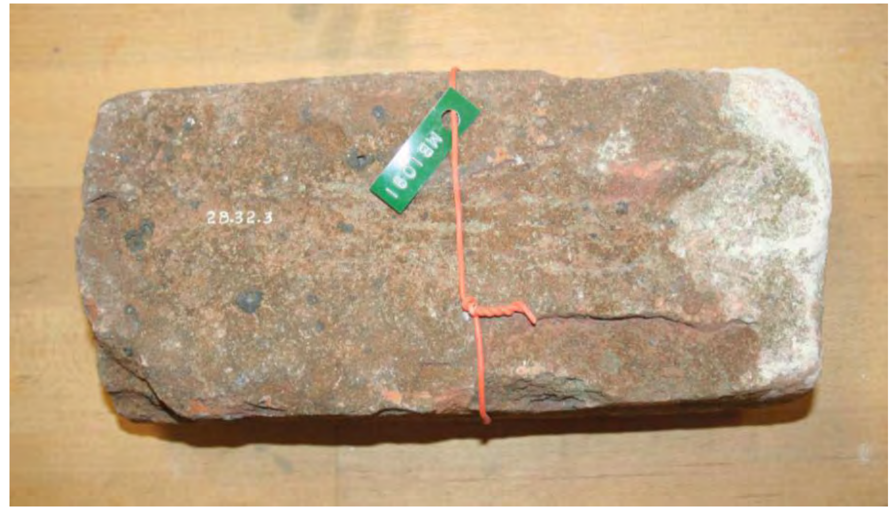


Thermal Expansion Coefficient from the Dilatometer for the Dorchester 1091 sample. The lab work was compiled at the National Brick Research Center.

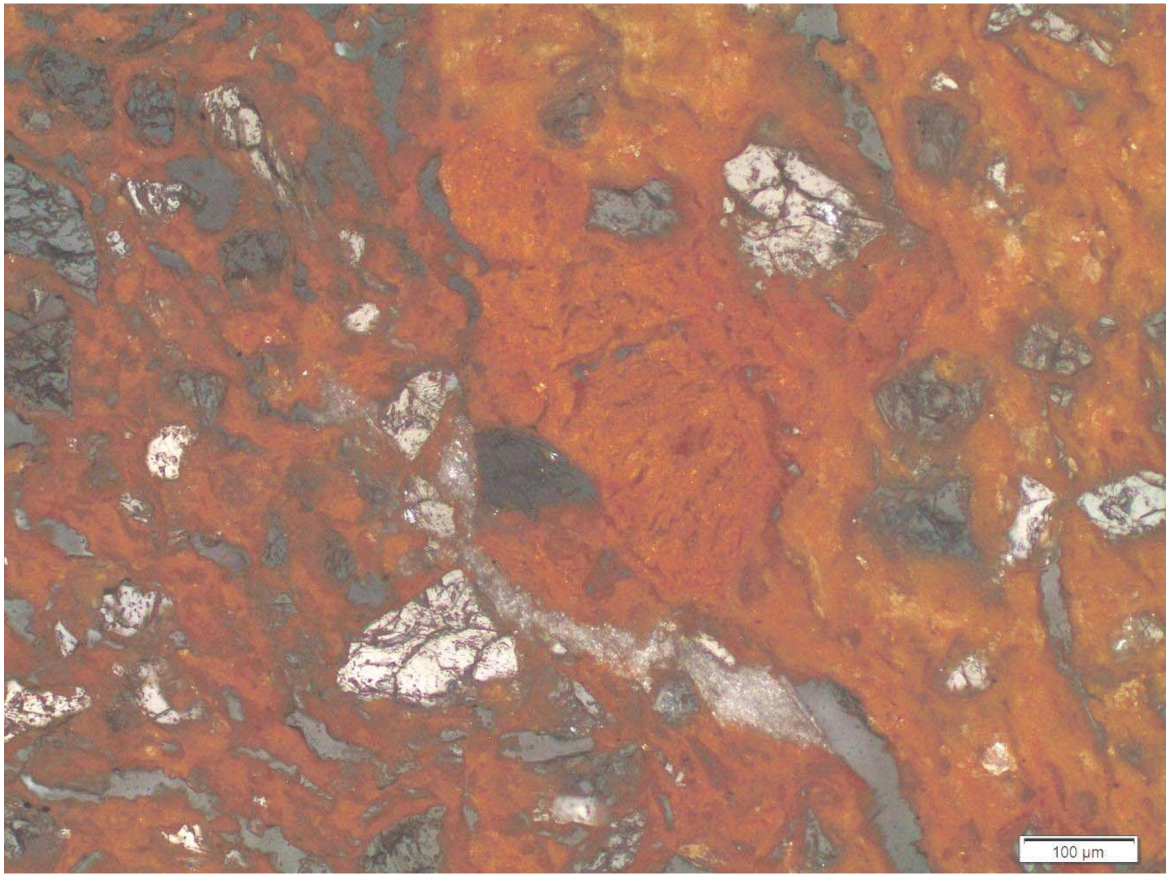
Sample #	Dry Weight (g)	24hr Cold Weight (g)	Boiled Weight	Suspended Weight	CWA (%)	BWA (%)	C/B	Bulk Density	Apparent Density	% Apparent Porosity
1	23.3846	26.7965	27.9835	14.4181	14.59	19.67	0.74	1.72	2.61	33.90
2	26.2335	30.1312	31.503	16.1214	14.86	20.09	0.74	1.71	2.59	34.26
3	24.1217	27.6796	29.1492	14.964	14.75	20.84	0.71	1.70	2.63	35.44
4	24.9823	28.3658	29.7452	15.4355	13.54	19.07	0.71	1.75	2.62	33.28
5	23.8657	27.2905	28.7049	14.7909	14.35	20.28	0.71	1.72	2.63	34.78
				Average	14.42	19.99	0.72	1.72	2.62	34.33
				Std Dev	0.52	0.67	0.02	0.02	0.02	0.82

Archimedian Density and Porosity results for Dorchester 1091 sample. The lab work was compiled at the National Brick Research Center

Run	L-value	a-value	b-value
1	43.16	15.19	22.36
2	41.84	15.89	22.82
3	42.92	14.9	22.04
Average	42.64	15.32667	22.40667
St Dev	0.7031358	0.508953	0.392088



Colorimeter results for Dorchester 1091 sample. Numbers can be compared to three-dimensional color chart. The lab work was compiled at the National Brick Research Center.



Standard Petrographic Thin Section result for Dorchester 1091 sample. he lab work was compiled at the National Petrographic Lab.

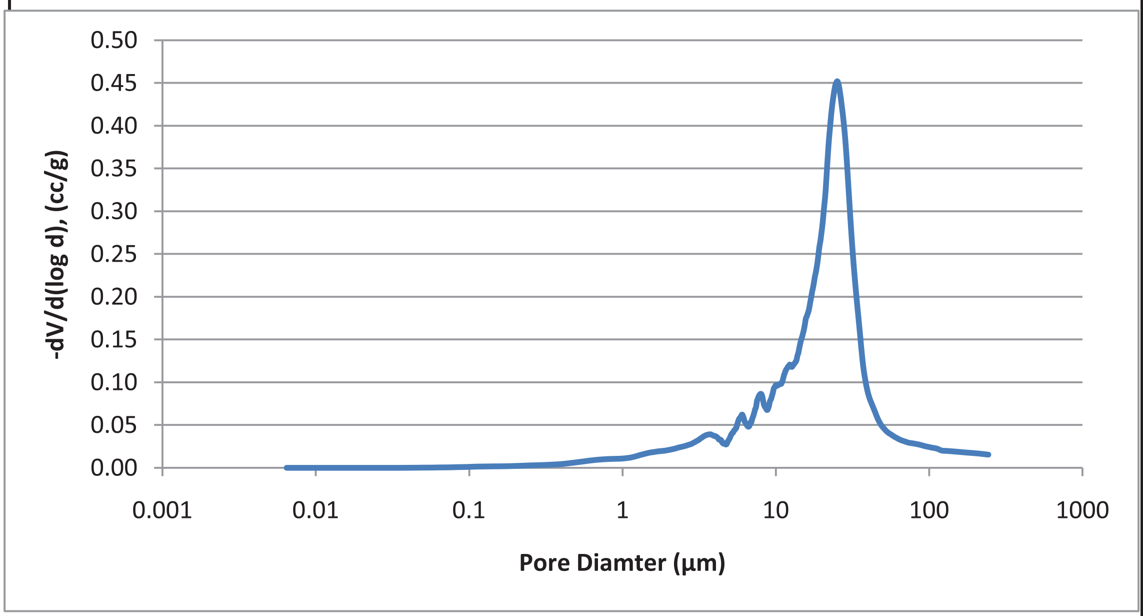
Appendix C- Dorchester 1428 Results

LOI	0.40	%
Chemisry (Oxidized Basis)		
Major Constituents		428- Fort Dorchest
Al2O3	%	12.13
SiO2	%	79.50
Na2O	%	<0.5
K2O	%	1.17
MgO	%	0.28
CaO	%	<0.01
TiO2	%	0.96
MnO	%	0.02
Fe2O3	%	5.46
P2O5	%	0.05
S	%	<0.05
Sum of Major Constituents	%	99.57
Minor Constituents		
Cl	ppm	<250
V	ppm	<150
Cr	ppm	<50
Ni	ppm	<10
Cu	ppm	49
Zn	ppm	<20
As	ppm	<20
Rb	ppm	<30
Sr	ppm	131
Zr	ppm	230
Ba	ppm	480
Pb	ppm	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI		

Chemistry/ XRF and Loss of Ignition results for Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center.

Poresize Data

Property	Unit	
Total Intrusion Volume	ml/g	0.20
Median Pore Diameter	microns	22.25
Bulk Density	g/cc	1.63
Apparent Density	g/cc	2.15
Porosity	%	33.44
Pores >3 Microns	%	93.17
Maage Index		239.24
Pores >10 Microns	%	80.06
Pores 10-1 Microns	%	17.57
Pores <1 Microns	%	2.37



Mercury Intrusion results for Dorchester 1428 sample. (Following table is the raw pore size data) The lab work was compiled at the National Brick Research Center.

Raw Pore Size Data		
Pore Diameter	Volume Intruded	Delta Volume
244.10	0.0004	1.54E-02
210.10	0.0013	1.67E-02
171.80	0.0028	1.80E-02
146.00	0.0042	1.91E-02
130.60	0.0052	1.97E-02
121.20	0.0059	2.02E-02
112.50	0.0067	2.25E-02
105.30	0.0074	2.34E-02
99.37	0.0082	2.44E-02
94.19	0.0087	2.53E-02
89.49	0.0093	2.64E-02
85.13	0.0098	2.74E-02
81.05	0.0104	2.81E-02
77.20	0.011	2.88E-02
73.63	0.0116	2.93E-02
70.32	0.0122	3.06E-02
67.28	0.0128	3.17E-02
64.49	0.0134	3.30E-02
61.78	0.0141	3.48E-02
59.17	0.0147	3.66E-02
56.73	0.0154	3.88E-02
54.50	0.0161	4.08E-02
52.49	0.0167	4.32E-02
50.67	0.0174	4.63E-02
49.05	0.0181	4.93E-02
47.57	0.0188	5.33E-02
46.20	0.0195	5.78E-02
44.86	0.0202	6.36E-02
43.45	0.0211	6.98E-02
42.03	0.0221	7.60E-02
40.68	0.0232	8.29E-02
39.45	0.0244	9.19E-02
38.35	0.0256	1.03E-01
37.38	0.0268	1.16E-01
36.53	0.028	1.32E-01
35.68	0.0292	1.52E-01
34.79	0.0309	1.72E-01
33.83	0.0331	1.95E-01
32.84	0.0357	2.20E-01
31.91	0.0387	2.48E-01
31.07	0.042	2.77E-01
30.33	0.0452	3.07E-01
29.68	0.0483	3.34E-01
29.06	0.0518	3.60E-01
28.41	0.0559	3.85E-01
27.72	0.0605	4.05E-01
27.03	0.0655	4.22E-01
26.37	0.0703	4.37E-01
25.78	0.0748	4.47E-01
25.26	0.079	4.52E-01
24.80	0.0827	4.50E-01
24.36	0.0864	4.45E-01
23.90	0.0902	4.36E-01
23.44	0.0941	4.26E-01
23.00	0.0976	4.12E-01
22.60	0.1006	3.97E-01
22.25	0.1032	3.84E-01
21.92	0.1055	3.67E-01
21.60	0.1076	3.49E-01
21.30	0.1095	3.32E-01
21.01	0.1114	3.17E-01
20.70	0.1134	3.05E-01
20.39	0.1153	2.92E-01
20.10	0.117	2.81E-01
19.82	0.1185	2.73E-01
19.56	0.1201	2.65E-01
19.28	0.1217	2.59E-01
19.00	0.1233	2.49E-01
18.74	0.1247	2.41E-01
18.48	0.1261	2.34E-01
18.23	0.1275	2.28E-01
17.98	0.1289	2.23E-01
17.73	0.1302	2.16E-01
17.48	0.1314	2.10E-01
17.25	0.1325	2.05E-01
17.03	0.1336	1.99E-01
16.80	0.1348	1.94E-01

16.57	0.136	1.87E-01
16.35	0.137	1.83E-01
16.14	0.138	1.80E-01
15.94	0.1389	1.77E-01
15.73	0.1399	1.75E-01
15.52	0.1409	1.68E-01
15.32	0.1418	1.63E-01
15.13	0.1427	1.58E-01
14.95	0.1435	1.55E-01
14.75	0.1445	1.51E-01
14.56	0.1453	1.48E-01
14.38	0.146	1.43E-01
14.21	0.1467	1.39E-01
14.04	0.1474	1.34E-01
13.86	0.1481	1.31E-01
13.69	0.1489	1.26E-01
13.52	0.1495	1.24E-01
13.37	0.15	1.23E-01
13.21	0.1506	1.22E-01
13.05	0.1513	1.20E-01
12.90	0.1519	1.19E-01
12.75	0.1524	1.18E-01
12.61	0.153	1.19E-01
12.47	0.1536	1.20E-01
12.34	0.1542	1.21E-01
12.20	0.1548	1.19E-01
12.06	0.1553	1.19E-01

11.94	0.1559	1.17E-01
11.81	0.1565	1.16E-01
11.68	0.1571	1.15E-01
11.55	0.1576	1.12E-01
11.43	0.1581	1.10E-01
11.31	0.1585	1.08E-01
11.19	0.159	1.04E-01
11.08	0.1595	1.02E-01
10.96	0.1599	9.95E-02
10.85	0.1604	9.81E-02
10.74	0.1608	9.80E-02
10.63	0.1612	9.82E-02
10.52	0.1616	9.73E-02
10.41	0.162	9.73E-02
10.31	0.1625	9.66E-02
10.21	0.1629	9.57E-02
10.10	0.1634	9.60E-02
10.00	0.1638	9.66E-02
9.91	0.1642	9.50E-02
9.81	0.1646	9.40E-02
9.72	0.1649	9.27E-02
9.62	0.1653	8.94E-02
9.53	0.1657	8.62E-02
9.44	0.1661	8.40E-02
9.35	0.1664	8.10E-02
9.27	0.1667	7.94E-02
9.19	0.167	7.81E-02

9.11	0.1673	7.56E-02
9.03	0.1675	7.21E-02
8.96	0.1678	7.03E-02
8.88	0.168	6.84E-02
8.81	0.1683	6.76E-02
8.74	0.1685	6.78E-02
8.68	0.1687	6.90E-02
8.62	0.1689	6.96E-02
8.55	0.1691	7.11E-02
8.49	0.1693	7.15E-02
8.42	0.1696	7.27E-02
8.36	0.1698	7.43E-02
8.30	0.1701	7.74E-02
8.24	0.1703	7.98E-02
8.19	0.1706	8.31E-02
8.13	0.1708	8.48E-02
8.07	0.1711	8.63E-02
8.00	0.1714	8.59E-02
7.94	0.1717	8.64E-02
7.89	0.172	8.52E-02
7.82	0.1723	8.51E-02
7.76	0.1726	8.38E-02
7.70	0.1729	8.25E-02
7.64	0.1732	8.02E-02
7.57	0.1735	7.93E-02
7.51	0.1737	7.58E-02
7.45	0.174	7.17E-02

7.39	0.1742	6.95E-02
7.34	0.1744	6.84E-02
7.28	0.1747	6.58E-02
7.22	0.1749	6.39E-02
7.17	0.1751	6.15E-02
7.11	0.1753	5.99E-02
7.06	0.1755	5.82E-02
7.01	0.1757	5.65E-02
6.96	0.1758	5.39E-02
6.90	0.176	5.28E-02
6.85	0.1762	5.33E-02
6.79	0.1764	5.09E-02
6.74	0.1765	4.90E-02
6.68	0.1767	4.83E-02
6.63	0.1769	4.80E-02
6.58	0.1771	4.85E-02
6.53	0.1772	4.91E-02
6.47	0.1773	5.01E-02
6.42	0.1775	5.11E-02
6.37	0.1777	5.20E-02
6.32	0.1779	5.31E-02
6.27	0.1781	5.44E-02
6.22	0.1783	5.67E-02
6.16	0.1785	5.88E-02
6.11	0.1787	6.04E-02
6.06	0.179	6.21E-02
6.01	0.1792	6.20E-02

5.96	0.1794	6.09E-02
5.91	0.1797	5.96E-02
5.86	0.1799	5.85E-02
5.81	0.1802	5.77E-02
5.76	0.1804	5.69E-02
5.71	0.1805	5.49E-02
5.66	0.1807	5.31E-02
5.61	0.1809	5.08E-02
5.57	0.1811	4.86E-02
5.52	0.1813	4.64E-02
5.48	0.1814	4.56E-02
5.43	0.1816	4.49E-02
5.39	0.1817	4.40E-02
5.35	0.1818	4.35E-02
5.31	0.182	4.23E-02
5.26	0.1821	4.10E-02
5.23	0.1823	4.08E-02
5.19	0.1824	4.01E-02
5.15	0.1825	3.96E-02
5.12	0.1826	3.84E-02
5.08	0.1827	3.75E-02
5.05	0.1829	3.59E-02
5.02	0.183	3.47E-02
4.98	0.1831	3.39E-02
4.95	0.1832	3.27E-02
4.91	0.1832	3.21E-02
4.88	0.1833	3.11E-02

4.85	0.1834	2.98E-02
4.81	0.1835	2.90E-02
4.78	0.1836	2.75E-02
4.74	0.1837	2.78E-02
4.71	0.1838	2.74E-02
4.67	0.1839	2.78E-02
4.64	0.1839	2.86E-02
4.61	0.184	2.88E-02
4.57	0.1841	2.84E-02
4.54	0.1842	2.84E-02
4.51	0.1843	2.89E-02
4.48	0.1844	2.94E-02
4.45	0.1845	3.03E-02
4.42	0.1845	3.20E-02
4.39	0.1846	3.22E-02
4.36	0.1847	3.29E-02
4.33	0.1848	3.31E-02
4.29	0.185	3.29E-02
4.25	0.1851	3.32E-02
4.21	0.1853	3.45E-02
4.17	0.1854	3.54E-02
4.13	0.1856	3.60E-02
4.08	0.1857	3.67E-02
4.03	0.1859	3.70E-02
3.99	0.1861	3.71E-02
3.94	0.1863	3.77E-02
3.89	0.1865	3.80E-02

3.84	0.1867	3.84E-02
3.80	0.1869	3.89E-02
3.75	0.1871	3.92E-02
3.71	0.1874	3.91E-02
3.66	0.1875	3.90E-02
3.62	0.1877	3.89E-02
3.58	0.1879	3.87E-02
3.54	0.1881	3.84E-02
3.50	0.1883	3.81E-02
3.46	0.1885	3.76E-02
3.42	0.1887	3.72E-02
3.38	0.1889	3.67E-02
3.35	0.189	3.61E-02
3.31	0.1892	3.55E-02
3.27	0.1894	3.49E-02
3.24	0.1896	3.44E-02
3.20	0.1897	3.37E-02
3.16	0.1899	3.30E-02
3.12	0.1901	3.23E-02
3.09	0.1902	3.18E-02
3.05	0.1904	3.13E-02
3.01	0.1906	3.07E-02
2.97	0.1907	3.01E-02
2.93	0.1909	2.95E-02
2.89	0.1911	2.90E-02
2.85	0.1913	2.84E-02
2.81	0.1914	2.78E-02

2.76	0.1916	2.74E-02
2.72	0.1918	2.71E-02
2.68	0.192	2.67E-02
2.64	0.1922	2.63E-02
2.60	0.1923	2.58E-02
2.55	0.1925	2.55E-02
2.51	0.1927	2.51E-02
2.47	0.1929	2.48E-02
2.43	0.1931	2.45E-02
2.39	0.1932	2.42E-02
2.35	0.1934	2.39E-02
2.31	0.1936	2.36E-02
2.27	0.1938	2.31E-02
2.23	0.1939	2.27E-02
2.19	0.1941	2.24E-02
2.15	0.1943	2.20E-02
2.11	0.1945	2.17E-02
2.07	0.1946	2.14E-02
2.03	0.1948	2.10E-02
1.99	0.195	2.08E-02
1.95	0.1952	2.05E-02
1.91	0.1953	2.02E-02
1.88	0.1955	2.00E-02
1.84	0.1957	1.99E-02
1.80	0.1958	1.97E-02
1.77	0.196	1.95E-02
1.74	0.1962	1.94E-02

1.70	0.1963	1.92E-02
1.67	0.1965	1.90E-02
1.64	0.1966	1.88E-02
1.61	0.1968	1.85E-02
1.58	0.1969	1.83E-02
1.55	0.1971	1.81E-02
1.52	0.1972	1.79E-02
1.49	0.1974	1.76E-02
1.46	0.1975	1.73E-02
1.44	0.1977	1.69E-02
1.41	0.1978	1.65E-02
1.38	0.198	1.60E-02
1.35	0.1981	1.56E-02
1.32	0.1983	1.52E-02
1.29	0.1984	1.47E-02
1.26	0.1985	1.42E-02
1.23	0.1987	1.37E-02
1.20	0.1988	1.31E-02
1.17	0.1989	1.27E-02
1.15	0.1991	1.22E-02
1.12	0.1992	1.18E-02
1.09	0.1993	1.15E-02
1.05	0.1995	1.13E-02
1.02	0.1996	1.10E-02
0.99	0.1998	1.08E-02
0.96	0.1999	1.07E-02
0.93	0.2	1.06E-02

0.90	0.2002	1.05E-02
0.87	0.2003	1.05E-02
0.84	0.2005	1.04E-02
0.81	0.2007	1.03E-02
0.79	0.2008	1.02E-02
0.76	0.201	1.00E-02
0.74	0.2011	9.83E-03
0.71	0.2013	9.65E-03
0.69	0.2014	9.40E-03
0.66	0.2015	9.14E-03
0.64	0.2017	8.87E-03
0.62	0.2018	8.56E-03
0.60	0.2019	8.23E-03
0.58	0.202	7.86E-03
0.56	0.2022	7.50E-03
0.54	0.2023	7.13E-03
0.52	0.2024	6.79E-03
0.50	0.2025	6.45E-03
0.49	0.2026	6.09E-03
0.47	0.2026	5.76E-03
0.45	0.2027	5.42E-03
0.44	0.2028	5.08E-03
0.42	0.2029	4.77E-03
0.40	0.203	4.48E-03
0.39	0.203	4.25E-03
0.37	0.2031	4.06E-03
0.36	0.2032	3.89E-03

0.35	0.2032	3.73E-03
0.33	0.2033	3.56E-03
0.32	0.2033	3.41E-03
0.31	0.2034	3.29E-03
0.29	0.2035	3.19E-03
0.28	0.2035	3.09E-03
0.27	0.2036	2.99E-03
0.26	0.2036	2.92E-03
0.25	0.2037	2.82E-03
0.24	0.2037	2.68E-03
0.23	0.2038	2.53E-03
0.22	0.2038	2.41E-03
0.21	0.2039	2.32E-03
0.20	0.2039	2.22E-03
0.19	0.2039	2.12E-03
0.19	0.204	2.01E-03
0.18	0.204	1.93E-03
0.17	0.204	1.87E-03
0.16	0.2041	1.81E-03
0.16	0.2041	1.77E-03
0.15	0.2041	1.76E-03
0.15	0.2041	1.74E-03
0.14	0.2042	1.68E-03
0.13	0.2042	1.62E-03
0.13	0.2042	1.57E-03
0.12	0.2043	1.52E-03
0.12	0.2043	1.51E-03

0.11	0.2043	1.46E-03
0.11	0.2043	1.37E-03
0.11	0.2044	1.27E-03
0.10	0.2044	1.16E-03
0.10	0.2044	1.04E-03
0.09	0.2044	9.56E-04
0.09	0.2044	9.09E-04
0.09	0.2044	8.72E-04
0.08	0.2045	8.10E-04
0.08	0.2045	7.52E-04
0.08	0.2045	6.56E-04
0.08	0.2045	5.81E-04
0.07	0.2045	5.36E-04
0.07	0.2045	5.03E-04
0.07	0.2045	4.81E-04
0.07	0.2045	4.80E-04
0.06	0.2045	4.52E-04
0.06	0.2045	3.96E-04
0.06	0.2045	3.39E-04
0.06	0.2045	3.01E-04
0.06	0.2045	2.69E-04
0.05	0.2045	2.57E-04
0.05	0.2045	2.45E-04
0.05	0.2045	2.34E-04
0.05	0.2045	2.21E-04
0.05	0.2045	2.09E-04
0.05	0.2046	1.67E-04

0.05	0.2046	1.38E-04
0.04	0.2046	1.23E-04
0.04	0.2046	1.08E-04
0.04	0.2046	9.33E-05
0.04	0.2046	7.81E-05
0.04	0.2046	6.30E-05
0.04	0.2046	4.75E-05
0.04	0.2046	3.18E-05
0.04	0.2046	1.61E-05
0.04	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.03	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
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0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.02	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00

0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
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0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
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0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
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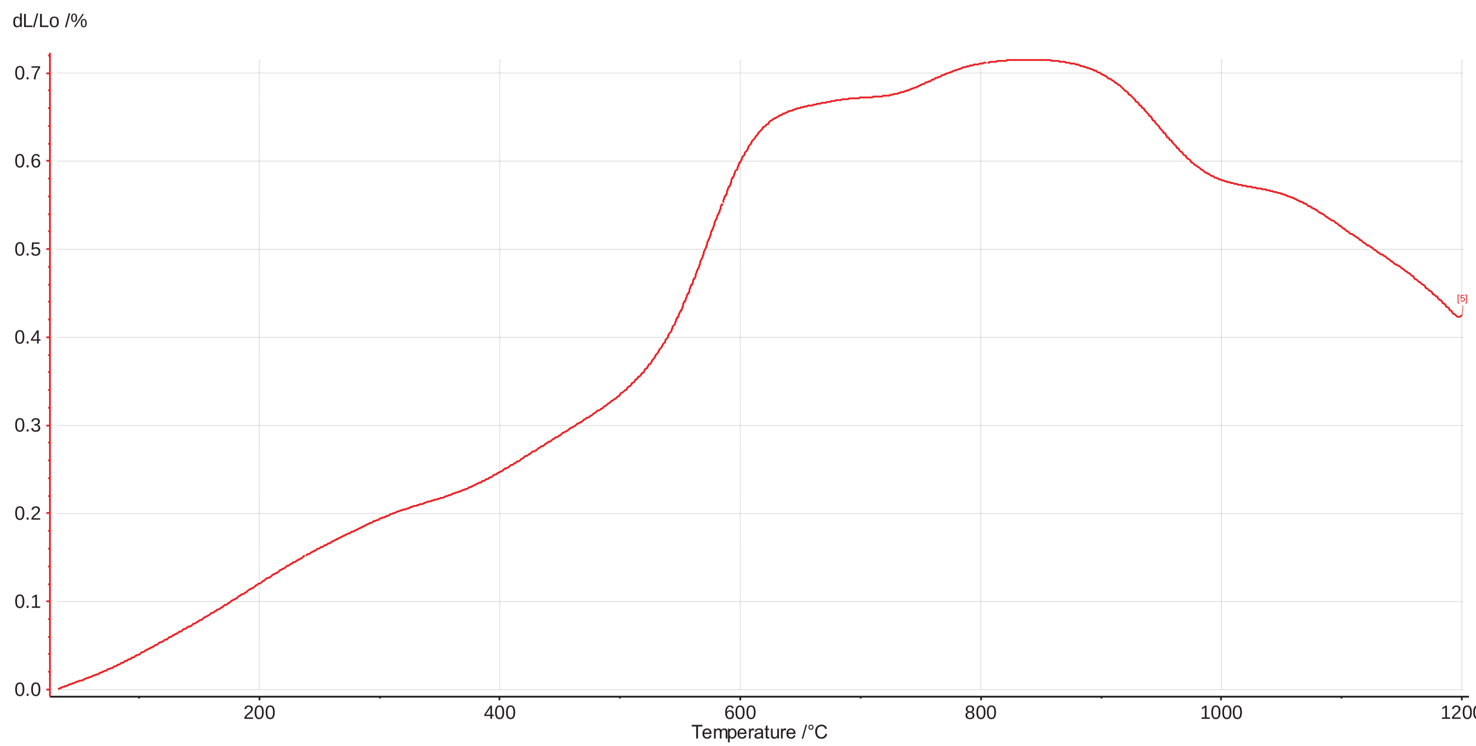
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00

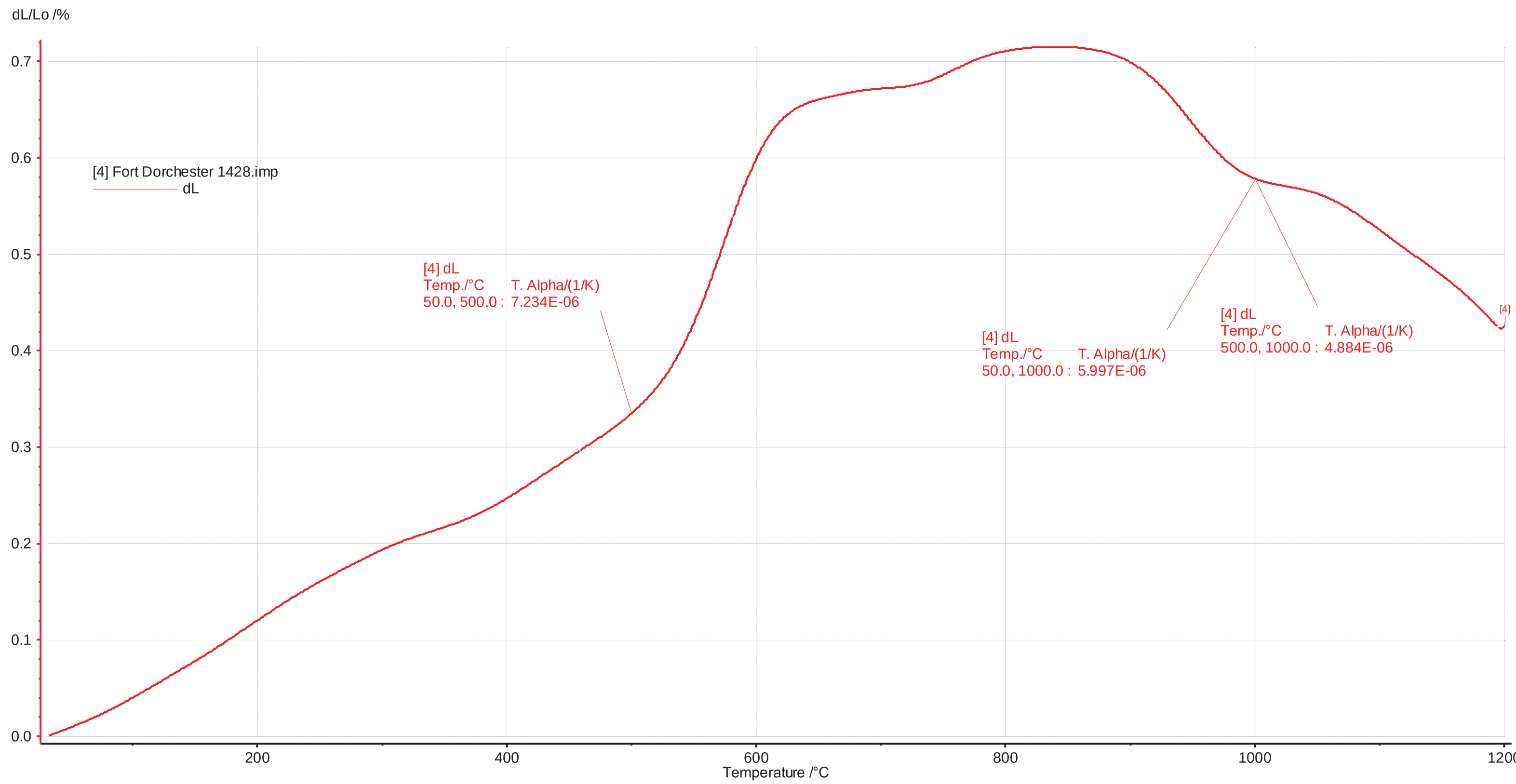
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00

0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	0.00E+00
0.01	0.2046	3.31E-07
0.01	0.2046	3.31E-07
0.01	0.2046	6.56E-07
0.01	0.2046	9.63E-07
0.01	0.2046	9.63E-07
0.01	0.2046	1.06E-06
0.01	0.2046	1.18E-06
0.01	0.2046	1.32E-06
0.01	0.2046	1.51E-06
0.01	0.2046	1.77E-06

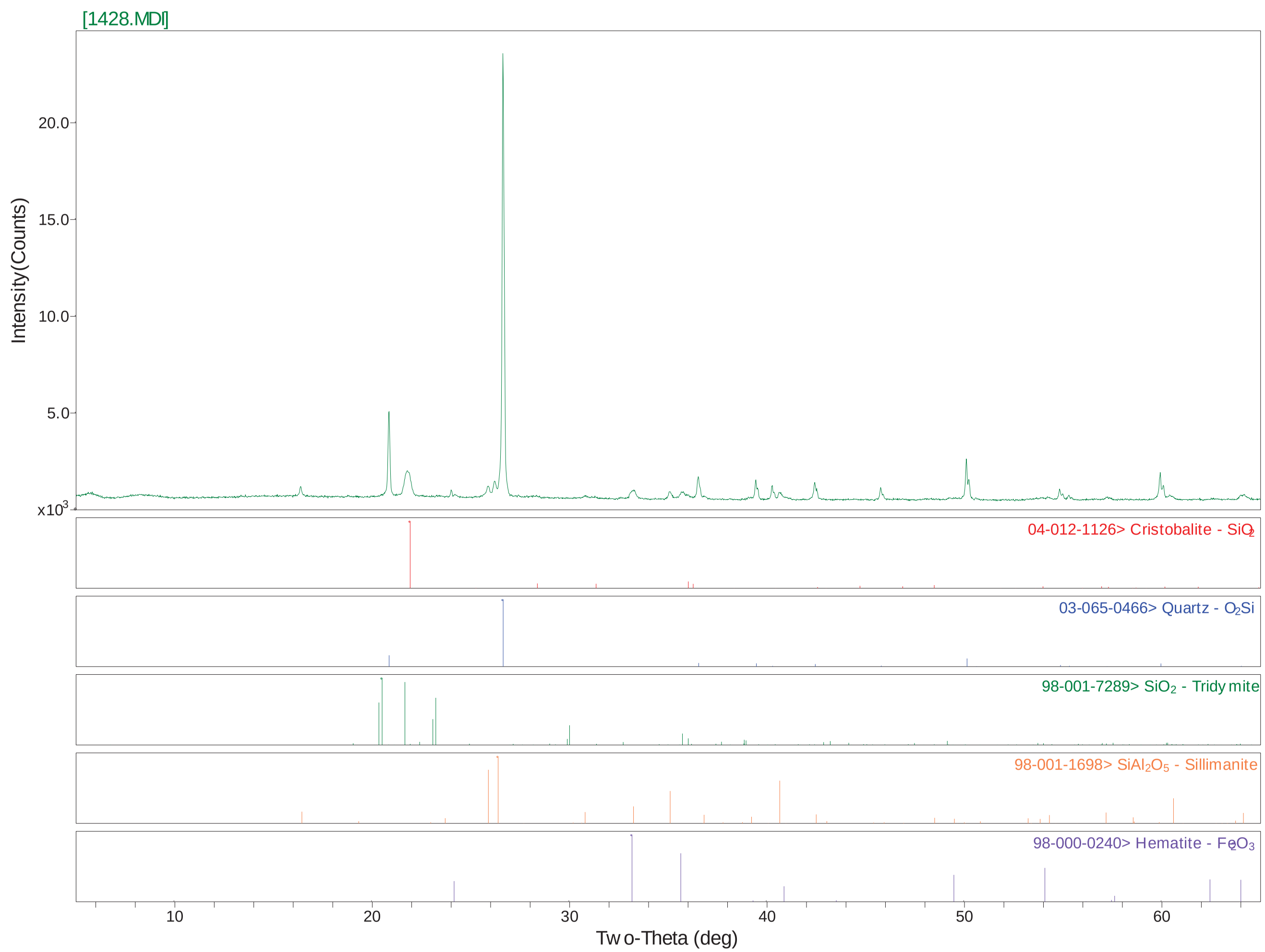
10	0.1638
3	0.1906
1	0.1998



Thermal Expansion curve from the Dilatometer for the Dorchester 1428 sample. The lab work was compiled at the National Brick Research Center.



Thermal Expansion Coefficient from the Dilatometer for the Dorchester 1428 sample. The lab work was compiled at the National Brick Research Center.



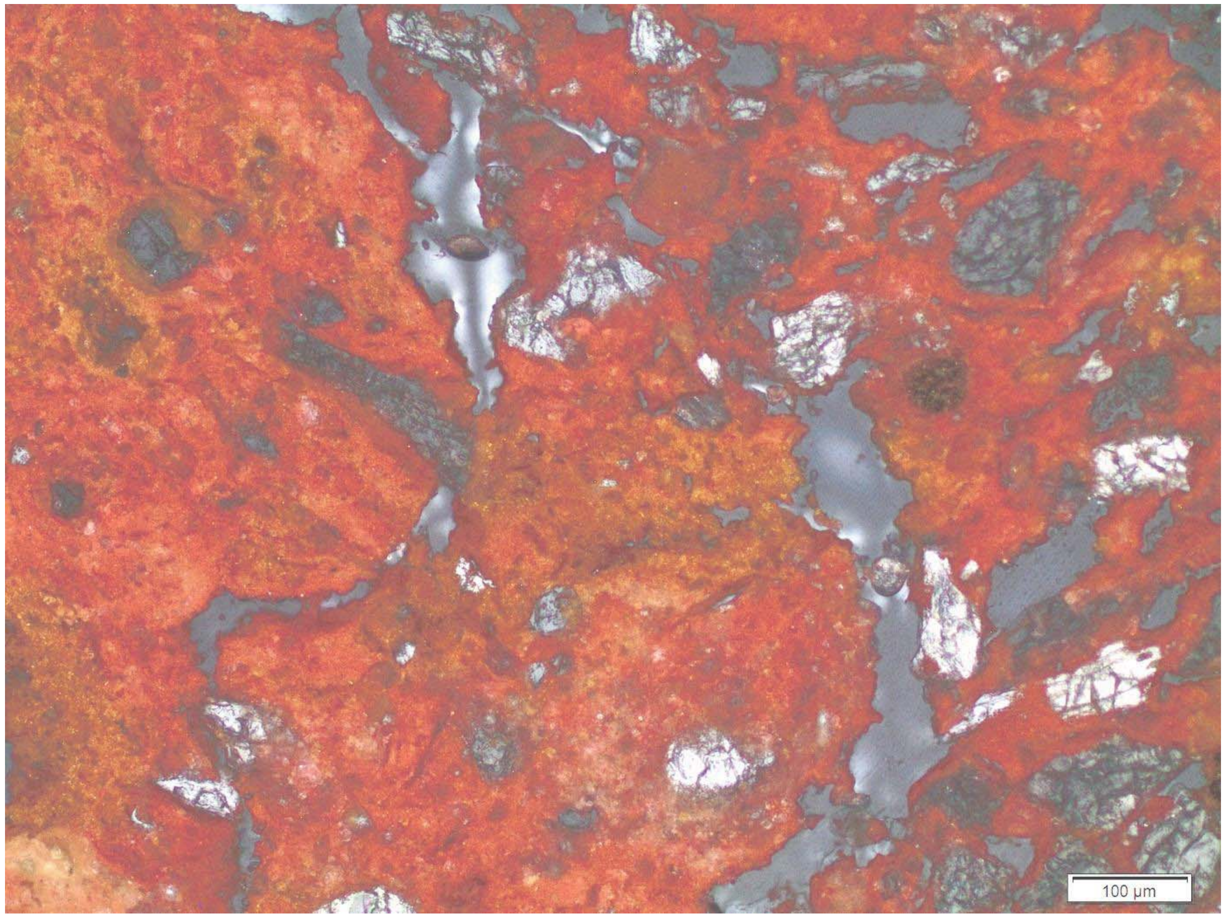
XRD results for Dorchester 1428. The minerals present are listed under the graph. The lab work was compiled at the National Brick Research Center.

Sampl e #	Dry Weight (g)	24hr Cold Weight (g)	Boiled Weight	Suspended Weight	CWA (%)	BWA (%)	C/B	Bulk Densit y	Apparent Density	% Apparent Porosity
1	17.1916	20.0351	20.994	10.6112	16.54	22.12	0.75	1.66	2.61	36.62
2	16.7902	19.6166	20.4243	10.2683	16.83	21.64	0.78	1.65	2.57	35.78
3	19.5916	22.6182	23.5962	11.9278	15.45	20.44	0.76	1.68	2.56	34.32
4	17.3443	20.1655	21.0193	10.652	16.27	21.19	0.77	1.67	2.59	35.45
5	16.1727	18.8396	19.8239	10.0308	16.49	22.58	0.73	1.65	2.63	37.28
				Average	16.32	21.59	0.76	1.66	2.59	35.89
				Std Dev	0.53	0.83	0.02	0.01	0.03	1.13

Archimedian Density and Porosity results for Dorchester 1428 sample. The lab work was compiled at the National Brick Research Center.

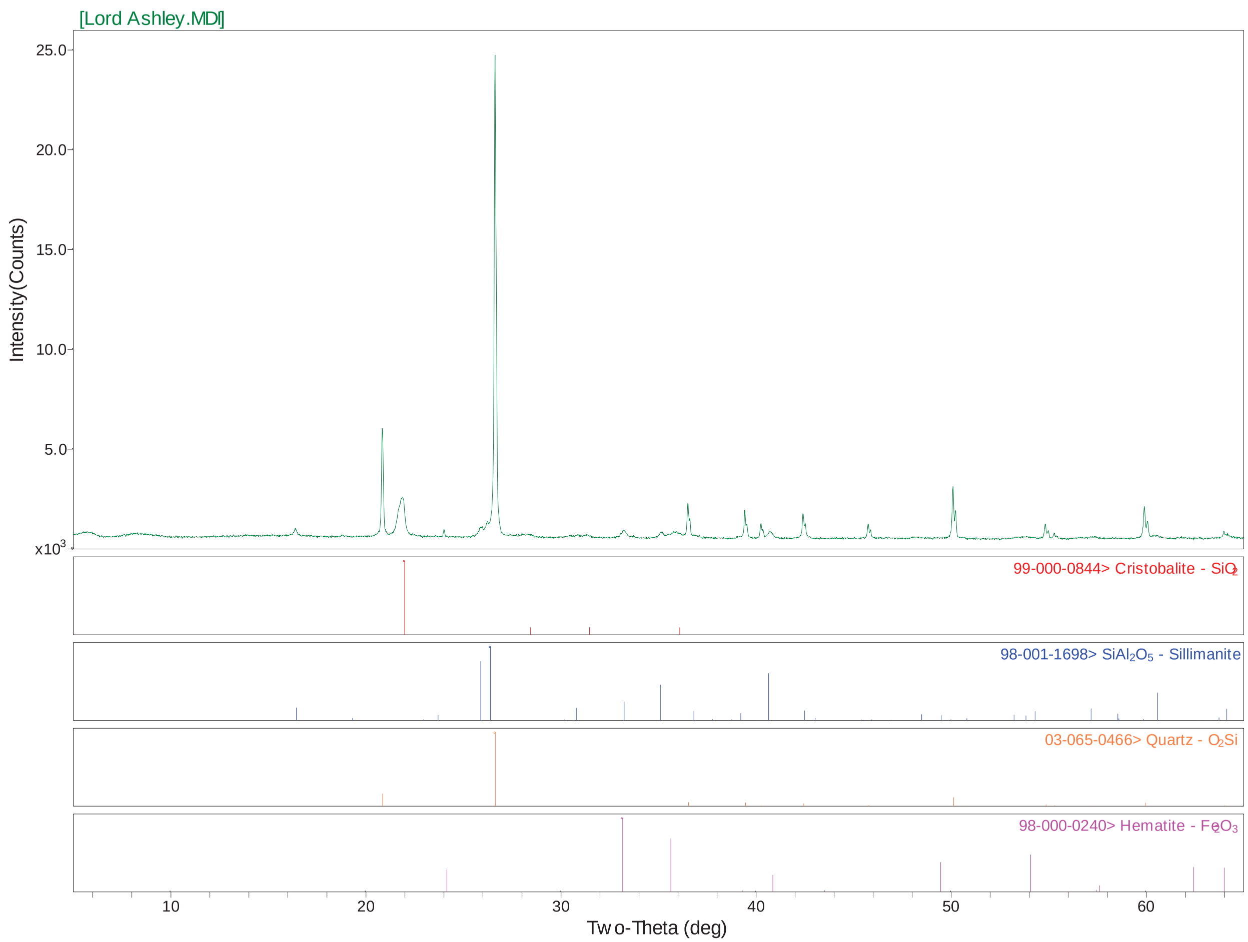
Run	L-value	a-value	b-value
1	39.22	19.84	17.66
2	38.84	20.54	18.15
3	39.09	20.07	17.97
Average	39.05	20.15	17.92667
St Dev	0.1931321	0.356791	0.247857

Colorimeter results for Dorchester 1428 sample. Numbers can be compared to three-dimensional color chart. The lab work was compiled at the National Brick Research Center.



Standard Petrographic Thin Section result for Dorchester 1428 sample. The lab work was compiled at the National Petrographic Lab.

Appendix D- Lord Ashley Site Results



XRD results for Lord Ashley sample. The minerals present are listed under the graph. The lab work was compiled at the National Brick Research Center.

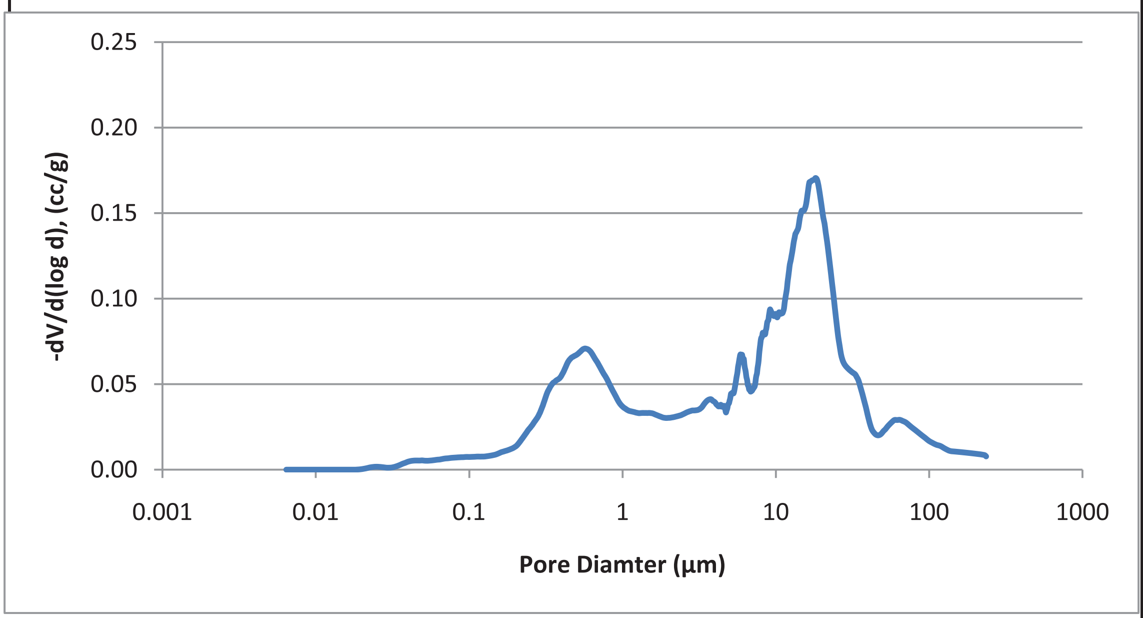
LOI	0.78	%

Chemisry (Oxidized Basis)		
Major Constituents		Lord Ashley
Al2O3	%	11.94
SiO2	%	81.19
Na2O	%	<0.5
K2O	%	0.50
MgO	%	<0.2
CaO	%	<0.01
TiO2	%	0.89
MnO	%	0.01
Fe2O3	%	4.92
P2O5	%	0.05
S	%	<0.05
Sum of Major Constituents	%	99.50
Minor Constituents		
Cl	ppm	<250
V	ppm	<150
Cr	ppm	75
Ni	ppm	<10
Cu	ppm	43
Zn	ppm	<20
As	ppm	27
Rb	ppm	<30
Sr	ppm	67
Zr	ppm	209
Ba	ppm	370
Pb	ppm	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI		

Chemistry/ XRF and Loss of Ignition results for Lord Ashley sample.
The lab work was compiled at the National Brick Research Center.

Poresize Data

Property	Unit	
Total Intrusion Volume	ml/g	0.16
Median Pore Diameter	microns	9.52
Bulk Density	g/cc	1.93
Apparent Density	g/cc	2.20
Porosity	%	31.25
Pores >3 Microns	%	66.06
Maage Index		178.33
Pores >10 Microns	%	48.93
Pores 10-1 Microns	%	26.75
Pores <1 Microns	%	24.32



Mercury Intrusion results for Lord Ashley sample. (Following table is the raw pore size data) The lab work was compiled at the National Brick Research Center.

Raw Pore Size Data		
Pore Diameter	Volume Intruded	Delta Volume
2.35E+02	0.0003	7.73E-03
2.29E+02	0.0003	8.56E-03
2.01E+02	0.0009	9.30E-03
1.71E+02	0.0017	1.00E-02
1.50E+02	0.0024	1.05E-02
1.37E+02	0.0029	1.09E-02
1.27E+02	0.0033	1.22E-02
1.19E+02	0.0037	1.38E-02
1.11E+02	0.0042	1.46E-02
1.05E+02	0.0045	1.57E-02
9.95E+01	0.0049	1.69E-02
9.44E+01	0.0052	1.85E-02
8.97E+01	0.0056	2.00E-02
8.52E+01	0.0061	2.16E-02
8.10E+01	0.0066	2.32E-02
7.72E+01	0.0071	2.46E-02
7.36E+01	0.0077	2.62E-02
7.03E+01	0.0083	2.77E-02
6.73E+01	0.0089	2.84E-02
6.45E+01	0.0095	2.91E-02
6.18E+01	0.0101	2.90E-02
5.94E+01	0.0107	2.90E-02
5.71E+01	0.0112	2.78E-02
5.51E+01	0.0116	2.64E-02
5.34E+01	0.0119	2.51E-02
5.18E+01	0.0122	2.36E-02
5.04E+01	0.0125	2.26E-02
4.91E+01	0.0127	2.13E-02
4.78E+01	0.0129	2.04E-02
4.64E+01	0.0131	2.01E-02
4.50E+01	0.0133	2.05E-02
4.36E+01	0.0136	2.17E-02
4.24E+01	0.0138	2.33E-02
4.13E+01	0.0141	2.60E-02
4.05E+01	0.0143	2.91E-02
3.96E+01	0.0145	3.23E-02
3.87E+01	0.0149	3.62E-02
3.77E+01	0.0154	4.00E-02
3.67E+01	0.016	4.44E-02
3.56E+01	0.0166	4.84E-02
3.46E+01	0.0172	5.21E-02
3.37E+01	0.0179	5.40E-02
3.30E+01	0.0185	5.56E-02
3.22E+01	0.0191	5.63E-02
3.15E+01	0.0198	5.70E-02
3.06E+01	0.0206	5.78E-02
2.98E+01	0.0212	5.88E-02
2.90E+01	0.0218	5.99E-02
2.83E+01	0.0224	6.11E-02
2.77E+01	0.0229	6.26E-02
2.71E+01	0.0234	6.46E-02
2.66E+01	0.0239	6.76E-02
2.61E+01	0.0246	7.25E-02
2.55E+01	0.0253	7.79E-02
2.50E+01	0.026	8.50E-02
2.45E+01	0.0268	9.17E-02
2.40E+01	0.0275	9.78E-02
2.37E+01	0.0283	1.03E-01
2.33E+01	0.0291	1.09E-01
2.29E+01	0.03	1.15E-01
2.24E+01	0.0311	1.21E-01
2.20E+01	0.0322	1.28E-01
2.16E+01	0.0333	1.34E-01
2.12E+01	0.0343	1.39E-01
2.08E+01	0.0355	1.44E-01
2.04E+01	0.0367	1.47E-01
2.00E+01	0.038	1.53E-01
1.96E+01	0.0395	1.58E-01
1.92E+01	0.041	1.64E-01
1.88E+01	0.0425	1.68E-01
1.85E+01	0.0438	1.70E-01
1.81E+01	0.0452	1.70E-01
1.78E+01	0.0466	1.70E-01
1.75E+01	0.0481	1.69E-01
1.72E+01	0.0495	1.69E-01
1.69E+01	0.0509	1.68E-01
1.66E+01	0.0521	1.68E-01

1.63E+01	0.0531	1.64E-01
1.60E+01	0.0542	1.60E-01
1.58E+01	0.0553	1.55E-01
1.55E+01	0.0565	1.53E-01
1.53E+01	0.0577	1.51E-01
1.50E+01	0.0588	1.51E-01
1.48E+01	0.0598	1.51E-01
1.45E+01	0.0606	1.49E-01
1.44E+01	0.0615	1.47E-01
1.42E+01	0.0623	1.44E-01
1.40E+01	0.0632	1.41E-01
1.38E+01	0.0642	1.40E-01
1.36E+01	0.065	1.39E-01
1.34E+01	0.0657	1.38E-01
1.33E+01	0.0664	1.35E-01
1.31E+01	0.067	1.33E-01
1.30E+01	0.0677	1.30E-01
1.28E+01	0.0683	1.27E-01
1.27E+01	0.069	1.25E-01
1.25E+01	0.0697	1.22E-01
1.23E+01	0.0703	1.20E-01
1.22E+01	0.0709	1.16E-01
1.21E+01	0.0715	1.13E-01
1.19E+01	0.072	1.10E-01
1.18E+01	0.0725	1.06E-01
1.17E+01	0.073	1.03E-01
1.15E+01	0.0735	1.00E-01

1.14E+01	0.0739	9.74E-02
1.13E+01	0.0743	9.41E-02
1.12E+01	0.0747	9.26E-02
1.11E+01	0.0751	9.15E-02
1.10E+01	0.0756	9.15E-02
1.08E+01	0.076	9.11E-02
1.07E+01	0.0763	9.12E-02
1.06E+01	0.0767	9.10E-02
1.05E+01	0.0771	9.20E-02
1.04E+01	0.0776	9.11E-02
1.03E+01	0.078	8.96E-02
1.02E+01	0.0784	8.90E-02
1.01E+01	0.0788	9.05E-02
9.99E+00	0.0792	9.10E-02
9.89E+00	0.0795	9.09E-02
9.80E+00	0.0799	8.98E-02
9.70E+00	0.0802	8.98E-02
9.61E+00	0.0806	9.01E-02
9.52E+00	0.0811	9.09E-02
9.42E+00	0.0815	9.08E-02
9.33E+00	0.0818	9.23E-02
9.25E+00	0.0822	9.31E-02
9.17E+00	0.0825	9.36E-02
9.09E+00	0.0829	9.18E-02
9.01E+00	0.0832	8.98E-02
8.94E+00	0.0836	8.74E-02
8.86E+00	0.0839	8.69E-02

8.79E+00	0.0842	8.61E-02
8.72E+00	0.0845	8.41E-02
8.66E+00	0.0847	8.21E-02
8.59E+00	0.085	8.13E-02
8.53E+00	0.0852	7.92E-02
8.47E+00	0.0855	7.89E-02
8.40E+00	0.0857	7.91E-02
8.34E+00	0.086	7.93E-02
8.28E+00	0.0863	7.91E-02
8.22E+00	0.0865	8.00E-02
8.16E+00	0.0868	7.84E-02
8.10E+00	0.0871	7.73E-02
8.04E+00	0.0873	7.70E-02
7.97E+00	0.0876	7.55E-02
7.91E+00	0.0878	7.30E-02
7.85E+00	0.0881	7.05E-02
7.79E+00	0.0883	6.77E-02
7.73E+00	0.0885	6.38E-02
7.66E+00	0.0888	6.13E-02
7.60E+00	0.089	5.92E-02
7.53E+00	0.0891	5.62E-02
7.47E+00	0.0893	5.51E-02
7.41E+00	0.0895	5.33E-02
7.35E+00	0.0897	5.06E-02
7.30E+00	0.0899	4.90E-02
7.24E+00	0.09	4.83E-02
7.19E+00	0.0902	4.82E-02

7.13E+00	0.0903	4.74E-02
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7.03E+00	0.0906	4.65E-02
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6.13E+00	0.0937	6.44E-02
6.08E+00	0.094	6.52E-02
6.03E+00	0.0942	6.71E-02
5.97E+00	0.0945	6.69E-02
5.92E+00	0.0948	6.71E-02
5.87E+00	0.095	6.73E-02

5.82E+00	0.0953	6.57E-02
5.77E+00	0.0955	6.38E-02
5.72E+00	0.0958	6.18E-02
5.67E+00	0.096	6.00E-02
5.62E+00	0.0962	5.70E-02
5.57E+00	0.0964	5.51E-02
5.53E+00	0.0966	5.34E-02
5.48E+00	0.0968	5.11E-02
5.44E+00	0.097	4.93E-02
5.39E+00	0.0971	4.74E-02
5.35E+00	0.0973	4.57E-02
5.30E+00	0.0974	4.46E-02
5.26E+00	0.0976	4.45E-02
5.22E+00	0.0977	4.50E-02
5.18E+00	0.0979	4.45E-02
5.14E+00	0.098	4.43E-02
5.10E+00	0.0982	4.44E-02
5.06E+00	0.0983	4.27E-02
5.03E+00	0.0985	4.12E-02
4.99E+00	0.0986	4.03E-02
4.96E+00	0.0987	3.91E-02
4.93E+00	0.0988	3.86E-02
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4.70E+00	0.0995	3.43E-02
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4.60E+00	0.0998	3.73E-02
4.57E+00	0.0999	3.71E-02
4.54E+00	0.1001	3.70E-02
4.50E+00	0.1002	3.70E-02
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4.27E+00	0.101	3.70E-02
4.23E+00	0.1012	3.70E-02
4.18E+00	0.1014	3.74E-02
4.14E+00	0.1016	3.78E-02
4.09E+00	0.1017	3.82E-02
4.04E+00	0.1019	3.90E-02
3.99E+00	0.1022	3.95E-02
3.94E+00	0.1024	3.99E-02
3.89E+00	0.1026	4.02E-02
3.84E+00	0.1028	4.07E-02
3.79E+00	0.1031	4.11E-02
3.74E+00	0.1033	4.12E-02
3.70E+00	0.1035	4.11E-02

3.65E+00	0.1038	4.09E-02
3.61E+00	0.104	4.06E-02
3.56E+00	0.1042	4.03E-02
3.52E+00	0.1044	3.98E-02
3.47E+00	0.1046	3.93E-02
3.43E+00	0.1048	3.87E-02
3.39E+00	0.105	3.80E-02
3.35E+00	0.1052	3.73E-02
3.31E+00	0.1054	3.67E-02
3.26E+00	0.1056	3.61E-02
3.22E+00	0.1058	3.57E-02
3.18E+00	0.106	3.53E-02
3.14E+00	0.1062	3.51E-02
3.10E+00	0.1064	3.49E-02
3.06E+00	0.1066	3.48E-02
3.02E+00	0.1068	3.47E-02
2.98E+00	0.107	3.46E-02
2.94E+00	0.1072	3.46E-02
2.90E+00	0.1074	3.46E-02
2.86E+00	0.1077	3.46E-02
2.82E+00	0.1079	3.44E-02
2.78E+00	0.1081	3.42E-02
2.74E+00	0.1083	3.41E-02
2.70E+00	0.1085	3.39E-02
2.66E+00	0.1087	3.36E-02
2.62E+00	0.109	3.34E-02
2.58E+00	0.1092	3.31E-02

2.54E+00	0.1094	3.28E-02
2.50E+00	0.1096	3.25E-02
2.46E+00	0.1098	3.22E-02
2.42E+00	0.11	3.19E-02
2.38E+00	0.1103	3.17E-02
2.34E+00	0.1105	3.15E-02
2.31E+00	0.1107	3.13E-02
2.27E+00	0.1109	3.12E-02
2.23E+00	0.1111	3.10E-02
2.19E+00	0.1114	3.08E-02
2.16E+00	0.1116	3.07E-02
2.12E+00	0.1118	3.06E-02
2.08E+00	0.1121	3.05E-02
2.05E+00	0.1123	3.03E-02
2.01E+00	0.1125	3.03E-02
1.98E+00	0.1127	3.03E-02
1.94E+00	0.113	3.02E-02
1.91E+00	0.1132	3.02E-02
1.88E+00	0.1134	3.03E-02
1.84E+00	0.1137	3.04E-02
1.81E+00	0.1139	3.07E-02
1.78E+00	0.1141	3.10E-02
1.75E+00	0.1144	3.12E-02
1.71E+00	0.1146	3.15E-02
1.68E+00	0.1149	3.18E-02
1.65E+00	0.1151	3.21E-02
1.62E+00	0.1154	3.24E-02

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1.56E+00	0.1159	3.29E-02
1.54E+00	0.1162	3.30E-02
1.51E+00	0.1165	3.31E-02
1.48E+00	0.1167	3.31E-02
1.45E+00	0.117	3.31E-02
1.43E+00	0.1173	3.31E-02
1.40E+00	0.1175	3.31E-02
1.37E+00	0.1178	3.31E-02
1.35E+00	0.1181	3.31E-02
1.32E+00	0.1183	3.31E-02
1.30E+00	0.1186	3.30E-02
1.28E+00	0.1189	3.30E-02
1.25E+00	0.1191	3.32E-02
1.23E+00	0.1194	3.33E-02
1.21E+00	0.1196	3.35E-02
1.19E+00	0.1199	3.37E-02
1.17E+00	0.1202	3.39E-02
1.14E+00	0.1204	3.40E-02
1.12E+00	0.1207	3.42E-02
1.10E+00	0.121	3.44E-02
1.08E+00	0.1213	3.47E-02
1.07E+00	0.1215	3.51E-02
1.05E+00	0.1218	3.56E-02
1.03E+00	0.1221	3.60E-02
1.01E+00	0.1223	3.66E-02
9.92E-01	0.1226	3.72E-02

9.74E-01	0.1229	3.80E-02
9.58E-01	0.1232	3.89E-02
9.41E-01	0.1235	3.99E-02
9.25E-01	0.1238	4.11E-02
9.09E-01	0.1241	4.24E-02
8.93E-01	0.1244	4.37E-02
8.78E-01	0.1248	4.50E-02
8.63E-01	0.1251	4.62E-02
8.49E-01	0.1255	4.74E-02
8.35E-01	0.1258	4.88E-02
8.21E-01	0.1262	5.01E-02
8.07E-01	0.1266	5.14E-02
7.94E-01	0.1269	5.27E-02
7.81E-01	0.1273	5.39E-02
7.68E-01	0.1277	5.49E-02
7.56E-01	0.1281	5.59E-02
7.44E-01	0.1285	5.70E-02
7.32E-01	0.1289	5.80E-02
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6.37E-01	0.1328	6.73E-02

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6.19E-01	0.1336	6.90E-02
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5.68E-01	0.1363	7.08E-02
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5.11E-01	0.1395	6.76E-02
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4.98E-01	0.1402	6.69E-02
4.92E-01	0.1406	6.66E-02
4.85E-01	0.1409	6.65E-02
4.79E-01	0.1413	6.61E-02
4.74E-01	0.1416	6.59E-02
4.68E-01	0.142	6.56E-02
4.62E-01	0.1423	6.52E-02
4.57E-01	0.1427	6.47E-02
4.51E-01	0.143	6.42E-02
4.46E-01	0.1434	6.35E-02

4.41E-01	0.1437	6.28E-02
4.36E-01	0.144	6.19E-02
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3.98E-01	0.1462	5.46E-02
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3.81E-01	0.1472	5.28E-02
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3.73E-01	0.1477	5.23E-02
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3.65E-01	0.1482	5.17E-02
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3.57E-01	0.1487	5.10E-02
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3.47E-01	0.1494	4.99E-02
3.43E-01	0.1496	4.93E-02
3.39E-01	0.1498	4.87E-02
3.36E-01	0.15	4.80E-02
3.33E-01	0.1502	4.72E-02

3.29E-01	0.1504	4.65E-02
3.26E-01	0.1507	4.57E-02
3.22E-01	0.1509	4.48E-02
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3.16E-01	0.1512	4.25E-02
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3.09E-01	0.1516	4.01E-02
3.06E-01	0.1518	3.90E-02
3.03E-01	0.152	3.77E-02
3.00E-01	0.1521	3.66E-02
2.97E-01	0.1523	3.56E-02
2.93E-01	0.1524	3.45E-02
2.90E-01	0.1526	3.34E-02
2.87E-01	0.1528	3.25E-02
2.84E-01	0.1529	3.16E-02
2.80E-01	0.1531	3.08E-02
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2.71E-01	0.1535	2.87E-02
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2.57E-01	0.1541	2.59E-02
2.54E-01	0.1543	2.53E-02
2.51E-01	0.1544	2.46E-02
2.47E-01	0.1545	2.40E-02
2.44E-01	0.1547	2.34E-02

2.40E-01	0.1548	2.26E-02
2.37E-01	0.155	2.17E-02
2.34E-01	0.1551	2.10E-02
2.30E-01	0.1552	2.01E-02
2.26E-01	0.1554	1.93E-02
2.23E-01	0.1555	1.84E-02
2.19E-01	0.1556	1.76E-02
2.16E-01	0.1557	1.67E-02
2.12E-01	0.1558	1.58E-02
2.09E-01	0.1559	1.50E-02
2.05E-01	0.156	1.43E-02
2.02E-01	0.1561	1.36E-02
1.98E-01	0.1562	1.32E-02
1.94E-01	0.1563	1.27E-02
1.91E-01	0.1564	1.24E-02
1.87E-01	0.1565	1.21E-02
1.84E-01	0.1566	1.18E-02
1.80E-01	0.1567	1.15E-02
1.76E-01	0.1568	1.12E-02
1.73E-01	0.1569	1.10E-02
1.69E-01	0.157	1.07E-02
1.65E-01	0.1571	1.04E-02
1.62E-01	0.1572	1.02E-02
1.58E-01	0.1573	9.78E-03
1.55E-01	0.1574	9.41E-03
1.51E-01	0.1575	9.04E-03
1.48E-01	0.1576	8.74E-03

1.44E-01	0.1577	8.53E-03
1.41E-01	0.1578	8.34E-03
1.38E-01	0.1578	8.17E-03
1.34E-01	0.1579	8.01E-03
1.31E-01	0.158	7.87E-03
1.28E-01	0.1581	7.73E-03
1.25E-01	0.1582	7.64E-03
1.21E-01	0.1583	7.64E-03
1.18E-01	0.1584	7.61E-03
1.15E-01	0.1584	7.64E-03
1.12E-01	0.1585	7.62E-03
1.09E-01	0.1586	7.55E-03
1.07E-01	0.1587	7.50E-03
1.04E-01	0.1588	7.46E-03
1.01E-01	0.1589	7.41E-03
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9.60E-02	0.159	7.44E-03
9.36E-02	0.1591	7.37E-03
9.12E-02	0.1592	7.29E-03
8.89E-02	0.1593	7.27E-03
8.66E-02	0.1594	7.22E-03
8.45E-02	0.1594	7.17E-03
8.23E-02	0.1595	7.10E-03
8.03E-02	0.1596	7.03E-03
7.83E-02	0.1597	6.96E-03
7.64E-02	0.1597	6.88E-03
7.45E-02	0.1598	6.76E-03

7.26E-02	0.1599	6.63E-03
7.08E-02	0.16	6.57E-03
6.91E-02	0.16	6.47E-03
6.74E-02	0.1601	6.29E-03
6.58E-02	0.1602	6.10E-03
6.42E-02	0.1602	5.92E-03
6.27E-02	0.1603	5.86E-03
6.11E-02	0.1604	5.75E-03
5.97E-02	0.1604	5.62E-03
5.82E-02	0.1605	5.49E-03
5.68E-02	0.1605	5.38E-03
5.55E-02	0.1606	5.29E-03
5.42E-02	0.1606	5.21E-03
5.29E-02	0.1607	5.20E-03
5.16E-02	0.1607	5.22E-03
5.04E-02	0.1608	5.32E-03
4.92E-02	0.1608	5.40E-03
4.80E-02	0.1609	5.32E-03
4.69E-02	0.161	5.31E-03
4.58E-02	0.161	5.33E-03
4.48E-02	0.1611	5.32E-03
4.37E-02	0.1611	5.29E-03
4.27E-02	0.1612	5.20E-03
4.18E-02	0.1612	5.08E-03
4.08E-02	0.1613	4.87E-03
3.99E-02	0.1613	4.64E-03
3.90E-02	0.1614	4.29E-03

3.81E-02	0.1614	3.92E-03
3.73E-02	0.1615	3.64E-03
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3.34E-02	0.1616	1.90E-03
3.27E-02	0.1616	1.64E-03
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3.13E-02	0.1616	1.25E-03
3.06E-02	0.1616	1.17E-03
3.00E-02	0.1616	1.15E-03
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2.19E-02	0.1618	1.05E-03

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1.95E-02	0.1618	2.10E-04
1.92E-02	0.1618	1.40E-04
1.88E-02	0.1618	8.20E-05
1.85E-02	0.1618	3.54E-05
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1.78E-02	0.1618	0.00E+00
1.75E-02	0.1618	0.00E+00
1.72E-02	0.1618	0.00E+00
1.69E-02	0.1618	0.00E+00
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1.46E-02	0.1618	0.00E+00
1.44E-02	0.1618	0.00E+00
1.42E-02	0.1618	0.00E+00
1.40E-02	0.1618	0.00E+00
1.38E-02	0.1618	0.00E+00

1.36E-02	0.1618	0.00E+00
1.34E-02	0.1618	0.00E+00
1.32E-02	0.1618	0.00E+00
1.30E-02	0.1618	0.00E+00
1.28E-02	0.1618	0.00E+00
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1.09E-02	0.1618	0.00E+00
1.08E-02	0.1618	0.00E+00
1.07E-02	0.1618	0.00E+00
1.05E-02	0.1618	0.00E+00
1.04E-02	0.1618	0.00E+00
1.03E-02	0.1618	0.00E+00
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1.00E-02	0.1618	0.00E+00
9.90E-03	0.1618	0.00E+00
9.78E-03	0.1618	0.00E+00
9.67E-03	0.1618	0.00E+00

9.55E-03	0.1618	0.00E+00
9.44E-03	0.1618	0.00E+00
9.34E-03	0.1618	0.00E+00
9.23E-03	0.1618	0.00E+00
9.13E-03	0.1618	0.00E+00
9.02E-03	0.1618	0.00E+00
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8.73E-03	0.1618	0.00E+00
8.63E-03	0.1618	0.00E+00
8.54E-03	0.1618	0.00E+00
8.45E-03	0.1618	0.00E+00
8.36E-03	0.1618	0.00E+00
8.27E-03	0.1618	0.00E+00
8.18E-03	0.1618	0.00E+00
8.10E-03	0.1618	0.00E+00
8.01E-03	0.1618	0.00E+00
7.93E-03	0.1618	0.00E+00
7.85E-03	0.1618	0.00E+00
7.77E-03	0.1618	0.00E+00
7.69E-03	0.1618	0.00E+00
7.61E-03	0.1618	0.00E+00
7.54E-03	0.1618	0.00E+00
7.46E-03	0.1618	0.00E+00
7.39E-03	0.1618	0.00E+00
7.32E-03	0.1618	0.00E+00
7.25E-03	0.1618	0.00E+00

7.18E-03	0.1618	0.00E+00
7.11E-03	0.1618	0.00E+00
7.04E-03	0.1618	0.00E+00
6.97E-03	0.1618	0.00E+00
6.90E-03	0.1618	0.00E+00
6.84E-03	0.1618	0.00E+00
6.77E-03	0.1618	0.00E+00
6.71E-03	0.1618	0.00E+00
6.64E-03	0.1618	0.00E+00
6.58E-03	0.1618	0.00E+00
6.51E-03	0.1618	0.00E+00
6.42E-03	0.1618	0.00E+00

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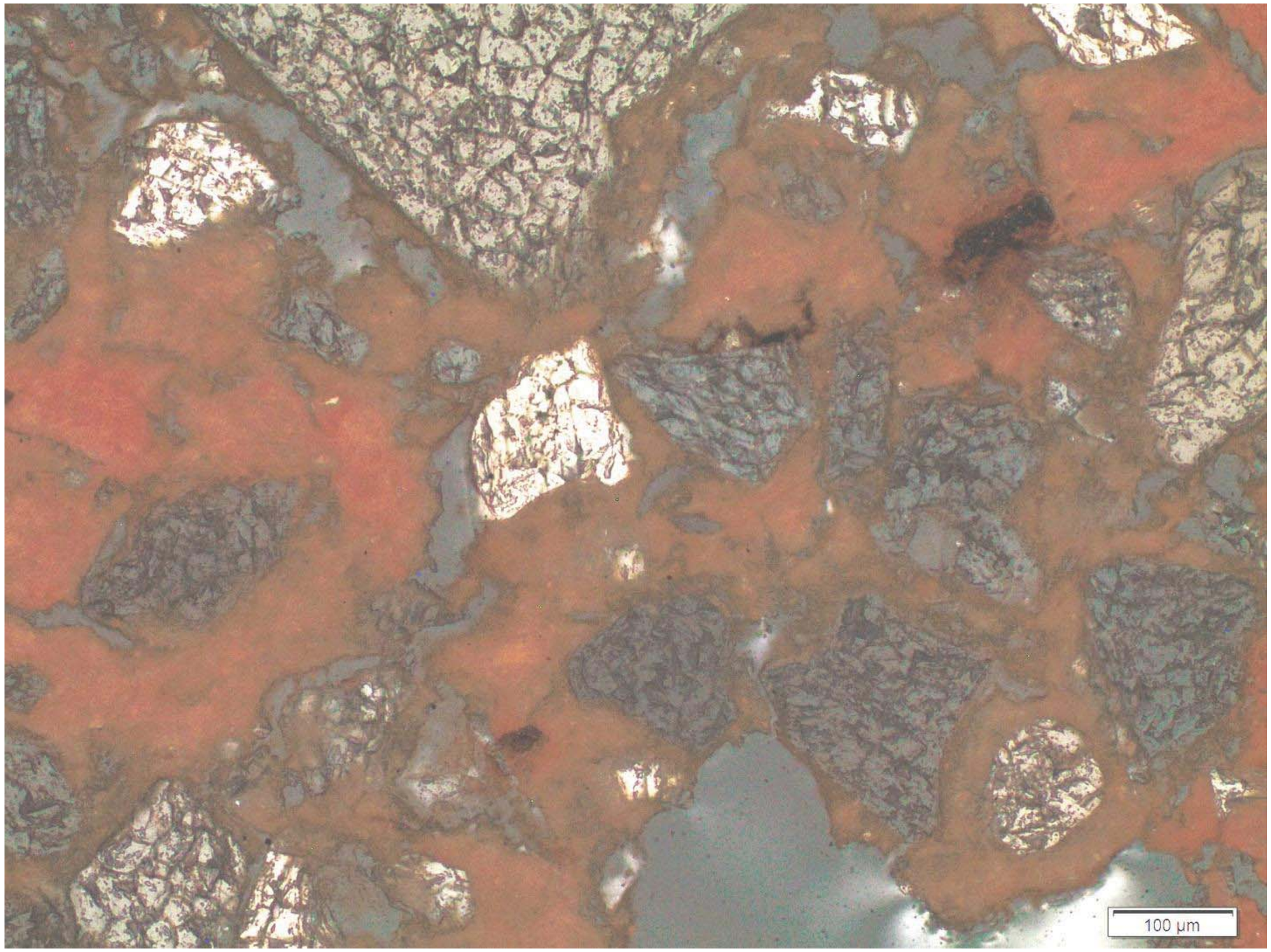
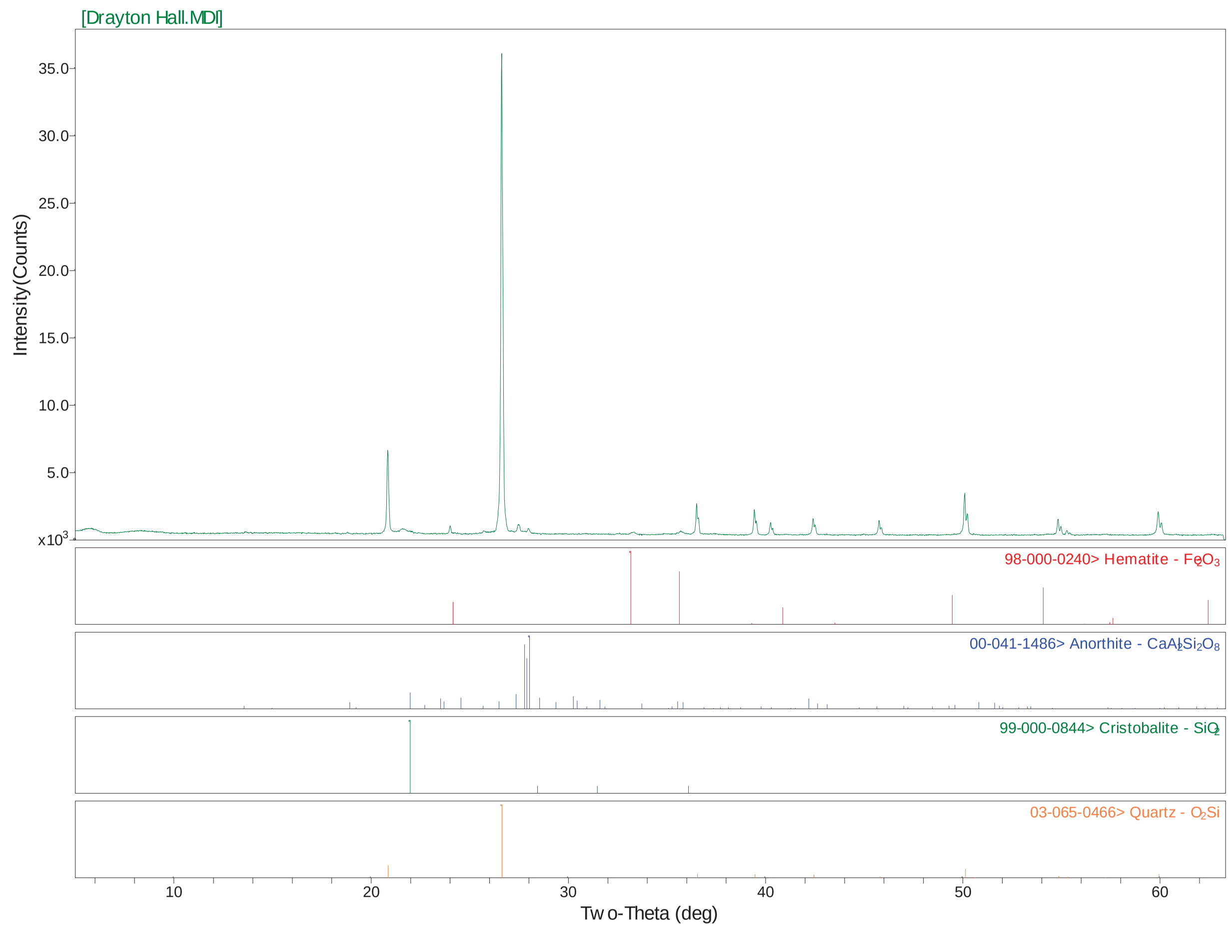


Standard Petrographic Thin Section result for Lord Ashley sample. The lab work was compiled at the National Petrographic Lab.

Appendix E- Drayton Hall 1118 Results

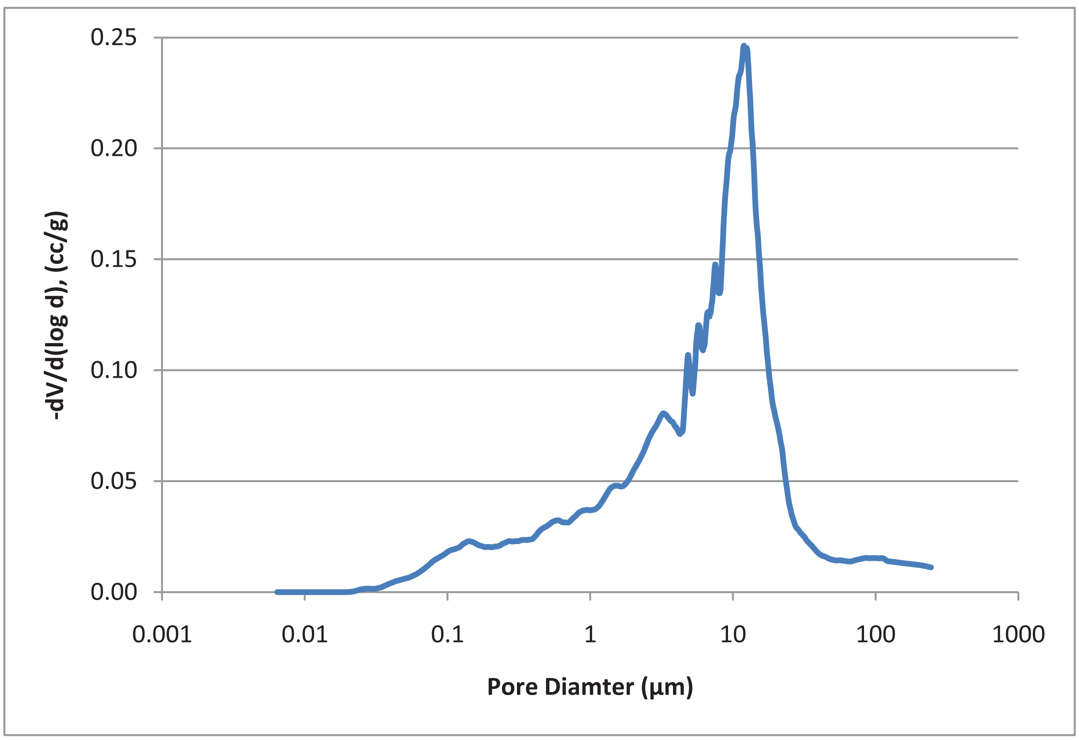


XRD results for Drayton 1118 sample. The minerals present are listed under the graph. The lab work was compiled at the National Brick Research Center.

LOI	0.81	%
Chemisry (Oxidized Basis)		
Major Constituents		1118- Drayton Hall
Al2O3	%	9.16
SiO2	%	83.78
Na2O	%	<0.5
K2O	%	0.81
MgO	%	<0.2
CaO	%	0.80
TiO2	%	0.97
MnO	%	0.04
Fe2O3	%	3.57
P2O5	%	0.17
S	%	<0.05
Sum of Major Constituents	%	99.30
Minor Constituents		
Cl	ppm	<250
V	ppm	<150
Cr	ppm	<50
Ni	ppm	<10
Cu	ppm	55
Zn	ppm	<20
As	ppm	26
Rb	ppm	<30
Sr	ppm	152
Zr	ppm	265
Ba	ppm	430
Pb	ppm	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI		

Chemistry/ XRF and Loss of Ignition results for Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center.

Property	Unit	
Total Intrusion Volume	ml/g	0.189
Median Pore Diameter	microns	7.698
Bulk Density	g/cc	1.72
Apparent Density	g/cc	1.84
Porosity	%	32.49
Pores >3 Microns	%	70.99
Maage Index		187.27
Pores >10 Microns	%	39.70
Pores 10-1 Microns	%	44.48
Pores <1 Microns	%	15.82



Mercury Intrusion results for Drayton Hall 1118 sample. (Following table is the raw pore size data) The lab work was compiled at the National Brick Research Center.

Raw Pore Size Data		
Pore Diameter	Volume Intruded	Delta Volume
244.10	0	1.12E-02
210.10	0.0009	1.21E-02
171.80	0.0019	1.27E-02
146.00	0.0028	1.33E-02
130.60	0.0035	1.37E-02
121.20	0.004	1.40E-02
112.50	0.0045	1.53E-02
105.30	0.0051	1.52E-02
99.37	0.0055	1.54E-02
94.19	0.0059	1.53E-02
89.49	0.0063	1.53E-02
85.13	0.0066	1.54E-02
81.05	0.0069	1.52E-02
77.20	0.0071	1.49E-02
73.63	0.0074	1.46E-02
70.32	0.0077	1.42E-02
67.28	0.008	1.38E-02
64.49	0.0083	1.38E-02
61.78	0.0085	1.40E-02
59.17	0.0088	1.42E-02
56.73	0.009	1.44E-02
54.50	0.0093	1.43E-02
52.49	0.0095	1.43E-02
50.67	0.0097	1.45E-02

49.05	0.0099	1.47E-02
47.57	0.0101	1.50E-02
46.20	0.0103	1.53E-02
44.86	0.0105	1.58E-02
43.45	0.0107	1.62E-02
42.03	0.011	1.65E-02
40.68	0.0112	1.70E-02
39.45	0.0114	1.77E-02
38.35	0.0117	1.85E-02
37.38	0.0119	1.94E-02
36.53	0.0121	2.01E-02
35.68	0.0123	2.09E-02
34.79	0.0125	2.16E-02
33.83	0.0128	2.24E-02
32.84	0.0131	2.33E-02
31.91	0.0134	2.46E-02
31.07	0.0137	2.54E-02
30.33	0.014	2.62E-02
29.68	0.0142	2.68E-02
29.06	0.0145	2.77E-02
28.41	0.0148	2.85E-02
27.72	0.0151	2.92E-02
27.03	0.0154	3.08E-02
26.37	0.0157	3.31E-02
25.78	0.016	3.51E-02
25.26	0.0163	3.76E-02
24.80	0.0166	3.97E-02

24.36	0.0169	4.28E-02
23.90	0.0173	4.66E-02
23.44	0.0177	5.03E-02
23.00	0.0182	5.43E-02
22.60	0.0186	5.85E-02
22.25	0.019	6.29E-02
21.92	0.0195	6.57E-02
21.60	0.02	6.75E-02
21.30	0.0204	7.02E-02
21.01	0.0209	7.20E-02
20.70	0.0214	7.41E-02
20.39	0.0219	7.60E-02
20.10	0.0223	7.76E-02
19.82	0.0228	7.91E-02
19.56	0.0232	8.11E-02
19.28	0.0237	8.27E-02
19.00	0.0242	8.48E-02
18.74	0.0248	8.75E-02
18.48	0.0253	9.11E-02
18.23	0.0259	9.43E-02
17.98	0.0265	9.71E-02
17.73	0.0271	1.01E-01
17.48	0.0277	1.05E-01
17.25	0.0284	1.09E-01
17.03	0.029	1.14E-01
16.80	0.0296	1.18E-01
16.57	0.0304	1.22E-01

16.35	0.0311	1.25E-01
16.14	0.0318	1.29E-01
15.94	0.0326	1.34E-01
15.73	0.0334	1.39E-01
15.52	0.0342	1.46E-01
15.32	0.035	1.50E-01
15.13	0.0358	1.55E-01
14.95	0.0367	1.61E-01
14.75	0.0376	1.64E-01
14.56	0.0387	1.69E-01
14.38	0.0396	1.74E-01
14.21	0.0405	1.82E-01
14.04	0.0416	1.90E-01
13.86	0.0425	1.98E-01
13.69	0.0436	2.03E-01
13.52	0.0446	2.08E-01
13.37	0.0457	2.15E-01
13.21	0.047	2.22E-01
13.05	0.0482	2.28E-01
12.90	0.0494	2.34E-01
12.75	0.0506	2.40E-01
12.61	0.0518	2.44E-01
12.47	0.053	2.45E-01
12.34	0.0543	2.44E-01
12.20	0.0555	2.44E-01
12.06	0.0567	2.45E-01
11.94	0.0578	2.46E-01

11.81	0.059	2.45E-01
11.68	0.0601	2.41E-01
11.55	0.0612	2.38E-01
11.43	0.0623	2.36E-01
11.31	0.0634	2.35E-01
11.19	0.0645	2.34E-01
11.08	0.0655	2.33E-01
10.96	0.0665	2.32E-01
10.85	0.0675	2.30E-01
10.74	0.0686	2.27E-01
10.63	0.0696	2.24E-01
10.52	0.0707	2.20E-01
10.41	0.0717	2.18E-01
10.31	0.0726	2.17E-01
10.21	0.0735	2.15E-01
10.10	0.0744	2.13E-01
10.00	0.0752	2.10E-01
9.91	0.0761	2.07E-01
9.81	0.077	2.04E-01
9.72	0.0778	2.02E-01
9.62	0.0787	2.00E-01
9.53	0.0796	1.98E-01
9.44	0.0804	1.98E-01
9.35	0.0811	1.97E-01
9.27	0.0819	1.95E-01
9.19	0.0826	1.92E-01
9.11	0.0833	1.89E-01

9.03	0.084	1.85E-01
8.96	0.0847	1.83E-01
8.88	0.0854	1.80E-01
8.81	0.086	1.78E-01
8.74	0.0866	1.74E-01
8.68	0.0871	1.70E-01
8.62	0.0877	1.67E-01
8.55	0.0882	1.62E-01
8.49	0.0887	1.57E-01
8.42	0.0892	1.53E-01
8.36	0.0897	1.48E-01
8.30	0.0902	1.44E-01
8.24	0.0906	1.40E-01
8.19	0.091	1.37E-01
8.13	0.0914	1.35E-01
8.07	0.0918	1.35E-01
8.00	0.0922	1.35E-01
7.94	0.0926	1.35E-01
7.89	0.093	1.36E-01
7.82	0.0935	1.38E-01
7.76	0.094	1.39E-01
7.70	0.0945	1.42E-01
7.64	0.0951	1.44E-01
7.57	0.0956	1.47E-01
7.51	0.0962	1.48E-01
7.45	0.0967	1.46E-01
7.39	0.0972	1.43E-01

7.34	0.0977	1.40E-01
7.28	0.0982	1.37E-01
7.22	0.0986	1.35E-01
7.17	0.099	1.32E-01
7.11	0.0994	1.30E-01
7.06	0.0998	1.29E-01
7.01	0.1002	1.27E-01
6.96	0.1006	1.26E-01
6.90	0.101	1.25E-01
6.85	0.1014	1.24E-01
6.79	0.1019	1.25E-01
6.74	0.1024	1.26E-01
6.68	0.1028	1.26E-01
6.63	0.1033	1.26E-01
6.58	0.1037	1.25E-01
6.53	0.1041	1.22E-01
6.47	0.1046	1.20E-01
6.42	0.105	1.16E-01
6.37	0.1054	1.13E-01
6.32	0.1058	1.11E-01
6.27	0.1061	1.11E-01
6.22	0.1065	1.10E-01
6.16	0.1068	1.09E-01
6.11	0.1072	1.10E-01
6.06	0.1076	1.10E-01
6.01	0.108	1.12E-01
5.96	0.1085	1.14E-01

5.91	0.1089	1.16E-01
5.86	0.1094	1.19E-01
5.81	0.1098	1.20E-01
5.76	0.1103	1.20E-01
5.71	0.1108	1.20E-01
5.66	0.1112	1.18E-01
5.61	0.1117	1.17E-01
5.57	0.1121	1.14E-01
5.52	0.1125	1.11E-01
5.48	0.1129	1.06E-01
5.43	0.1132	1.02E-01
5.39	0.1136	9.96E-02
5.35	0.1139	9.68E-02
5.31	0.1142	9.41E-02
5.26	0.1145	9.16E-02
5.23	0.1147	8.95E-02
5.19	0.115	9.04E-02
5.15	0.1153	9.12E-02
5.12	0.1155	9.25E-02
5.08	0.1158	9.39E-02
5.05	0.116	9.70E-02
5.02	0.1164	1.01E-01
4.98	0.1167	1.01E-01
4.95	0.117	1.03E-01
4.91	0.1173	1.04E-01
4.88	0.1176	1.06E-01
4.85	0.118	1.07E-01

4.81	0.1183	1.06E-01
4.78	0.1187	1.03E-01
4.74	0.119	9.95E-02
4.71	0.1193	9.65E-02
4.67	0.1197	9.33E-02
4.64	0.1199	8.91E-02
4.61	0.1202	8.68E-02
4.57	0.1204	8.38E-02
4.54	0.1206	8.06E-02
4.51	0.1208	7.74E-02
4.48	0.1211	7.50E-02
4.45	0.1213	7.31E-02
4.42	0.1215	7.23E-02
4.39	0.1217	7.27E-02
4.36	0.1219	7.23E-02
4.33	0.1222	7.20E-02
4.29	0.1224	7.17E-02
4.26	0.1227	7.13E-02
4.22	0.1229	7.14E-02
4.18	0.1232	7.19E-02
4.14	0.1235	7.26E-02
4.10	0.1238	7.30E-02
4.06	0.1241	7.37E-02
4.02	0.1245	7.41E-02
3.97	0.1248	7.43E-02
3.93	0.1252	7.49E-02
3.89	0.1255	7.52E-02

3.85	0.1259	7.59E-02
3.80	0.1263	7.63E-02
3.76	0.1266	7.68E-02
3.72	0.127	7.70E-02
3.68	0.1274	7.71E-02
3.64	0.1277	7.73E-02
3.60	0.1281	7.78E-02
3.56	0.1285	7.83E-02
3.52	0.1289	7.86E-02
3.48	0.1292	7.89E-02
3.45	0.1296	7.94E-02
3.41	0.13	7.98E-02
3.37	0.1304	8.01E-02
3.34	0.1307	8.03E-02
3.30	0.1311	8.05E-02
3.27	0.1315	8.06E-02
3.23	0.1319	8.05E-02
3.20	0.1322	8.01E-02
3.16	0.1326	7.97E-02
3.13	0.133	7.93E-02
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3.06	0.1337	7.81E-02
3.03	0.1341	7.75E-02
3.00	0.1345	7.68E-02
2.96	0.1348	7.61E-02
2.93	0.1352	7.55E-02
2.89	0.1356	7.49E-02

2.86	0.136	7.44E-02
2.83	0.1363	7.40E-02
2.79	0.1367	7.34E-02
2.76	0.1371	7.29E-02
2.73	0.1375	7.23E-02
2.69	0.1379	7.18E-02
2.66	0.1382	7.11E-02
2.63	0.1386	7.04E-02
2.60	0.139	6.97E-02
2.56	0.1394	6.89E-02
2.53	0.1398	6.80E-02
2.50	0.1402	6.71E-02
2.47	0.1405	6.61E-02
2.43	0.1409	6.53E-02
2.40	0.1413	6.43E-02
2.37	0.1416	6.34E-02
2.34	0.142	6.26E-02
2.30	0.1424	6.18E-02
2.27	0.1427	6.10E-02
2.24	0.1431	6.02E-02
2.21	0.1435	5.95E-02
2.18	0.1438	5.87E-02
2.15	0.1442	5.81E-02
2.12	0.1446	5.73E-02
2.09	0.1449	5.66E-02
2.05	0.1453	5.59E-02
2.02	0.1456	5.52E-02

1.99	0.146	5.44E-02
1.96	0.1464	5.35E-02
1.93	0.1467	5.27E-02
1.91	0.1471	5.19E-02
1.88	0.1474	5.11E-02
1.85	0.1477	5.04E-02
1.82	0.1481	4.98E-02
1.79	0.1484	4.92E-02
1.76	0.1487	4.87E-02
1.74	0.149	4.82E-02
1.71	0.1494	4.79E-02
1.68	0.1497	4.77E-02
1.65	0.15	4.76E-02
1.63	0.1504	4.76E-02
1.60	0.1507	4.78E-02
1.58	0.151	4.79E-02
1.55	0.1514	4.80E-02
1.53	0.1517	4.80E-02
1.50	0.152	4.79E-02
1.48	0.1524	4.79E-02
1.45	0.1527	4.77E-02
1.43	0.1531	4.74E-02
1.41	0.1534	4.71E-02
1.38	0.1537	4.67E-02
1.36	0.1541	4.61E-02
1.34	0.1544	4.54E-02
1.32	0.1547	4.47E-02

1.30	0.155	4.39E-02
1.27	0.1553	4.31E-02
1.25	0.1557	4.23E-02
1.23	0.1559	4.15E-02
1.21	0.1562	4.08E-02
1.19	0.1565	4.02E-02
1.17	0.1568	3.95E-02
1.15	0.1571	3.89E-02
1.14	0.1573	3.84E-02
1.12	0.1576	3.80E-02
1.10	0.1579	3.76E-02
1.08	0.1581	3.74E-02
1.06	0.1584	3.71E-02
1.05	0.1587	3.71E-02
1.03	0.1589	3.70E-02
1.01	0.1592	3.69E-02
1.00	0.1595	3.69E-02
0.98	0.1597	3.70E-02
0.96	0.16	3.70E-02
0.95	0.1602	3.71E-02
0.93	0.1605	3.70E-02
0.92	0.1608	3.69E-02
0.90	0.161	3.69E-02
0.89	0.1613	3.68E-02
0.87	0.1615	3.66E-02
0.86	0.1618	3.64E-02
0.85	0.162	3.62E-02

0.83	0.1623	3.59E-02
0.82	0.1625	3.54E-02
0.81	0.1628	3.50E-02
0.80	0.163	3.45E-02
0.78	0.1632	3.41E-02
0.77	0.1635	3.37E-02
0.76	0.1637	3.33E-02
0.75	0.1639	3.29E-02
0.74	0.1641	3.25E-02
0.72	0.1643	3.20E-02
0.71	0.1646	3.16E-02
0.70	0.1648	3.14E-02
0.69	0.165	3.14E-02
0.68	0.1652	3.13E-02
0.67	0.1654	3.14E-02
0.66	0.1656	3.14E-02
0.65	0.1658	3.15E-02
0.64	0.166	3.15E-02
0.63	0.1662	3.16E-02
0.62	0.1664	3.18E-02
0.61	0.1666	3.22E-02
0.61	0.1668	3.23E-02
0.60	0.167	3.24E-02
0.59	0.1672	3.23E-02
0.58	0.1674	3.23E-02
0.57	0.1676	3.22E-02
0.56	0.1678	3.21E-02

0.55	0.168	3.19E-02
0.55	0.1682	3.17E-02
0.54	0.1684	3.15E-02
0.53	0.1686	3.12E-02
0.52	0.1688	3.09E-02
0.52	0.169	3.06E-02
0.51	0.1691	3.03E-02
0.50	0.1693	3.01E-02
0.50	0.1695	2.98E-02
0.49	0.1696	2.96E-02
0.49	0.1698	2.94E-02
0.48	0.1699	2.93E-02
0.47	0.1701	2.91E-02
0.47	0.1702	2.89E-02
0.46	0.1704	2.86E-02
0.46	0.1705	2.84E-02
0.45	0.1707	2.82E-02
0.45	0.1708	2.79E-02
0.44	0.171	2.75E-02
0.44	0.1711	2.72E-02
0.43	0.1713	2.68E-02
0.43	0.1714	2.64E-02
0.42	0.1715	2.59E-02
0.42	0.1717	2.55E-02
0.41	0.1718	2.51E-02
0.41	0.1719	2.48E-02
0.40	0.1721	2.44E-02

0.40	0.1722	2.41E-02
0.39	0.1723	2.39E-02
0.39	0.1725	2.38E-02
0.38	0.1726	2.37E-02
0.37	0.1727	2.36E-02
0.37	0.1729	2.36E-02
0.36	0.173	2.36E-02
0.36	0.1732	2.35E-02
0.35	0.1734	2.35E-02
0.35	0.1735	2.35E-02
0.34	0.1737	2.35E-02
0.34	0.1738	2.36E-02
0.33	0.174	2.35E-02
0.33	0.1741	2.34E-02
0.32	0.1743	2.32E-02
0.32	0.1744	2.31E-02
0.31	0.1746	2.30E-02
0.31	0.1747	2.30E-02
0.30	0.1749	2.30E-02
0.30	0.175	2.30E-02
0.30	0.1751	2.29E-02
0.29	0.1753	2.29E-02
0.29	0.1754	2.28E-02
0.28	0.1755	2.28E-02
0.28	0.1757	2.28E-02
0.28	0.1758	2.29E-02
0.27	0.1759	2.30E-02

0.27	0.1761	2.30E-02
0.27	0.1762	2.29E-02
0.26	0.1763	2.27E-02
0.26	0.1765	2.25E-02
0.26	0.1766	2.24E-02
0.25	0.1767	2.22E-02
0.25	0.1769	2.20E-02
0.25	0.177	2.19E-02
0.24	0.1771	2.17E-02
0.24	0.1773	2.14E-02
0.24	0.1774	2.11E-02
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0.23	0.1776	2.08E-02
0.23	0.1778	2.07E-02
0.22	0.1779	2.06E-02
0.22	0.178	2.06E-02
0.22	0.1781	2.06E-02
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0.21	0.1784	2.04E-02
0.21	0.1785	2.03E-02
0.20	0.1786	2.03E-02
0.20	0.1788	2.03E-02
0.20	0.1789	2.03E-02
0.20	0.179	2.04E-02
0.19	0.1792	2.04E-02
0.19	0.1793	2.03E-02
0.19	0.1794	2.03E-02

0.18	0.1796	2.03E-02
0.18	0.1797	2.04E-02
0.18	0.1798	2.05E-02
0.18	0.18	2.07E-02
0.17	0.1801	2.08E-02
0.17	0.1803	2.09E-02
0.17	0.1804	2.11E-02
0.16	0.1806	2.12E-02
0.16	0.1807	2.14E-02
0.16	0.1808	2.17E-02
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0.15	0.1811	2.22E-02
0.15	0.1813	2.24E-02
0.15	0.1814	2.26E-02
0.15	0.1816	2.27E-02
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0.13	0.1829	2.18E-02
0.13	0.183	2.16E-02
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0.12	0.1833	2.09E-02

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0.09	0.1859	1.59E-02
0.09	0.186	1.57E-02
0.09	0.1861	1.54E-02
0.08	0.1863	1.52E-02
0.08	0.1864	1.49E-02

0.08	0.1865	1.47E-02
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0.08	0.1867	1.41E-02
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0.01	0.1894	0.00E+00
0.01	0.1894	0.00E+00
0.01	0.1894	0.00E+00
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0.01	0.1894	8.38E-07
0.01	0.1894	9.22E-07
0.01	0.1894	1.02E-06
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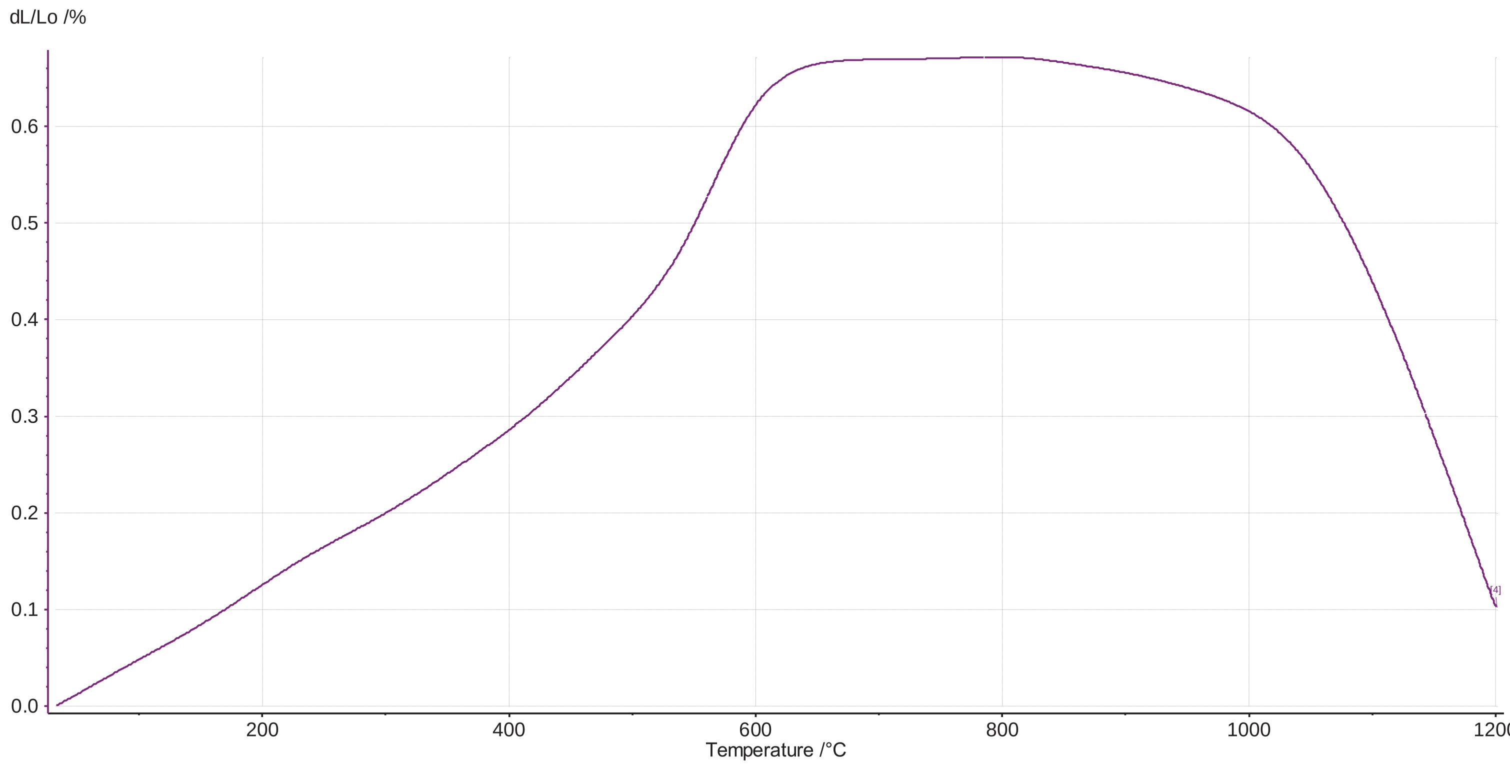
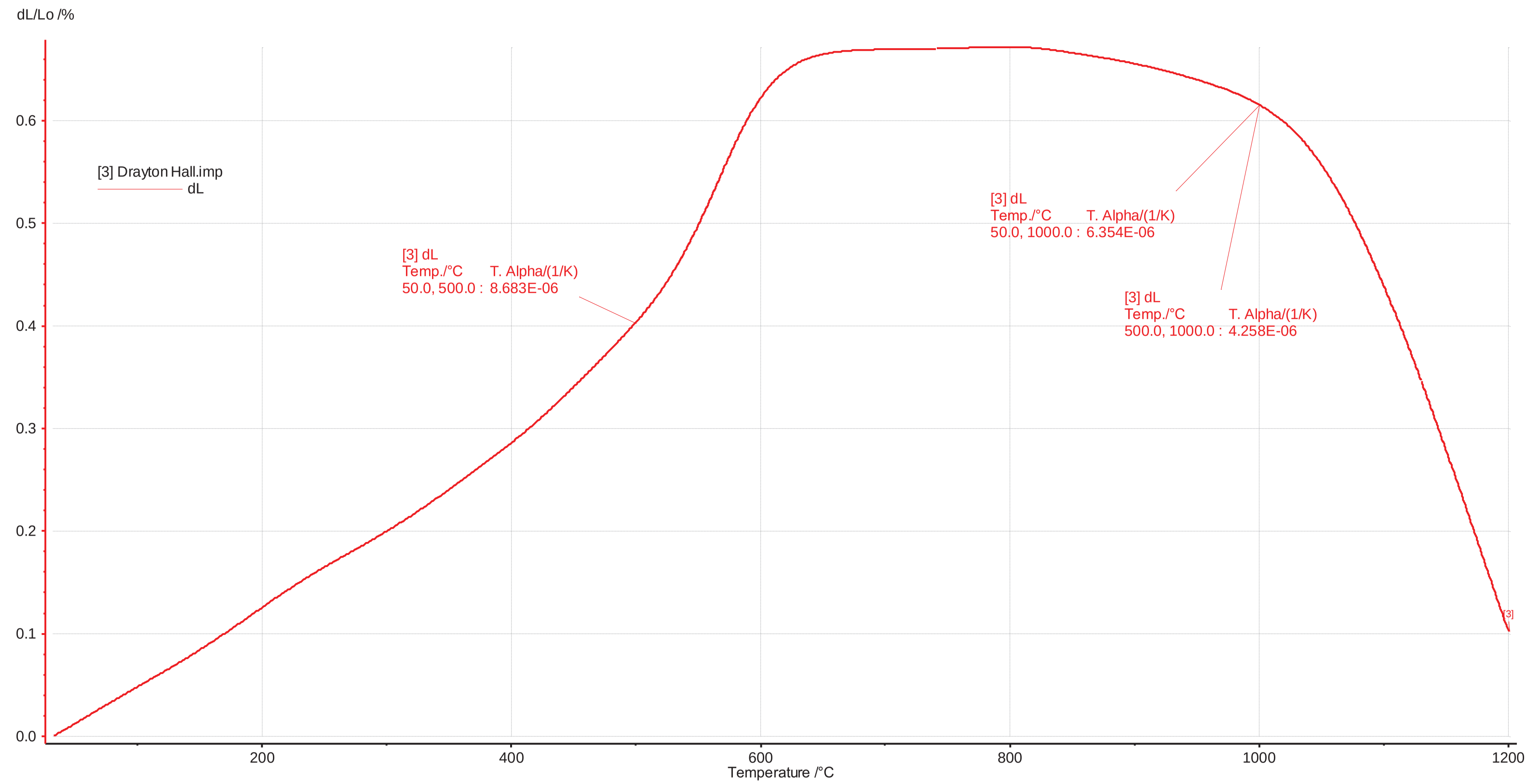
0.01	0.1894	1.32E-06

0.01	0.1894	1.54E-06

10.00	0.0752
3.00	0.1345
1.00	0.1594



Thermal Expansion curve from the Dilatometer for the Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center.



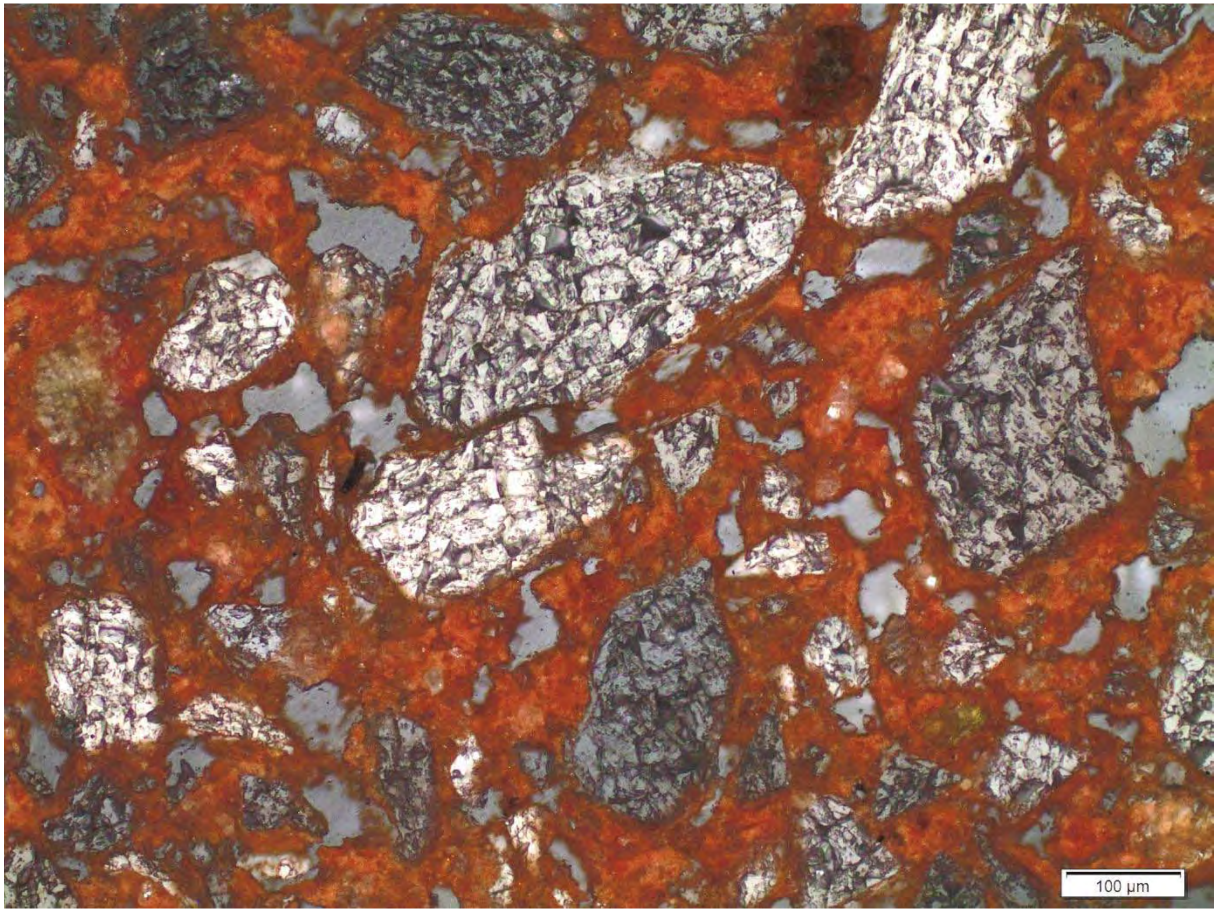
Thermal Expansion Coefficient from the Dilatometer for the Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center.

Sample #	Dry Weight (g)	24hr Cold Weight (g)	Boiled Weight	Suspended Weight	CWA (%)	BWA (%)	C/B	Bulk Density	Apparent Density	% Apparent Porosity
1	20.7851	23.524	24.6093	12.6624	13.18	18.40	0.72	1.74	2.56	32.01
2	26.158	29.7264	31.0485	16.1704	13.64	18.70	0.73	1.76	2.62	32.87
3	24.7729	28.2268	29.6569	15.2153	13.94	19.72	0.71	1.72	2.59	33.82
4	19.3052	21.9605	22.8892	11.876	13.75	18.56	0.74	1.75	2.60	32.54
5	26.4517	29.9923	31.3842	16.1548	13.39	18.65	0.72	1.74	2.57	32.39
				Average	13.58	18.80	0.72	1.74	2.59	32.73
				Std Dev	0.30	0.52	0.01	0.02	0.02	0.68

Archimedian Density and Porosity results for Drayton Hall 1118 sample. The lab work was compiled at the National Brick Research Center.

Run	L-value	a-value	b-value
1	48.4	22.56	28.7
2	48.7	23.08	29.89
3	48.53	23.21	29.66
Average	48.543333	22.95	29.41667
St Dev	0.1504438	0.343948	0.631216

Colorimeter results for Drayton Hall 1118 sample. Numbers can be compared to three-dimensional color chart. The lab work was compiled at the National Brick Research Center.

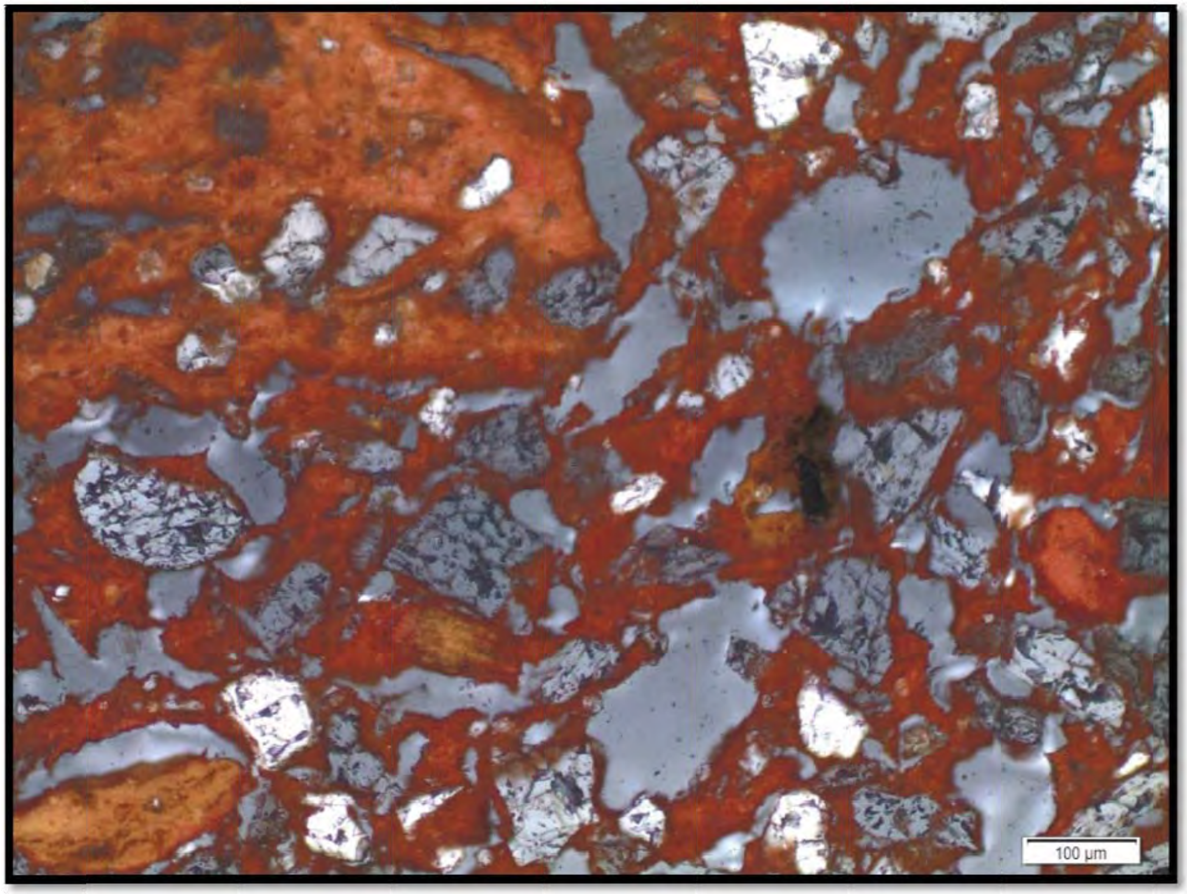


Standard Petrographic Thin Section results for Drayton Hall 1118 sample. The lab work was compiled at the National Petrographic Lab.

Appendix F- Drayton Hall: Pre-Drayton, Attic and North Flanker Results

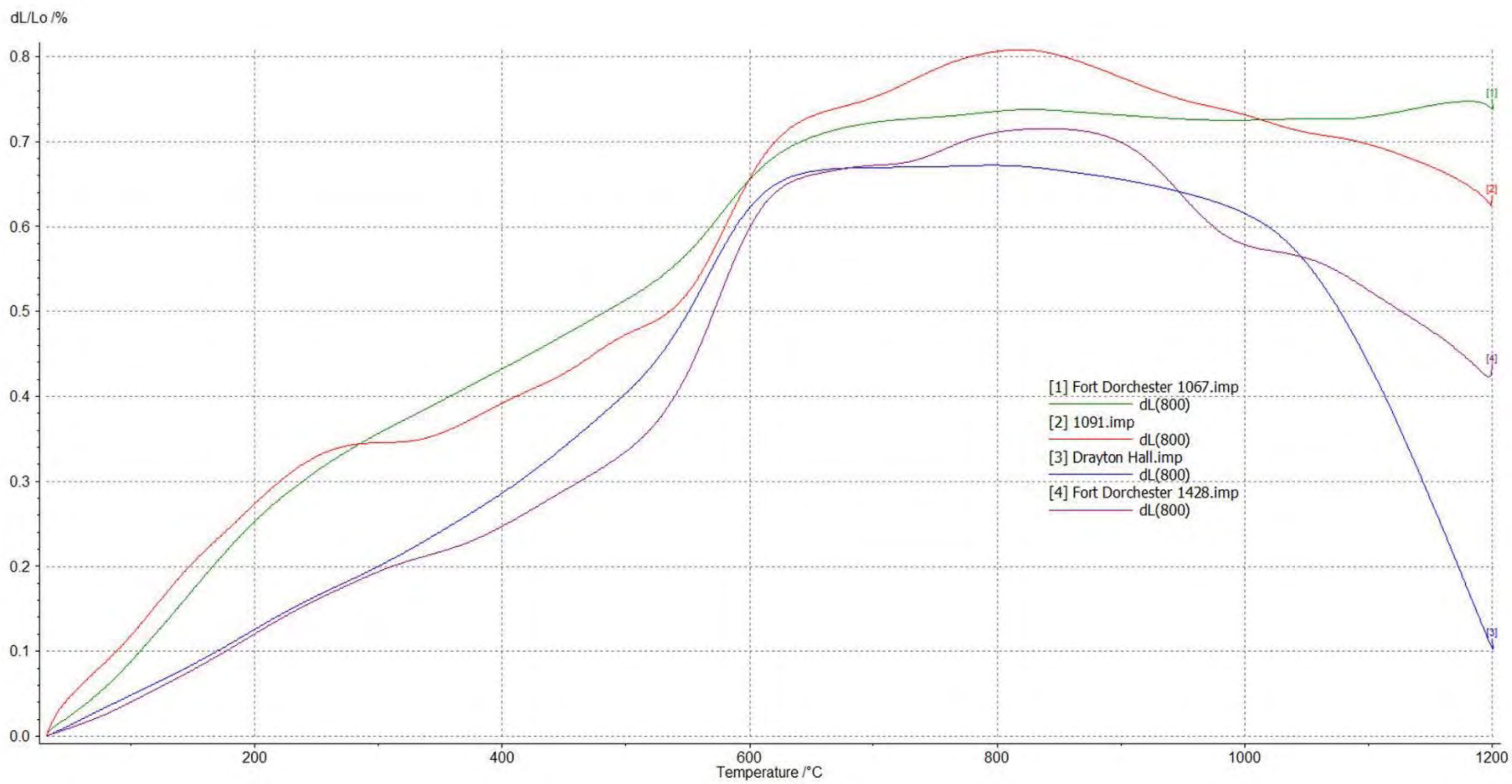
		Clay II	Pre Drayton House	Drayton Hall 1738 Attic	Drayton Hall North Flanker Wall
LOI	%	4.63	1.20	0.34	0.81
Chemistry (Oxidized Basis)					
Major Constituents		Clay II	Pre Drayton House	Drayton Hall 1738 Attic	Drayton Hall North Flanker Wall
Al2O3	%	9.06	11.24	8.08	10.37
SiO2	%	84.37	81.12	85.44	82.25
Na2O	%	<0.5	<0.5	<0.5	<0.5
K2O	%	0.23	1.35	0.80	0.69
MgO	%	<0.2	0.21	0.27	0.21
CaO	%	<0.01	0.33	0.44	0.66
TiO2	%	0.75	1.13	0.71	1.02
MnO	%	0.01	0.04	0.03	0.03
Fe2O3	%	5.05	3.99	3.45	4.06
P2O5	%	0.05	0.12	0.34	0.28
S	%	<0.05	<0.05	<0.05	<0.05
Sum of Major Constituents	%	99.53	99.52	99.56	99.57
Minor Constituents					
Cl	ppm	<250	<250	<250	<250
V	ppm	<150	<150	<150	<150
Cr	ppm	79	91	<50	102
Ni	ppm	<10	<10	<10	<10
Cu	ppm	<25	45	32	29
Zn	ppm	<20	<20	<20	<20
As	ppm	20	<20	26	<20
Rb	ppm	<30	<30	<30	<30
Sr	ppm	33	109	181	125
Zr	ppm	199	473	347	292
Ba	ppm	<200	560	320	350
Pb	ppm	<50	84	<50	<50
*Samples Oxidized and 950C and Fused. Results are normalized and do not include the LOI					

Chemistry/ XRF and Loss of Ignition results for four samples: Drayton Hall Attic, Pre-Drayton Hall house, Drayton Hall North Flanker and Colonial Dorchester clay. The lab work was compiled at the Brick Institute of America.

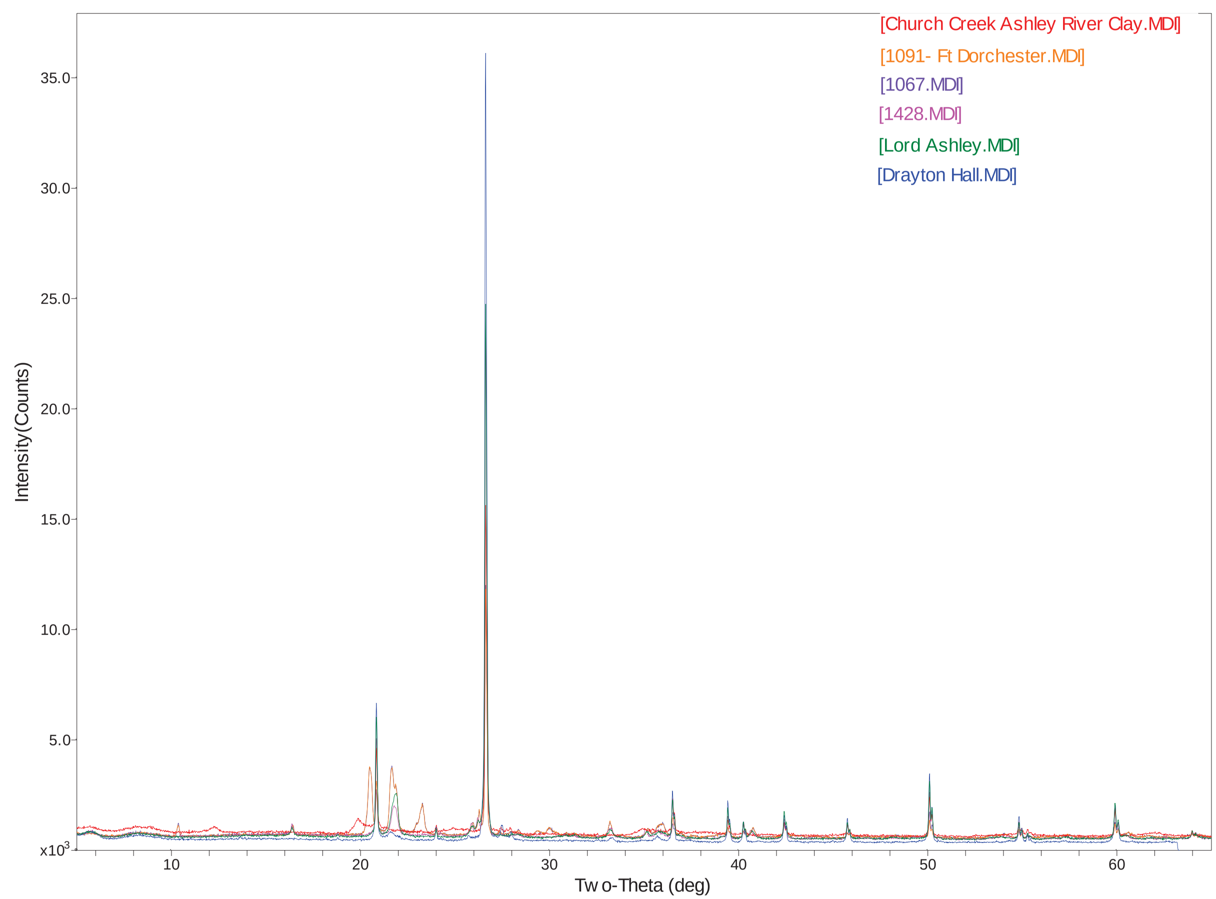


Standard Petrographic Thin Section results for Pre- Drayton Hall sample. The lab work was compiled at the National Petrographic Lab.

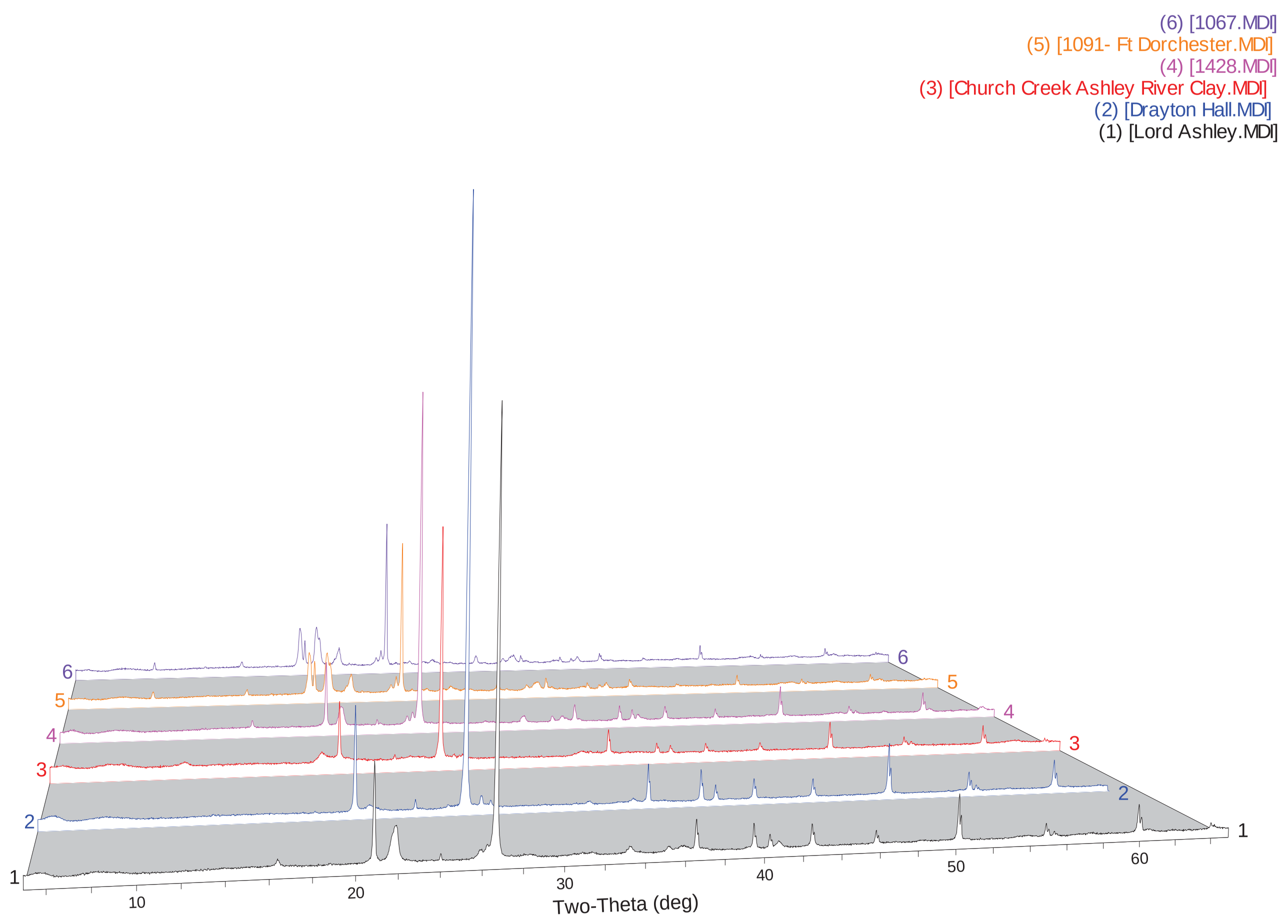
Appendix G- Compiled Results: Thermal Expansion and X-ray Diffraction



Dilatometer Results. Four samples: Fort Dorchester (green), Dorchester 1091 (red), Drayton Hall (blue), and Fort Dorchester 1428 (purple). The lab work was compiled at the National Brick Research Center.



X-ray Diffraction (XRD) results. An overlay of five bricks and one clay sample, as indicated in the key. The largest peak is quartz in all the samples. The rest of the peaks are other minerals common to ceramics and bricks. The lab work was compiled at the National Brick Research Center.



X-ray Diffraction (XRD) results. An overlay of five bricks and one clay sample that were tested. This view allow the difference between the five samples to easily be seen. The lab work was compiled at the National Brick Research Center.