# MORTAR ANALYSIS FOR ARCHAEOLOGICAL STRATIGRAPHY:
# THE STADT HUYS BLOCK AND SEVEN HANOVER SQUARE SITES

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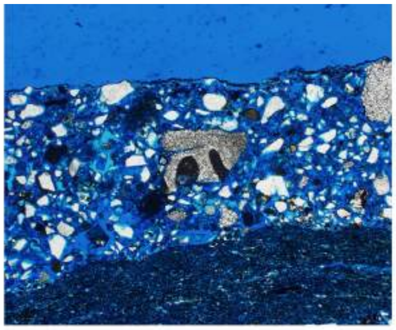
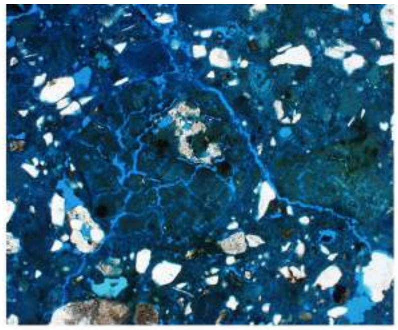
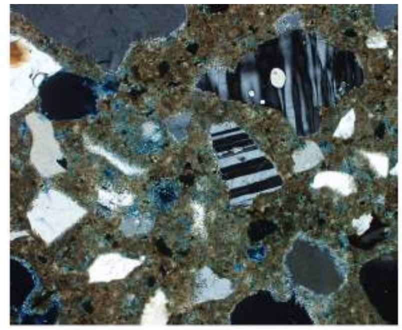
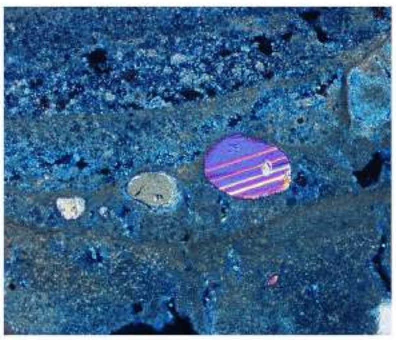
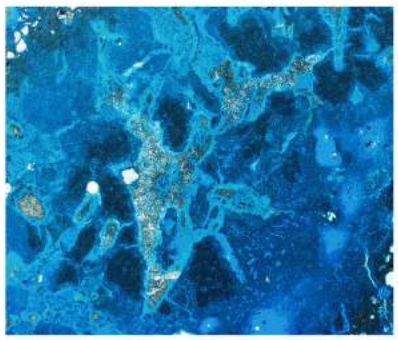
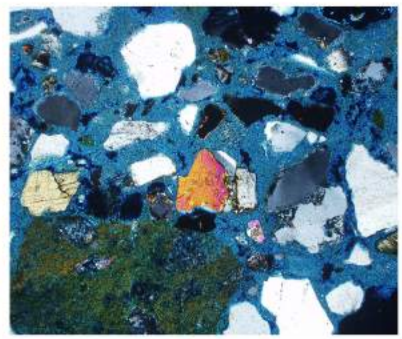
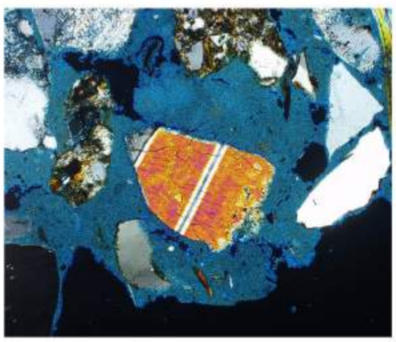
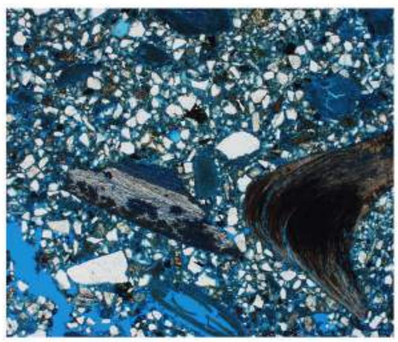
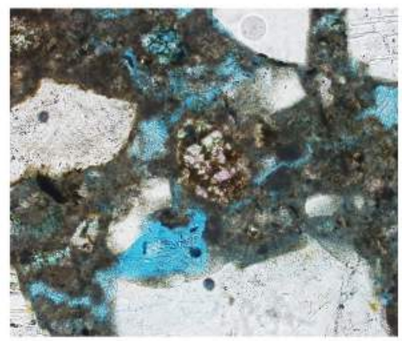
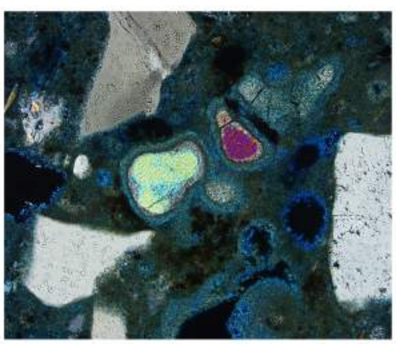
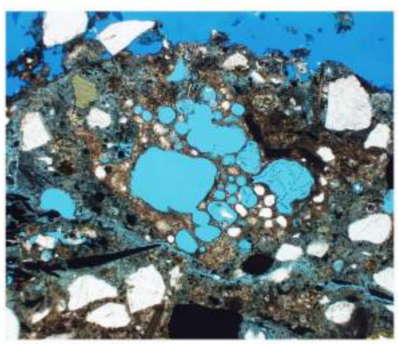
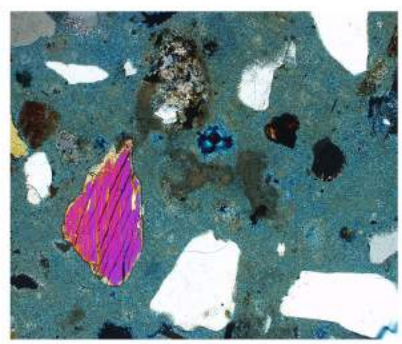
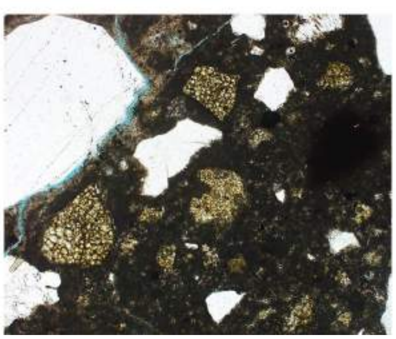
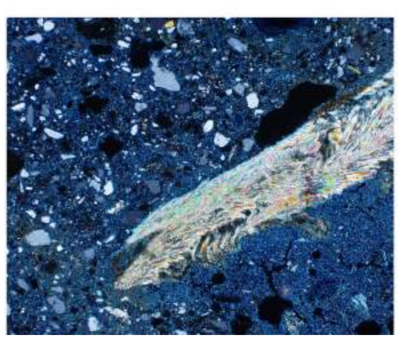
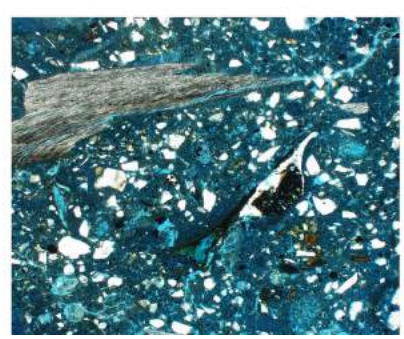

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## 1. Introduction

New York City has a long history of architectural and industrial innovation, resulting in a diverse urban landscape. However, New York's rich early history as a Colonial settlement is largely underrepresented as few buildings remain from the 17th and 18th centuries. This, coupled with the lack of records on local building practices and early material sources, poses a serious challenge to the study of New York's architectural history. For these reasons, the architectural features uncovered by archaeological excavations offer a unique and invaluable opportunity to analyze early building materials. While archaeologists often encounter architectural remains, they are mainly concerned with collecting artifacts that contextualize stratified deposits and place date constraints, and in this process, building materials that similarly hold informational value are often overlooked and discarded. Changing this practice requires challenging the conception of what artifacts are "diagnostic," meaning characteristic of a particular time period or cultural tradition. Archaeologists consider architectural features, such as foundation walls and cisterns, to be diagnostic because they can be dated to a period of construction corroborated by building records. However, loose building materials collected from within a stratified layer are not given the same consideration as other artifacts. For example, loose ceramic fragments are considered diagnostic because they have identifiable characteristics that are representative of a style of a certain period or cultural tradition, and in some cases even a manufacturer's mark, that can offer a date constraint for a stratigraphic layer. Building materials can be similarly useful for dating as they can be placed within a trajectory of material technology that has developed and evolved over time. While artifacts

like ceramics can be dated and associated with local manufacturers, they are portable objects that can move through spaces over time, whereas building materials have the advantage of being directly associated with a construction event. Mortars can be especially useful in that they cannot be reused or imported, and so they can reflect local handiwork and material sourcing. For this reason, mortars have been used by both archaeologists and architectural conservators to date architectural features, and yet there has been little work done to demonstrate the informational value of mortars collected from stratified archaeological deposits.

The central aim of this thesis is to argue for the diagnostic capabilities of mortars collected from stratified deposits, as demonstrated through an analysis of the mortars collected from the Stadt Huys Block and Seven Hanover Square excavations in Lower Manhattan in 1980. Together, these sites represent some of the earliest and most continuous history of European development in New York City, with deposits dating back to the mid-17th century settlement of New Amsterdam through the period of English colonization and later development into the 20th century. Most of the building materials collected from this excavation were considered to be non-diagnostic, and so they were not extensively studied or incorporated into the interpretations of the archaeological sites. In revisiting this discarded collection, the following research objectives will be addressed:

**1. To demonstrate the capabilities of mortars as diagnostic tools for archaeological dating.**

Mortars can be analyzed to identify the composition and source material for their binders. They can then be assigned a date range as the identified binder materials can be correlated

to a known history of binder use. Mortars sampled from stratified archaeological deposits offer an additional source of information for the archaeologist that can support or refute previous interpretations. Mortars can also provide a date constraint for where there is no other supplementary information, as well as help to link strata across the archaeological site.

**2. To supplement the history of mortars and binder use in Lower Manhattan from the Colonial period to the Industrial Revolution.**

These archaeological collections offer an opportunity to investigate little-known transitions in binder technologies in New York's early Colonial history, such as the general shift from shell lime to rock lime. These transitions are well known in New York from the Industrial Revolution onward, but there is little information from the Dutch and English colonial periods. This information can be useful for distinguishing early periods of construction in architectural features with little to no documentation.

Goals 1 and 2 inform each other, demonstrating how specialists in materials science can benefit from the context of archaeology and archaeologists can benefit from the interpretations of specialists. Martin Carver, in his work *Archaeological Investigation,* states, "It is obvious that the most fruitful working relationships between field archaeologists and specialists are those that begin in the design stage and develop through dialogue on the site itself and then on into the lab."[1] By maintaining a dialogue between

[1] Carver, 224

archaeologists and materials scientists, architectural building remains can serve to inform interpretations of cultural influences on the built environment.

## 2. Historic Mortars

Mortar is a building material made by combining a binder with water to form a paste that is then mixed with sand and other admixtures to produce a plastic material that hardens over time. Binders used in mortar are cementitious materials that produce structural cohesion between masonry elements. The addition of sand adds workability to the binder paste and creates a more economical product. The resulting mortar, when applied in masonry construction, strains to accommodate the movement in the structure and creates a water-resistant barrier, preventing the deterioration of the surrounding masonry elements. While the amount of mortar used is dependent on the types of materials and the packing density of masonry elements, mortars can make up to 20 percent of the volume of a brick structure or significantly more in a rubble wall construction.

There are several unique characteristics that differentiate mortar from other building materials in archaeological contexts. The manufacture of mortar is guided more by practicality than aesthetics as it is mainly used as a structural element. As a result, mortars are more likely to represent local resources, as it is unlikely that one would transport large amounts of sand or binder material when there are local sources available of acceptable quality. Resources are largely derived from local geology, influencing the lithology of the sand and the different available binder materials. In contrast to other building materials, such as stone and brick, mortar is generally prepared at the time of construction. For example, in hydraulic mortars, the process of hardening begins from the moment the binder is mixed with water. This property also defines mortar as a non-recyclable material, since the hardening process cannot be reversed. When repairs are required, a new mortar

is applied over the earlier material. This also means that some mortars have a shorter lifespan in a building than other structural materials. In this way, mortars can be more directly tied to episodes of construction in a building. Identifying a period of use for a particular binder technology or mix design in a mortar can be used to provide date constraints for these construction episodes.

The value of mortars for placing date constraints in archaeological contexts is dependent on having a reference of known transitions in binder technologies and mortar mix designs. Mortars in North America from the time of Colonial settlement onward have a higher diagnostic potential for archaeological study than mortars in Europe or other parts of the world from earlier time periods. In European history and American prehistory, similar sources for building materials were implemented over long periods of time. As a result, when viewing these mortars in archaeological contexts, their characteristics are not unique to a particular time period. In contrast, transitions in binder and mortar use follow a trajectory in North America, punctuated with major events in development, beginning with Colonial settlement. It is sometimes possible, then, to distinguish changes in material sourcing within a short period of time.

The period following Colonial settlement in America, from 1830 to the present, has been marked by advancements in industrialization and infrastructural development. This period began with the creation, and improvement, of large infrastructural systems and military defenses. Builders sought after materials that offered improved characteristics, such as high strength, water resistance, and the ability to set under water. In order to meet new demands of performance, new advancements in mortar technology were required. Many of these early developments were pioneered in Europe. As a result, novel binder

products were imported from Europe to the U.S. until local manufacturers developed a comparable product. The latter parts of this period were marked by the establishment of standardizations in building materials. This drove new technological developments in the sourcing and manufacture of binder products. The marketing of these materials focused on their ability to meet new standards in safety and quality. Standardization also resulted in more controlled methods of manufacture, so that binder products began to have more consistent characteristics. This detailed history of manufacturing and technological development allows one to associate mortars of this period within well-defined dates of earliest use.

Admittedly, methods of processing building materials were less developed at the time of Colonial settlement, and there is little technological variation in mortars of this time period. Despite their simplicity, Colonial lime mortars are characteristic of the rapid growth of settlements, transportation, and trade that occurred during this period. This created a punctuated history in mortar design that, although subtle, is similar to that observed in the Industrial Era. Lime was the primary binder material, and the sources of lime varied based on what was locally available. Mortars of this period are more distinguishable in their application as well as in their aggregates, admixtures, and mix design. Colonial settlers in North America came from diverse cultural backgrounds, and they often implemented their unique traditions in the construction of their settlements. This resulted in a variety of mortar application techniques. Settlers sometimes incorporated imported materials. Generally, however, Colonial building practices relied on the convenience of locally available materials, as modes of ground transportation were limited. Later infrastructural developments in Colonial settlements resulted in the

establishment of new transportation routes. This resulted in an expanded access to a greater variety of natural resources, and materials with more favorable properties were eventually chosen over more convenient materials for use in building.

## History of Mortar in the United States

The history of mortar in the United States follows general trends in the use and development of building techniques. These broad transitions are represented in binder types and mortar mix design. The history of binders typically begins with the use of lime and later shifted to the use of natural cement sometime in the mid-19th century. This was followed by a general shift to portland cement by the beginning of the late 19th century. Mix designs for mortars in the United States also follow a broad trend from cruder to more carefully designed preparations. These shifts occur at different times in different locations across the country. However, this broad trajectory is useful for generally contextualizing mortars in archaeological contexts.

All masonry mortar design involves the addition of an aggregate. The gradation and proportioning of aggregates clearly vary among different places at different times. There has been little comprehensive research on sand use in mortars in the United States. However, practicing professionals in the field of architectural conservation have noted general characteristics of mortar mix designs that are typical of certain time periods. An analysis of mortars in Charleston, South Carolina by petrographer John Walsh demonstrated that earlier mortars, from before 1830, contained a higher content of silt and

clay.[2] He also found that earlier sands had coatings of clay around sand grains, indicating that they were unwashed.[3] "In effect, the sand, silt, and clay were all part of a single unscreened aggregate addition." He contrasted this to mortars dated after 1830, which contained clean, graded sand with a lower ratio of lime to sand. This analysis can serve as a demonstrated example of this trend that is evidenced in mortars across the country, although the transitions in practices may occur at different times.

It would stand to reason that early sand sourcing would be guided by convenience. This is because the earliest buildings were made to meet immediate needs for shelter and infrastructure. The most available sand sources did not require much excavation. In coastal regions, these would include clay-rich coastal silts in estuaries and river banks. Later practice shifted to a more selective quarrying of sand. Coarser-grained sand that is well-graded results in a mortar with more favorable qualities, improving the workability, packing quality, and volume stability. A well graded sand decreases the water demand of the fresh mix, increasing the strength of the mortar. Mortar with a higher sand content is also more economical, as binder is generally more expensive than sand.

Lime is a type of binder that is sourced from materials containing calcium carbonate and sometimes dolomite, the double carbonate of calcium and magnesium. Lime properties can best be understood through an explanation of the series of chemical reactions that take place during manufacture and processing, known as the lime cycle. This is easiest to understand with respect to pure calcium carbonate though similar reactions take place with dolomite. The first step is calcination, in which the calcium carbonate ($CaCO_3$) is

[2] Walsh, John J. and Magdalena Malaj. *Masonry Materials Analysis at Charleston City Jail.* Highbridge Materials Consulting, Inc.
[3] Ibid.

heated to produce CaO or "quicklime." With the addition of water, the quicklime reacts with a release of heat to produce hydrated lime ($Ca(OH)_2$). This process is called "slaking." The hydrated lime is the binder that then can be mixed with sand and other additives. After the lime is installed, it absorbs atmospheric carbon dioxide that has been dissolved in pore water. In a process called carbonation, the hydrated lime reacts with the carbon dioxide to produce calcium carbonate.[4] As such, the hardened lime is chemically similar to the source material.

Mortars before the Industrial Revolution were typically lime-based. The source materials for lime production are common in many parts of the world, and include many types of carbonate rocks and shells. In Colonial coastal settlements, there tended to be an evolution in binder sourcing from the shells of invertebrates, such as oysters, to rock sources, which can be either local or nonlocal. The prevalence of shell lime use is obviously dependent on the availability of local sources. In the United States, most coastal towns were using shell lime before advancing to rock sources. Mollusk shell was a very abundant resource early on and was used to produce lime not only in building but also for soil conditioner, food processing, tanning, and other industries.[5]

Shell lime is a nearly pure calcium oxide, with possible impurities introduced by any sand or clay adhered to the shells and not removed before firing. With expanded settlements and increased trade came a shift toward the use of rock lime.[6] Potential sources for rock lime include chalk, limestone, and marble. Later commercially produced lime usually implemented rock lime technology. Though there were countless

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[4] Eckel, 6
[5] Krotzer, 46
[6] Ibid.

manufacturers of local rock lime, the robustness of some sources coupled with advances in kiln design and increased access to markets led to the rise of several large producing centers. The rock lime industry in Rockland, Maine was especially influential in the Northeast. Rockland was the primary source for lime used in Boston and New York City beginning in 1792, and continued to be a significant provider through the 19th and early 20th century.[7]

In some cultures, there was a practice of making modifications to lime binders with additives to produce hydraulic properties. Materials containing glassy silica and alumina react with the calcium in lime to produce calcium silicate hydrate, which results in a product that will set under water.[8] These materials are termed "pozzolans", named after the island of Pozzuoli in Italy, which was a source of volcanic ash used by the Romans to produce a sort of hydraulic lime. Pozzolans can be either naturally sourced, from volcanic ash or earth, or artificially from brick dust (and, in modern times, slag). Both natural and artificial pozzolans are chemically similar "due to the processes of (1) fusion of a silico-aluminous material, and (2) rapid cooling of the resulting product by ejection into air or immersion in water."[9] The type of pozzolan used and method of incorporation can be indicative of specific cultural traditions in building practices. For example, brick dust was identified in the mortars collected from an 18th century building in Old San Juan, Puerto Rico.[10] This is representative of Spanish settlers using traditional practices in the construction of their settlements in North America.

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[7] Finch, 390
[8] Lazell, 632
[9] Ibid., 633
[10] Wells, 37

There are several limitations to using lime mortar. For example, hydrated lime must be used at time of slaking as it will begin to harden immediately. Also, lime expands in the process of slaking, and will shrink in the process of drying. This volume change could pose a structural issue in masonry construction, although the addition of sand as an aggregate is meant to deter this. Other binder types would eventually replace lime as they offered increased strength and durability.

While lime was a common early binder technology in the United States, there was an eventual transition to include binders with more preferable properties. Unlike lime, hydraulic cement binders can set under water through a process called hydration. This characteristic makes these binders especially useful for underwater construction projects, such as canals. A precursor and contemporary to the manufacture of hydraulic cements, hydraulic lime binders are sourced from siliceous or clayey limestones that have more calcium than can be chemically combined with these impurities. Hydraulic cements were popularized in the 18th century through John Smeaton's work on the Eddystone Lighthouse in England. In the 1750s Smeaton, in his efforts to reinforce a lighthouse that had been repeatedly destroyed by storms, discovered that binder sourced from local stone had naturally hydraulic properties.[11] He is often referenced for his standards of testing the properties of hydraulicity in lime binder, building on the work of Roman architect Andrea Palladio, who wrote on hydraulic limes in the 16th century.[12] While popular in Europe, hydraulic lime was not commonly made or used in the United States. Hydraulic cements, such as natural cement and portland cement, were the predominant hydraulic binders used

[11] Redgrave, 13
[12] Sala, 958

throughout the United States beginning in the mid-19th century. Hydraulic cements are differentiated from hydraulic limes in that they do not slake, and are instead ground so that they can be mixed with water to form a workable paste.

In the United States, natural cement was usually sourced from a rock containing dolomite (calcium magnesium carbonate), quartz, and clay. Calcite-based sources were more common in Europe. When burned, the resulting material does not slake and instead must be ground finely so that with the addition of water it becomes a workable paste. Natural cement can harden in either open air or under water.[13] John Parker was the first to manufacture a natural cement product in England. In his 1796 patent for "A certain Cement or Terra [trass] to be Used in Aquatic and other Buildings, and Stucco Work," Parker described a binder sourced from stones with clay nodules that are burned to powder.[14] He termed this product "Roman cement" because he compared its properties to those seen in cements of ancient Roman constructions.[15] There was limited importation of this product into North America from around the early 19th century.

In 1818, Canvass White discovered natural cement sources in Chittenango, New York while working on the Erie Canal.[16] This was the first discovery of natural cement in the United States. In 1825, Joseph G. Totten performed tests on two New York cements at Fort Adams, RI which outperformed Parker's cement. These discoveries shifted the market for natural cement used in the United States from imported to local sources.

[13] Eckel, 200
[14] Redgrave, 17
[15] Ibid., 17
[16] Cummings, 18

One of the first natural cements to be commercially manufactured were those sourced from Rosendale, New York. Beginning in 1825, the Rosendale cements were not the first to be manufactured in United States, however they were the most popular natural cements to be produced on the east coast. The area was rich with dolostone of the Rondout Formation, which was noted for producing high quality cement.[17] Rosendale cement was widely popular by 1843 and had a wide distribution made possible due to its proximity to a network of canals.[18] The mid-19th century was a period of explosive growth in the market for natural cement, with localized manufacturers across the country. While not a large distributor, the natural cement plant at Round Top, Maryland experienced great success within its local market.[19] Initially discovered in 1837, this cement was used in the construction of the Chesapeake and Ohio Canal.[20]

The market for natural cement was challenged by the end of the 19th century with the manufacture of portland cement in the United States. However, the Rosendale and Round Top companies were successful into the 20th century. In 1889, a General Market Report for Building Materials in the New York Daily Tribune noted that "the popularity of Rosendale natural cement persisted long after the introduction of Portland cements in the 1870s because of its reputation for quality at competitive prices."[21] The use of natural cement peaked in 1899 and began to decline in early 20th century with the advanced development of portland cement. The Century Cement Manufacturing Company in Rosendale was the last to close in 1970.[22]

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[17] Werner, 12.
[18] Eckel, 289
[19] Cummings, 20
[20] Ibid.
[21] Werner, 6
[22] Ibid., 5

Portland cement is an artificial binder with hydraulic properties. It is made by heating source materials, including limestone and clay minerals, at a high temperature so that they are chemically and physically combined.[23] This "clinker" is then finely ground and will not slake with the addition of water.[24] Early development of this binder began in England the early 19th century. Joseph Aspdin is considered to be the first to create a type of portland cement product, described in his 1824 patent, "An Improvement in the Modes of Producing an Artificial Stone."[25] This product was not manufactured in Portland, England, but was instead named after its visual similarity to the rounded granular texture of Portland oolitic limestone.[26] By the later 1840s Joseph Aspdin's son, William Aspdin, experimented with higher burning temperatures resulting in alite crystals produced from an accidental clinker.[27] His work was taken over by I.C. Johnson, who  continued to refine the processing of portland cement at higher temperatures.[28]

Portland cement was imported from England to the United States beginning after the Civil War, although natural cement still dominated the market in the States.[29] The early development of portland cement continued in Europe, and a German product eventually took over the market around 1895.[30] David O. Saylor was the first to produce a portland cement product in the United States after establishing the Coplay Cement Company along the Lehigh Valley in Pennsylvania.[31] In 1871, Saylor filed a patent for an American Portland

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[23] Eckel, 268
[24] Ibid.
[25] Redgrave, 24
[26] Ibid.
[27] Lea, 8
[28] Ibid., 8
[29] Carroll, 15
[30] Lea, 12
[31] Hull. 1

Cement, which he marketed as a superior product to European counterparts.[32] This product was made from entirely locally sourced materials. The Saylor Portland Cement was featured in the Philadelphia Centennial Exhibition in 1876.[33] This event served as a catalyst for the manufacture of portland cement in the United States. This change in market share is shown in the *Directory of American Cement Industries* from 1909.[34] In 1880, natural cement made up 90 percent of the market for cements in the United States, compared to domestic portland cement, imported portland cement, and pozzolanic cements.[35] There was a sharp increase in the use of portland cement through the last decade of the 19th century, eventually overpassing natural cement by 1900.[36]

There are several variables involved in the development of portland cement products through the 20th century. These included technological developments in kiln design and milling. In the United States, early shaft kilns, like the "Schoefer" type seen in the Coplay Cement Company, created a product with inconsistent grain size and underfired material.[37] In 1873, Frederick Ransome patented a rotary kiln that was the basis for rapid advancements in cement manufacture. The Hurry and Seam rotary kiln, developed in 1898 in the United States, was the first iteration successful in producing portland cement using powered coal as a fuel source.[38] This kiln type largely replaced the shaft kiln, as it allowed for a continuous and consistent burning process.[39] This kiln type resulted in a product with more regular grain sizes, and created a product with more consistent properties.

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[32] Ibid., 10
[33] Ibid., 13
[34] Carroll, 15
[35] Ibid.
[36] Ibid.
[37] Hull, 20
[38] Lea, 12
[39] Ibid.

Portland cements were also influenced by the developments in grinding, such as the ball mill.[40] This mill allowed for a finer grinding of the clinker. Portland cement grains from the later 20th century are more finely ground than those from the late 19th and early 20th centuries.[41] This distinction in grain size can be noted microscopically and is useful for placing well-defined date constraints on portland cement mortars from archaeological contexts.

The preceding summary addresses major shifts in binder technologies which are relevant to this study, from the 17th to early 20th centuries in the United States. These shifts serve as useful references for archaeological study. A binder with a known history of use and date of invention can help establish a TPQ, or date of earliest deposition, for the archaeological deposit from which it is sampled. There are a wide range of binder types not covered in this history that can be used for this purpose. One example is slag cement, in which slag is added to lime as a pozzolan addition. Slag is a byproduct of Bessemer steel production, which began in the late 19th century. Slag cements made from a mixture of hydrated lime and ground granulated blastfurnace slag fell out of use in the early 20th century when portland cement became more popular as a component for these products. Therefore, this cement can be used to contextualize a tight date constraint for an archaeological deposit.

[40] Ibid., 99
[41] Walsh, 4

**Patterns of Transition**

While the trajectory of development in binder technologies follows a general trend in the United States, there are variables that influence local differences. At any given time, there are variations in mortars based on where they were produced. There can also be differences in the mix designs of mortars used in the same construction. Different methods of production may be implemented depending on how the mortar is applied in construction. Understanding these subtle differences can add to the informational value of mortars in archaeological contexts.

The geographic variations in mortars reflect local history of material sourcing. Differences in material accessibility influenced different transitions in binder technology from place to place. This is especially relevant to the transition of shell lime to rock lime technology in the United States. Shell lime was a common early product, but the choice was mainly one of convenience. Access to other lime sources may have been limited depending on location, and so the use and transitions of early lime technologies are highly variable across the Unites States. Mortar analysis from extant buildings from the 17th and 18th centuries shows that rock lime was adopted much earlier in northern states. In fact, rock lime has been identified in the mortars of most extant 17th century houses in Rhode Island and Southeastern Massachusetts. In the period of early Colonial settlement, areas of Massachusetts and Rhode Island experienced a lime shortage that heavily impacted masonry construction. The oyster deposits in these areas were very limited, and so settlers sourced from local deposits of limestone instead.[42] Limestone sources were discovered in

[42] Jenison, 23

Rhode Island in the mid-17th century.[43] This natural limestone was less expensive to mine then shells, and so the use of rock lime was quickly adopted in this region.[44]

The use of rock lime spread progressively southward along the east coast. For example, in Charleston, South Carolina, the shift from shell to rock did not occur until the 1830s.[45] Shells were plentiful and convenient sources for lime in this area, and so there was no incentive to source from rock deposits. Shell lime was eventually replaced by stone lime imported from northern states, as it became the more economical option.[46]

The question of when this transition occurred in New York has yet to be answered. This is largely because the lack of extant buildings from the early periods of Colonial settlement makes it difficult to gain statistical information on early binders. While New York has various local sources for limestone and marble, it is also known to have had extensive shell deposits. The transition from shell lime to rock lime in New York is likely to have occurred at some point between the transitions of Rhode Island and Charleston. One aim of this study is to demonstrate whether stratified deposits can be used to identify a transition in binder technology for a geographic region. Archaeological deposits may span many years and can contain the remains of multiple buildings over several construction episodes. Therefore, it is possible that mortars from archaeological contexts could provide the statistical evidence needed to gain a broad understanding of transitions in early binder technologies.

[43] Ibid.
[44] Ibid., 24
[45] Krotzer, 46
[46] Ibid.

Regional differences should also be noted for the periods of use for natural cement. Rosendale, New York was a popular center for natural cement production because it was an area with plentiful high-quality sources and had access to a wide distribution network. However, there were sources of natural cement scattered throughout the United States. While these sources produced cements of variable quality, it is possible that once a viable source was discovered, locally produced cements replaced imported products like Rosendale. Eckel writes that of the 65 plants in operation in 1903, "20 were in New York state; 15 in the Louisville district of Indiana-Kentucky; 7 in the Lehigh region of Pennsylvania; 4 in Maryland; and 3 in the Utica district of Illinois. The remainder were scattered at various points in Georgia, Kansas, Minnesota, Ohio, Texas, Virginia, Wisconsin, North Dakota, and West Virginia."[47] These plants were all established at varying dates, and their time of operation was highly varied as well. Knowledge of the history of natural cement production for a specific region would provide more detailed context for using the appearance of specific cements as date markers.

Variations in mortars of the same time period can also be a result of different methods of preparation for different applications. While binder technology and mix design for mortar generally advanced over time in the United States, different technologies and quality of processing can be seen in mortars of the same time period. In some cases, this is the result of socioeconomic differences. For example, while portland cement was available before the 20th century, it was not widely adopted initially as natural cement was a more economical option. Therefore, wealthier people were more likely to use portland cement mortar in the construction of their buildings earlier on. This was also the case for high

[47] Eckel, 208

profile buildings. Before the Industrial Revolution, the construction of vernacular residences was usually a domestic process in which people prepared their own building materials in small batches. In contrast, commercial, infrastructural, and military constructions usually involved a team of skilled workers. The mortars of these buildings, therefore, are likely to be more refined than those seen in vernacular constructions.

Mortars within the same building can also vary depending on their function in construction. For example, consider a building with a rubble wall foundation and brick masonry in the upper levels. Rubble wall mortars usually contain large aggregate and is incorporated as a fill for large voids between rubble units. Pointing mortars tend to be more refined, however. This is because it requires a relatively fine and consistently-sized aggregate to fit between thin mortar joints. While more refined than rubble wall mortars, masonry mortars can still be cruder than mortars used in plaster finishes. Jenison writes that of the shell lime mortars used in early Colonial construction, plasters are less likely to have only partially burned shells than a mortar for masonry construction.[48] This is a result of a more thorough screening and incorporation of the lime, resulting in a more refined product.[49] It stands to reason that a more refined mortar would improve the quality and appearance of a plaster finish. However, the quality of the mix can also vary between the different layers of plaster application. The first layer, or scratch coat, is meant to provide a base for the subsequent layers to adhere to. This mortar may have a less refined composition than the finish coat, which is meant to be a smooth and regular surface.

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[48] Jenison, 1
[49] Ibid.

With the knowledge of transitions in binder technology and mix design as a reference, mortars can be of diagnostic value for archaeological study. Mortars with a known date of invention can be especially useful for establishing a TPQ (terminus post quem), or date of earliest deposition in archaeological strata. The date of invention is not always representative of the beginning of its use in construction, however. For example, portland cement was invented in the early 19th century but was not widely used until the beginning of the 20th century. Still, a portland cement mortar within an archaeological context can be used to differentiate later deposits from earlier ones. The last appearances, or uses, of different binder types is less defined. As discussed in the preceding sections, the transitions between binder technologies can be impacted by several variables. The history and patterns of use for mortars of a specific region can serve as a local reference for contextualizing an archaeological excavation.

## 3. Early Colonial Building Practices in New York City

The mortars referenced in this study were collected from two archaeological sites in Lower Manhattan. A history of known building practices for this region is necessary to provide cultural and temporal context for this data set. Most of what is known on the history of building practices in New York City dates from the Industrial Revolution. Due to the lack of extant buildings from before this period, the history of building practices in New York City from the early 17th to early 18th centuries needs to be supplemented with both documentary and archaeological data.

The Dutch colonists first sailed to North America as early as 1622. These early settlers sought to capitalize on an economic opportunity in fur trading, and by 1625 there were thirty families in what is present-day New York City.[50] While northern settlements, in the area of present-day Albany, had a primarily Dutch population, New Amsterdam was a place of ethnic diversity. This was due to its role as a trading center in which various European settlers sought new economic opportunities.[51] Historian Edwin Burrows describes New Amsterdam as more of a factory than a settlement and as such there were unique requirements for establishing a built environment. For example, in most other European settlements, a church was among the first buildings constructed but this was not the case for New Amsterdam.[52] I.N. Stokes, in his work *The Iconography of Manhattan Island,* states, "[a]mong the first buildings erected upon Manhattan Island after its settlement under Minuit was the 'counting house' of the West India company," this being a

[50] Burrows, 20
[51] Merwick, 53-78
[52] The first church in New Amsterdam was the Dutch Reformed church, constructed in 1628

"stone building, thatched with reed."[53] As a center of the Dutch West India Company and capital of New Netherland, the settlers of New Amsterdam were connected with several different channels for imported building materials. However, their decisions on what to build with were ultimately influenced by local material accessibility, the presence of skilled workers, and the gradual development of local building industries.

The earliest Dutch settlers of New Amsterdam noted the locally available materials: "fine oak timber and good building stone."[54] The geologic formations within and surrounding Manhattan included outcroppings of schist, marble, and gneiss.[55] Minister Jonas Michaelius noted of the new settlement, "for building purposes there is a greater lack of laborers than of materials. For besides many kinds of good timber, there is here clay for the making of bricks and tiles, though rather poor, but the quarry stones, not far away, are better for our use."[56] Due to the challenges of working with the local clay deposits, brick was not produced in New Amsterdam until the 1650s, and so any earlier construction was done with wood, stone, or imported brick.[57] While these materials were all available at the same time, material choice ultimately varied depending on the type of building construction.

For the largest construction project of the new settlement, Fort Amsterdam, the choice was stone. While the first iteration of the fort was made of earthen walls, it was finished with stone by 1635.[58] This use of stone was encouraged by developments in

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[53] Stokes, 10
[54] Lamb, 106
[55] Merguerian
[56] Stokes, 14
[57] Ibid.,
[58] Stokes, 133

material processing, with five stone workshops operating by 1638.[59] Building with stone was further made possible by the use of slave labor facilitated by the West India Company's role in Atlantic slave trade. African slaves were involved in the construction and later reconstruction of Fort Amsterdam in 1659.[60] Stokes notes that enslaved Native American laborers were involved as well, "employed in quarrying and hauling stone… and other materials for its walls."[61]

Different trends are seen in house construction, which in the earlier years of the settlement, when resources were scarce, were executed in the simplest construction. About 30 houses are visible in the Hartgers view of Manhattan in 1626, most of which were made using the locally available wood that was being processed to be shipped to Europe.[62] By 1643, sawmills had been established and were producing wood boards for use in construction.[63] In a letter from merchant Kiliaen van Rensselaer to Adriaen van der Donck on March 9, 1643, he addresses the mounting limitations of building with wooden boards compared to the limitations of other material options. He states, "perishable boards… will cost nearly as much as hard and permanent bricks; consequently… I have urgent need of a good brick-maker."[64] More viable options for construction materials would come in later years with an increasing population consisting of skilled workers emigrating from various parts of Europe.

Most construction throughout the early years of Dutch settlement was done on an individual basis without general regulations. By 1647, director-general Peter Stuyvesant

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[59] Burrows, 31
[60] Stokes, 77
[61] Ibid.
[62] Valentine, 25, Stokes 133 (Joost Hartgers, issued 1651)
[63] *Van Rensselaer Bowier Manuscripts,* 638
[64] Ibid., 637

began making orders for infrastructural improvements and standardizing building.[65] This resulted in the adaptation and reconstruction of many buildings. This also resulted in an increased demand for skilled laborers. New Amsterdam was officially designated a Dutch municipality in 1653.[66] As a result, the first tavern of New Amsterdam, "a fine stone tavern" originally constructed in 1642 was made the Stadt Huys or "state house."[67] Most buildings along the water were made of brick by 1655.[68] Further regulations in 1656 included orders to fortify wooden houses against fire, as well as a 1657 ordinance to remove all thatched roofs and other fire risks to buildings.[69] With these new limitations there grew an urgent need for fire-proof materials. Several brick kilns had been established in New Amsterdam by 1660.[70] The Van Rensselaer Bowier manuscripts contain details on the work of brick-maker Andries Herbertsz, who between 1659 and 1662 "furnished the colony with brick and tiles from the kiln conveyed to him by Pieter Meusz."[71] Urban development, and the increased investment in establishing stability lead to the paving of Stone Street in 1658.[72] In these years, builders in New Amsterdam continued to incorporate traditional Dutch features of urban design, including a canal running through present-day Broad Street, and buildings packed close together with stepped end gables facing the street.[73]

In 1664, New Amsterdam was taken over by the English and renamed New York.[74] Even through the period of English settlement the visual characteristics of the built

[65] Stokes, 25
[66] Rothschild (1990), 10
[67] Valentine, 30
[68] Innes, 45
[69] Valentine, 63, Stokes, 65
[70] Lamb, 196
[71] Van Rensselaer Bowier manuscripts, 829
[72] Valentine, 64
[73] Rothschild (1990), 11
[74] Bridenbaugh, 5

environment in this region were primarily Dutch. By the 1670s, settler Daniel Denton wrote of this place as being "built mostly of brick and stone, and covered with red and black tile…" describing the remaining elements of Dutch urban design.[75] In 1677, 81 percent of the population of New Amsterdam was Dutch.[76] Although the English had replaced all roles of government, Dutch tradesmen were still overrepresented in the building trades.[77] Historian Joyce Goodfriend attributes this phenomenon to the effects of the apprenticeship system long set in place by the Dutch which resulted in the exponential growth of skilled laborers. She states, "the employment of local Dutch workmen in the construction of Trinity Church testifies to the monopolization of the building trades by the Dutch."[78] However, the research of Jeroen van den Hurk into building contracts of the early Colonial period suggests that this may be a misunderstanding. He states, "The ethnic origins of these people is sometimes disguised in the contracts, because of the provincial secretary's tendency to write names down phonetically, making them appear to be Dutch."[79] Whichever the case, the English began to leave their mark on the built environment by the last decade of the 17th century as a result of several new building regulations that began to alter the built fabric of the city.[80] New York consisted mostly of brick buildings by the beginning of the 18th century.[81]

Elements of traditional Dutch building practices would not entirely disappear. The house of merchant William Walton, constructed in 1752, was "built of costly, yellow-hued

[75] Lamb, 248
[76] Archdeacon, 79
[77] Ibid.
[78] Goodfriend, 69
[79] Van den Hurk (2005), 144
[80] Valentine, 211
[81] Ibid., 215

"Holland" brick" despite being designed in the Georgian style.[82] This was the beginning of the transition to British cultural influences that are presently seen in the built environment of New York City. By the end of the 18th century, the population had grown drastically from 270 in 1628, to 4937 individuals in 1698, to 33,131 inhabitants by 1790.[83]

Brick and stone were key elements in establishing a built environment that provided the foundations of the evolving city, and mortar played a significant role. The shores of New York were laden with oysters and minister Jonas Michaelius noted the great amount of oysters as a valuable resource for the making of mortar.[84] However, records are not clear on exactly how, or for how long, shell lime mortar was used. In his work, *The Big Oyster: History of the Half Shell,* Mark Kurlansky writes, "[b]urning oyster shells for lime was such a common activity that private homes in the New York area built their cellars with one side open for burning shells when household repairs were needed."[85] Records from 1630 state that lime was being shipped from New Amsterdam to the northern Dutch settlement of Rensselaerswyck.[86] However, in the same year lime was also being imported to the new settlement as ballast and this continued through the latter half of the 17th century, as corroborated by records from 1657.[87] This might have been done to supply other Dutch settlements that did not have such large oyster deposits, as the lime from oyster shells was reported as being of better quality than the imported lime.[88] It could also be that the need for lime was not met by local production alone. Few detailed records exist

[82] Burrows, 177
[83] Rosenwaike, 2, 7
[84] Stokes, 14
[85] Kurlansky, 80
[86] Van Rensselaer Bowier Manuscripts, 814
[87] Ibid., 240
[88] Lamb, 106

describing the types of mortar used for most episodes of construction, although a specification for shell lime in the construction of the first Trinity Church in 1697 suggests that it was in use throughout the 17th century.[89]

Various legislative actions suggest that, to some degree, access to oyster shell would become limited as issues of health and safety arose. In April 11, 1658, an ordinance was passed to "forbid all persons from continuing to dig or dredge any Oyster shells on the East River or on the North [Hudson] River, between this City and the Fresh Water."[90] Then, in June 19, 1703, the New York provincial government passed a "[b]ill for prohibiting the distilling of rum and burning of oyster shells into lime within the City of New York or within a mile's distance of the City Hall."[91] This bill referred specifically to the health issues presented by the processing of oyster shell lime, stating that "The nautious and unwholesome smoke and smell whereof hath been thought a very great means and occasion of increasing the malignant distemper with which the inhabitants have been and still are grievously afflicted."[92] By March 24, 1714 a stricter ordinance was passed prohibiting the burning of shell for lime. This legislation may have encouraged a shift to rock lime. Stones had been quarried for building the fort and other large structures since the beginnings of the Dutch settlement. This might have included the quarrying of dolomitic marbles in upper Manhattan. Other possible sources for rock lime available in the earlier colonial period were limestones imported from Florida to New Amsterdam along with the limestone available in the area of the Rensselaerswyck settlement, which

[89] Kurlansky, 80
[90] *Laws and Ordinances of New Netherland, 1638-1674*
[91] *Calendar of State Papers, Colonial: North America and the West Indies 1574-1739*
[92] Ibid.

frequently interacted in exchange of goods and materials with New Amsterdam.[93] Any documentation on the use of these stones can be misleading, however, as marbles were often referred to as limestones.[94] The documentary record alone is not a reliable source to establish a chronology for the use of rock lime mortars in New York City.

Rock lime from Rockland Maine was being sent to New York by 1792.[95] Larger industries established for rock quarries and rock lime would suggest that the use of shell lime had become obsolete, and yet in 1869, "[o]n the 8th day of December orders were entered by the Board against the several lime and shell burning establishments in the cities of New York and Brooklyn, directing the business to be discontinued until it could be so conducted that no offensive odors should escape into the external air." The legislation goes on to state "[t]hose located in the suburbs were allowed to continue the business upon the introduction of the most approved plans for rendering it inoffensive."[96] By this time, shell-lime was not any cheaper than stone lime, although shell lime was noted as being "an exceedingly fine form of lime. Its subdivisions or laminations render it peculiarly favorable."[97] It is difficult to determine, based on documentary sources alone when shell lime was ultimately supplanted by rock lime in New York.

There is also the question of how traditional Dutch practices influenced mortar in New Amsterdam. Trass (or tuff), a rock of consolidated volcanic ash, was used by the Dutch as a pozzolan for lime mortar.[98] Although there are no records of trass being shipped out of the Netherlands, St. Eustatius would have provided the Dutch with a new source for trass in

93 *Van Rensselaer Bowier Manuscripts,* 147
94 Jenison
95 Finch, 389
96 *Fourth Annual Report of the Metropolitan Board of Health of the State of New York, 1869*, 14
97 Ibid.
98 Nijland, 69

West Indies. However, trass had largely fallen out of use by the 12th century and was not revived in Dutch building practices until the 19th century, and so it may not have been introduced in the buildings of New Amsterdam.[99]

The physical record can provide clarification on the use of binder sources and general practices with mortar that documentary sources cannot. Methods of materials analysis combined with the constrained dates of archaeological deposits are capable of showing general trends that are representative of a common building practices.

[99] Ibid.

## 4. The Stadt Huys Block and Seven Hanover Square Archaeological Sites

The Stadt Huys Block and Seven Hanover Square archaeological sites both contain artifacts from the early colonial settlement and subsequent periods of development in New York City. They are invaluable resources for understanding trends and transitions in the use of building materials. The Stadt Huys and Seven Hanover sites were excavated in 1980 and 1982, respectively. These projects were a groundbreaking experiment in urban archaeology. The archaeologists were faced with the challenging limitations and logistical issues of organizing an archaeological excavation in an urban setting and sampling was heavily impacted by the activities and scheduling constraints of planned construction.[100]

These excavations were done as part of an agreement for de-designation for a 1970 development plan on landmarked property designated in 1966 by the Landmarks Preservation Commission. In fulfillment of the National Historic Preservation Act, the developers and the LPC came to an agreement to remove the façade of the designated building and move it to another location for subsequent rebuilding.[101] In the following years, the original developer had backed out and a new development plan set forth in 1979 required a different strategy because the façade of the landmarked building had been lost. The LPC agreed to an archaeological excavation of the block to fulfill the de-designation, which was thought to contain remains of the Dutch Stadt Huys as evidenced by an earlier excavation by Regina Kellerman in 1970--71 that unearthed artifacts from the 17th century.[102] Nan Rothschild and Diana Wall were chosen to lead the excavation of the Stadt

[100] Cantwell
[101] Wall, 111
[102] Ibid.

Huys Block and were given three months to work before development began.[103] With this time constraint, archaeologists had to prioritize areas with higher potential for containing artifacts in undisturbed contexts, based on documented building episodes. Towards the end of the excavation, however, archaeologists discovered the remains of the Lovelace Tavern from the 17th century that contained thousands of glass bottle fragments, ceramic pipes, and other artifacts.[104] The archaeologists were allowed a 25-day excavation extension and continued to work as bulldozers razed the site around them in preparation of the planned construction.[105] The Stadt Huys excavation was crucial in that it proved that there were 17th century remains under New York City and sparked various other excavations, including the subsequent Seven Hanover block excavation.

**Architectural History**

Before beginning their excavation, archaeologists conducted archival research to identify areas of highest potential for undisturbed artifact deposits and architectural remains. They researched historic documents such as maps, deeds, and tax records to provide dates for episodes of construction. Records were not always available, however, and some building lots had a complicated history of ownership that made construction periods difficult to distinguish.

The Stadt Huys Block had several episodes of well-documented construction. In 1653, General Francis Lovelace (second governor of the English settlement) ordered that

[103] Cantwell, 24
[104] Ibid., 28
[105] Ibid., 28

the "City Tavern" be converted into the "City Hall or "Stadt Huys."[106] Then, "in 1670, Lovelace built an inn, joining it to the Stadt Huys by a bridge."[107] Archaeologists found no remains of the Stadt Huys but did uncover the foundation walls of the "inn," later named the Lovelace Tavern. Between 1656 and 1660 the area north of Stone Street was developed. This street was widened in 1838, which resulted in modification or destruction of the 18th century buildings along either side of it. A summary of the recorded building episodes for each lot within the Stadt Huys site is included in Table 1.

The Seven Hanover Square site was developed after several landfilling episodes. The Dongan Charter in 1686 gave the city rights to establish land grants, which allowed for building on undeveloped areas of the Seven Hanover block.[108] Water lots were granted for all lots within the Seven Hanover site from 1686--1694, with expansions granted in 1697.[109] These lots were landfilled and developed over. A fire in 1835 destroyed many of the buildings on the block, resulting in wide spread reconstruction in the following years. A summary of the recorded building episodes for each lot within the Seven Hanover site is included in Table 2.

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[106] Stokes, 127
[107] Ibid.
[108] Nan A. Rothschild and Arnold Pickman, *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report* (NYC Landmarks Preservation Commission: December 1990), 2
[109] Ibid., 2

Table 1: Summary of Recorded Building Episodes of the Lots within the Stadt Huys Block Site[110]

| Lot | # of Building Episodes | Dates of Construction | Test Cuts | Notes |
|---|---|---|---|---|
| 6 | 3-5 | 1655, late 17th century, 1784, 1819, 1835, | AH, AD, AE | |
| 7 | 3 | 1655, 1699, 1791 | H, AV, AM, AJ, F, AP, AL, BU, AK | |
| 8+9+15 | 5 | 1670, 1730s, 1830, 1833, 1940s | AQ, AU, BH, BM, BG, BP, BG, BL, BE, BW, BS, BI, BF, BJ, BN, BK&BQ, BO, BX, BY, BR, BT, BC, BD, AT, AW, Y | Containing remains of the Lovelace Tavern |
| 10+17 | 6 | 1642, 1653, 1672, pre-1826, post-1826, 1830s | Lot 10: K, R, X, P, N, Q, W, BB, AX, AY, BA, AN, AZ<br>Lot 17: | Original location of the Stadt Huys |
| 12 | 3 | 1660-1695, 1830s, 1907 | AA, AB, AC | |
| 14 | 1 | 1827 | AG, AI, CD | |
| 16 | 2 | 1660-1672, 1870 | AF, U, L, I, Z, B, D | |
| Stone Street | | | CA, CB, CC, BZ | |

110 Compiled from *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 2: Summary of Recorded Building Episodes of the Lots within the Seven Hanover Site[111]

| Lot | # of Building Episodes | Dates of Construction | Test Cuts | Notes |
|---|---|---|---|---|
| 9+10+26+27 | 10 | 17th century, 18th century, 1721, 1734, 1751, 1795, 1810-1824 (two structures, joined in 1825, demolished 1853), 1836, 1860 | I, N, AN, AQ, AR, AS, AT, AP, AU, (Lot 10: AA, AB, AC, P, X, K, P, L) | Location of Robert Livingston's House |
| 11+25 | 4 | 1717, 1793, 1836, 1860 | C, H | |
| 12+24 | 6 | 1703-1727, 1727 (lots subdivided), 1727 (lot 24), 1809, 1832, 1836 | B, G, E, AG, F | |
| 13 | 3 | 1703-1709, 1724, 1810 | V, AI, AM, AE, AJ, AK | |
| 14 | 3-4 | 1703-1709, 1724, possibly pre-1810, 1810 | O, Y, AD, AL | |
| 15 | 3 | 1789, 1808, 1815 | A, S, D/W | |
| 19 | 2 | Pre-19th century, late 19th century | R, Q | |
| 28+29 | 4 | 1703, late 18th century, 1806-1813, 1836 | J, M | |

[111] Compiled from *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

**Deposit Types**

The basic premise of stratigraphic succession is that periods of deposition are layered over time so that the lowest layers within a stratigraphy are older than overlying layers. Interpreting stratigraphic deposits is made complicated by the presence of younger intrusive layers from above -- the result of human processes disturbing the natural strata. Archaeologists working on the Stadt Huys and Seven Hanover sites defined strata according to distinctive changes in the soil.[112] Archaeologists also defined "contexts," or the vertical and horizontal positions and associations of an artifact, feature, or other archaeological find within an archaeological excavation.[113] Artifacts collected from these "contexts" were later interpreted to assign date constraints for the deposits. Archaeologists encountered many different types of deposits, including historic ground surfaces (or "horizons"), landfill, cistern fill, privy fill, and impacts of construction episodes. Privies usually contained two deposits: a lower layer of "night soil" deposited while it was in use, and a top layer from when it was no longer in use and filled.[114] Large deposits of building materials were associated with episodes of building demolition. The excavations also uncovered a series of foundation walls, which were used to provide spatial and temporal context for artifacts from strata adjacent to these features.[115]

The Stadt Huys site has a wide range of dates represented in stratified layers with links across the site defining consistent ground surfaces from the early 17th and early 19th centuries. Seven Hanover similarly had layers of undisturbed landfill with documented

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[112] *Archaeological Investigation of the Stadt Huys Block: A Final Report,* Appendix B, 4
[113] Carver, 139
[114] Cantwell, 245
[115] *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*, 8

dates for deposition that provide date constraints when interpreting the artifacts within those deposits.

## Excavation Strategy

For the Stadt Huys and Seven Hanover sites, archaeologists took sample borings from various locations within the site to test for the presence of artifacts and other remains.[116] A backhoe was used to remove the most recent construction and concrete floors, followed by manual excavation.[117] Archaeologists defined a sampling strategy depending on the type of deposit they encountered.

In the Stadt Huys, archaeologists defined a targeted excavation strategy for four types of areas: early structure areas, early backyard areas, modern backyard areas, and the area along Stone Street. For early structure areas, archaeologists placed test cuts in locations for which there were recorded episodes of construction where they were likely to find foundational remains. When they encountered the foundation walls of the Lovelace Tavern, archaeologists placed 25 additional test cuts within lots 8 and 9 "to sample approximately 50% of these late seventeenth-century tavern deposits."[118] Early backyard areas were built over, while modern backyard areas were found undisturbed. Test cuts were also placed along Stone Street and near the corner of Pearl Street and Coenties Alley, the location of the Regina Kellerman Stadt Huys excavation in 1970. Earlier structure walls were found near Coenties Alley, but there were no undisturbed deposits.[119] Two trenches

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[116] *Archaeological Investigation of the Stadt Huys Block: A Final Report*, 8
[117] Ibid.
[118] Ibid., 9
[119] "six test cuts (AN, AX, AY, AZ, BA, and BB) were excavated alongside the walls that were encountered in this area." (*The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*, 11)

on the east and west end of stone street uncovered ground surface deposits dating from early 17th and early 19th centuries.[120]

Archaeologists sorted artifacts into three major categories: “diagnostic”. “non-diagnostic”, and floral/faunal. “Diagnostic artifacts included ceramics, bottle glass, clay pipes, coins, personal items such as jewelry, and other small finds. Non-diagnostic artifacts were building materials and construction/destruction related hardware.”[121] Building materials were categorized as such based on the assumption that they could not yield information useful for dating stratigraphy. As a result, artifacts “such as brick, building stone, coal and cinder, and mortar… were weighed and discarded in the field, with only a sample of the materials actually being sent to the laboratory. The weights of the discarded materials were recorded on the field provenience sheets.”

For Seven Hanover, the total number of “non-architectural” artifacts were compared to “architectural” artifacts in each stratum as a “NA/A” ratio, by weight.[122] This was used to interpret deposits as relating to episodes of building demolition. The mortar collected from these contexts were not analyzed by the archaeologists for their composition or noted for their distinguishable features. Instead, a separate mortar analysis was conducted by consulting specialists for both excavations.

**Mortar Analysis**

Architectural conservators Raymond Pepi and Frank Matero served as consultants for the mortar analysis of the Seven Hanover and Stadt Huys sites, respectively. Pepi’s

[120] *Archaeological Investigation of the Stadt Huys Block: A Final Report*, 12
[121] Ibid., 14
[122] Ibid., 17

analysis was used to date a foundation wall thought to be the remains of the Stadt Huys. The analysis of mortar sampled from that wall "showed that its composition was similar to that of mortar made in the eighteenth and nineteenth centuries."[123] All the mortars in Pepi's analysis were sampled directly from architectural features. The study listed several limitations to mortar analysis, stating "It is usually acknowledged that mortar investigation is not a reliable method for dating purposes; it is rather a comparative tool."[124] While it may not have been an accessible resource at the time, petrographic analysis could have been used to identify later binder technologies with known periods of use and development, such as portland cement, that could serve as a date constraint. Instead, Pepi used the method of acid digestion for sand extraction, which provided visual comparative analysis that was used to make general associations within the sample set.[125] Pepi concluded that "The more information we find and catalogue about materials used, construction techniques, mortar content, etc., the easier it will be to date walls. Right now there is only isolated data rather than the quantity needed to produce more reliable conclusions about 17th and 18th-century building techniques."[126] If they had been analyzed, the mortar samples collected from the stratified deposits of the Stadt Huys and Seven Hanover excavations could have provided the needed quantity for a wider sample set, which could have provided additional information for the interpretation of the archaeological site.

[123] Wall, 112
[124] Dierickx. 1
[125] Ibid., 10
[126] Ibid.

In the years following the excavation, the architectural finds from both excavations were given to the Center for Building Conservation (CBC), at the time based in the South Street Seaport. In the following years, however, the CBC disbanded and as a result the architectural material collection remained at the South Street Seaport Museum with no long-term plan for storage. Other artifacts, including "ceramics; table and bottle glass; pipes; metal, bone, and stone artifacts; faunal, floral, and soil samples" were moved to the Department of Anthropology at Columbia University in 1985 and were later transferred to the Nan A. Rothschild Research Center, where they are still housed today.[127]

**Data Set**

In the process of selecting samples for this research, test cuts were chosen based on their potential for containing early mortars as well as undisturbed stratigraphic deposits spanning several time periods, which could potentially reveal trends and transitions in binder technologies. Additional information on this sampling strategy is included in Section 5.

The mortars sampled from the Stadt Huys collection included those associated with the test cuts along Stone Street: test cuts CA, BZ, CB, and CC. [Appendix C] These test cuts had the potential for containing mortars spanning various time periods, as "Stone Street has been in continuous use as a thoroughfare… from the 1640s until the construction of 85 Broad Street in 1980."[128] Stone Street was realigned in 1656 and widened in 1838, and so there were well-defined markers within the stratigraphy to provide a general date

[127] *Archaeological Investigation of the Stadt Huys Block: A Final Report*, 6
[128] Ibid., 270

constraint.[129] Test cut BZ contained stone wall remains, but was significantly disturbed by 20th century construction. Test cut CA contained mixed deposits from a 1907 construction, including foundation wall remains potentially dating to that year, as well as builder's trenches and other intrusive layers potentially disturbing this context. Test cut CC included foundation wall remains from before the 1830s street widening.[130] Test cuts CC and CB were connected by a mid-17th century ground surface.[131] This was represented in stratum 23 in CC and 19 in test cut CB. The Stadt Huys report states that "the deposit on the south side of the street contained building materials (such as window glass and nails) present at three times the density of the corresponding stratum in test cut CC (30.7 architectural artifacts per cubic foot in CB as compared with 10.1 in CC). This suggests that the southern side of Stone Street in the area of Test Cut CB may have been developed during the period when this surface was in use."[132] This is corroborated by depictions of the settlement from between 1656 and 1661 that show the south side undeveloped.[133] There is a gap in the stratigraphy for the second and third quarters of 18th century, probably a result of grading for late eighteenth and early 19th century sidewalk and pavement beddings.[134]

Other samples collected from the Stadt Huys include those associated with the Lot 9 Backyard: test cuts AO, AR, and T. These cuts contain a stratigraphy of deposits spanning 17th and early 18th to mid-19th and early 20th centuries. They also contain privy and cistern structures, with fill deposits.[135] As cisterns were constructed to store rain water,

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[129] Ibid., 271
[130] Ibid., 287
[131] Ibid., 307
[132] Ibid., 210
[133] Ibid., 308
[134] Ibid., 313
[135] Ibid., 192

they were built to hold the weight of water and lined with mortar to be water-tight.[136] These structures were likely to use hydraulic mortars during later periods, which are of interest for this study. Lot 7, containing test cuts AP and F, included a brick feature and a mid-17th century ground surface associated with strata in CC and CB.[137] Also sampled were mortars from test cut AH (lot 6) and test cut O (lot 17), as they both contained foundation walls from 17th century constructions.

From the Seven Hanover collections, Test cut G (lot 12) included a cistern feature with layered deposits from late 18th and early 19th centuries.[138] Test cut J (lot 28) contained a construction sequence of floors, dating from 1805, 1836, and post-1857, which were supported by round logs and fill.[139] This test cut also includes mortars from a privy with two fill deposits. Finally, mortars from test cut I (lot 9) were sampled based on an association with two landfill deposits from early and late 17th century.[140] This cut also contains a brick floor construction dated to 1824, with leveling deposits beneath, as well as a complex of foundation walls dating from before the 1835 fire.[141]

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136 Ibid., 249
137 Ibid., appendix M, 3
138 *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*, 167
139 Ibid., 331
140 Ibid., 38
141 Ibid., 46

## 5. Methods of Analysis

The following section provides a review of the current methods of mortar analysis used in the fields of architectural analysis and archaeology. Mortar analysis in these two fields may be guided by disparate goals. However, common methods of analysis are used in both fields for similar purposes. As composite materials, mortars should be analyzed using targeted investigative methods. Most bulk analyses do not allow for an interpretation of the data as it relates to a specific component in a mortar sample. Both architectural conservators and archaeologists consider this limitation when selecting methods of analysis.

**Methods of Mortar Analysis in the Field of Architectural Conservation**

Mortar analysis is commonly implemented for use in architectural analysis. These analyses are usually focused on documenting original materials in a building. Methods of analysis are chosen based on their ability to characterize mortar constituents and mix design. This information is used for informing the performance and durability of mortars in built structures. It is also used for informing the compatibility of repair materials. Mortar analysis are mainly conducted by specialists using a toolkit of investigative techniques.

Benchtop methods, such as acid digestion, require minimal equipment and are commonly used for making general characterizations of the sands within the mortars. Acid digestion was initially developed in the 1970s by E. Blaine Cliver.[142] His procedure involves dissolving mortars in dilute HCl and observing the digestion and residues as a method

[142] Cliver, 68

ostensibly for characterizing binder.[143] Acid digestion is more commonly used for extracting sands to make visual observations on color, mineralogy, inclusions, additives, and pigments. This analysis assumes that only the binder has been dissolved. This is not the case for mortars with shell aggregate, which will dissolve in acid, and result in a sample that is not an accurate representative of the original aggregate.[144] This method is also destructive of the sample's microstructure, which can be critically informative for characterizing mortars.[145]

Another method of analysis commonly implemented in the architectural analysis of mortars is petrography, using polarized light microscopy. This is based on the principle that crystalline minerals refract light. This creates an optical effect that can be used by the petrographer to identify specific mineral groups.[146] Petrography allows for direct observation as a magnifying tool to detect fine artifacts and microtextural relationships.[147] It is especially useful as the microstructure is preserved and visible in cross section. This allows for the evaluation of artifacts in situ and in relation to the surrounding matrix. Petrography is useful for informing other methods of analysis. For example, it can be used to distinguish acid-soluble and base-soluble species, as well as secondary reactions, which can inform a sampling procedure for chemical analysis.

Chemical analysis is implemented for identifying the chemical composition of binder constituents. It is also used for determining the weight proportions of binder to aggregate and volatile species (such as water and carbon dioxide). Chemical analysis requires

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[143] Ibid.
[144] Krotzer, 43
[145] Ibid.
[146] Ibid., 44
[147] Ibid.

separating the various components of mortar, using multiple methods. These soluble components can then be analyzed with some type of spectrometer. ICP-OES is an example.[148] Once the components are identified through petrography, the chemical composition can be accurately reverse-engineered to calculate the original mortar mix design.

Scanning electron microscopy (SEM), provides three-dimensional images of microscopic areas to assess textures and shapes of minerals, within fractured sections.[149] EDS (electron dispersive spectra) is an application of SEM that can be used to produce elemental maps within a microscopic area.[150] This analysis offers targeted elemental information.

**Methods of Mortar Analysis in the Field of Archaeology**

Archaeological excavations often include the study of architectural remains. Mortar analysis is implemented as a tool for analyzing architectural features in many of the same ways as architectural analyses. Archaeologists primarily implement mortars as a tool for dating architectural remains, as well as for identifying phases of construction. Archaeological projects that include mortar analysis mainly involve sampling mortar off of architectural features to confirm building phases.[151] Mortars are also used to "identify and classify the different vernacular techniques for producing mortar over history in a given geographical region… going on to classify and date constructions for which there were no

[148] Oliver, 486
[149] Adriano, 58
[150] Ibid.
[151] Chiarelli, 442

recorded data."[152] The benefits of using mortar for architectural analysis are commonly understood in the field of archaeology, as it is "an omnipresent and non-recyclable material whose making is undoubtedly contemporary to the building process."[153]

Many of the methods archaeologists use are the same as those applied in architectural analysis. These can include polarized light microscopy and trace elemental chemistry. Archaeologists often integrate petrography as an initial characterization method, which is then used in conjunction with other analytical methods.[154]

Archaeologists commonly work with ancient materials, and so mortars analysis is often done through dating techniques that are more accurate with older materials. For example, Optically Stimulated Luminescence (OSL) uses radiation dosimetry to measure the last time a mineral was exposed to light. This is applied to quartz and feldspar grains from the sand in a mortar sample.[155] This method has many limitations, however, as inadequate exposure to light during the processing of sand for mortar can result in an overestimated age.[156] This method is generally applied for authenticating original materials and identifying different periods of construction in a building.

Another analytical method that archaeologists commonly implement for the analysis of mortars is $C_{14}$ radiocarbon dating. This method is based on the principal that radioactive carbon decays at a known rate. Different materials exchange carbon with the atmosphere, and an age can be estimated from time this exchange stops. In organisms this is the age from the time of death. In lime binders, it is the age from the point it has fully

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[152] Garcia-Esparza et al., 83
[153] Urbanova et al. (2018), 307
[154] Ibid., 312
[155] Ibid., 308
[156] Urbanova et al. (2015), 100

carbonated. There have been mixed results on the use of $C_{14}$ dating for lime binders. A study by Hajdas et al. in 2017 demonstrated that it is possible to get consistent dates amongst different laboratories using this method.[157] While the dates are precise, one cannot be sure of their accuracy. In mortars, $C_{14}$ dating is best applied to the analysis of once-living inclusions such as shell, wood cinder, and charcoal.[158]

## Research Design

In designing a strategy for sampling a data set of mortars for this research, it was important to acknowledge the limitations of the information represented in the archaeological reports. As they were excavated, the mortars from the Stadt Huys and Seven Hanover sites were recorded by weight and then bagged and labeled with the context number from which they were found. Besides weight and context number, no additional information was recorded for the mortars sampled from the stratified deposits of either site. Considering this, as well as the limitations of time for this research, a targeted selection of mortar samples was guided by the recorded interpretations of the stratified deposits with which the mortar fragments were associated.

Mortars associated with test cuts containing deposits dating from the 17th century were selected for sampling from both archaeological collections, as well as those with undisturbed stratigraphic contexts spanning several time periods. Archaeological field reports from the Stadt Huys and Seven Hanover excavations were referenced for the recorded weight and number of mortars collected. All mortar fragments within the same

157 Hajdas et. al.
158 Mathews, 395

context number were bagged together. In cases where there were several mortars of different compositions under the same context number the sample was denoted with a letter (ex. 332a). As most building materials were discarded in the field, many catalogue numbers contain less mortar than was documented. For context numbers that had a large amount of mortar with a high visual similarity, only a partial sample was taken. Otherwise, all mortar was collected from each of the context numbers within each test cut.

Research methods were chosen based on their ability to identify compositions of samples and their process of manufacture, as well as to identify mortars from the same era or construction episode. Results of these analyses were used to identify transitions and periods of use for different binders. Mortar samples were categorized into groups according to their composition. Mortar samples were also correlated to the dated context of the strata from which they were sampled.

First, a visual analysis was conducted for all of the collected samples. Mortars were grouped based on the similarities of particular features, such as hardness, water absorptivity, acid solubility, color, and inclusions. Low-powered microscopy was used to help identify inclusions and characterize the sands. However, this method does not enable an accurate identification of the binder source and composition, or other characterizing features that are not visible from a low-powered microscope. And so, other methods were used to confirm and further characterize mortar groupings.

A sand separation was conducted for all mortars samples that were large enough to provide at least 10 grams for the analysis and still save a representative piece for continued visual analysis. For each of these mortars, a partial sample was digested in a 10% solution

of hydrochloric acid to provide a clean view of the color and texture of the aggregate. The sands were then graded using sieve sizes specified for masonry sands in ASTM C144.

Petrographic analysis was limited by the cost of sample preparation, and so several representative samples were selected from each of the groups defined by the visual analysis and sand extraction. Any samples from a well-defined stratigraphy were also chosen for this analysis. Petrography was used to provide a magnified view of the microstructure within undisturbed binder lumps as well as to conduct a mineralogical analysis of the sand. Mortar samples were prepared for thin section by casting in a blue-dyed epoxy resin to highlight pores, voids, and cracks. As the thickness of the thin section affects the interference colors displayed through polarized light, all samples were milled to 27-28 microns thick. This allowed for the direct visual observation for the characterization of binders, aggregates, and their microstructural relationships. This method was primarily used to identify binders, as well as to characterize mortars of the same construction or similar composition.

## 6. Data

### Shell Lime Binders

Shell lime binders have distinct characteristics that can be differentiated from other lime binders through petrography. Within the data set that was chosen for petrographic analysis, 39 samples were identified as having characteristics of lime binder sourced from mollusk shell. [Table 3, Appendix D] The mortars within this group, when observed in hand sample, all have disaggregated shell fragments of about 1 cm in size and below that are visible by eye. These samples have the following characteristics when observed petrographically: unfired shell fragments, partially burned shell fragments, and texture representative of relict shell microstructure in undispersed binder lumps. Unfired shell fragments consist of calcium carbonate, seen microscopically as laminated layers surrounding a prismatic columnar structure. [Figure 1] The microscopic fabric is consistent with that of oyster shell. This texture was observed in shell fragments that were prevalent throughout the samples in this grouping.

In Sample 1631, there is a surface plane with two adjacent layers of mortar. The shells in both layers are oriented parallel to each other and to the surface plane. This indicates that both layers were similarly compacted. This is more consistent with a surface finish where multiple layers were successively built up, such as in a plaster or stucco.

The presence of shell fragments alone does not necessarily indicate that the binder was produced from a shell source. However, there are other petrographic observations that allow this conclusion. In 31 samples, fine spheres of submicroscopic calcium carbonate were observed within the boundary of the shell fragment that are texturally different than

the surrounding shell. [Figure 2] These spheres are zones of incipient calcination that have slaked and carbonated while the rest of the shell remained unaffected. These features are evidence for exposure of the shell fragment to high temperature.

In many of the shell lime mortars, the unfired shell fragments usually only occur as discrete particles that are at least several hundred microns in size. However, 15 of the samples in this grouping contain single crystals of calcium carbonate in the size range of tens of microns that are evenly distributed throughout the carbonated lime binder. These fine particles are fragments of the inner columnar structure of a mollusk shell. In the firing process, the structure disaggregates around grain boundaries, and the fine particles are then dispersed throughout the binder. These fines are unfired and so they have not completely broken down to the texture of the fully fired lime paste. In Sample 304, these particles were observed to be prevalent throughout the binder matrix at a higher concentration than in the other samples.

A feature common to all of the samples within this group were long, fine, irregular parallel separations within the binder lumps, similar in size and texture to the unfired shell inclusions. [Figure 3] A crude mixing of the binder paste will result in binder lumps than have not been disaggregated. As a result, when viewed microscopically, undisturbed lumps of shell binder have a preserved texture of the shell. These features can be used diagnostically to identify a lime binder sourced from shell.

Within the shell lime grouping were samples that also contained glass fragments (fired quartz sand) that were thin, concave, and plate-like, and matched the scale and form of the shell inclusions within the sample. [Figure 4] This glass sometimes contains vesicles and relict quartz particles. The glass is interpreted to be the result of firing unwashed

shells, possibly from middens or beaches where sediment could have accumulated and adhered to the shell surfaces. When fired in a pit or kiln, the adhered sand begins to melt and the molten portion quenches to form a glass upon cooling. These pieces of glass are then incorporated into the binder matrix.

Some samples within this grouping also contained carbonaceous inclusions of wood cinder. These inclusions are not an inherent characteristic of shell lime binder but would have been introduced in the process of firing. These inclusions were observed in the sample as having a cellular texture and this distinguishes the cinder as a wood derivative rather than coal. The carbonaceous inclusions are introduced to the binder as a result of the inadvertent mixing of the fuel into the source materials in either a pit fire or intermittent kiln. In earlier settlements, wood was the most likely fuel source as there was an abundance of locally available wood that was easy to process. Coal is not likely to be used as a fuel source until later developments, as it had to be mined and transported from non-local deposits.

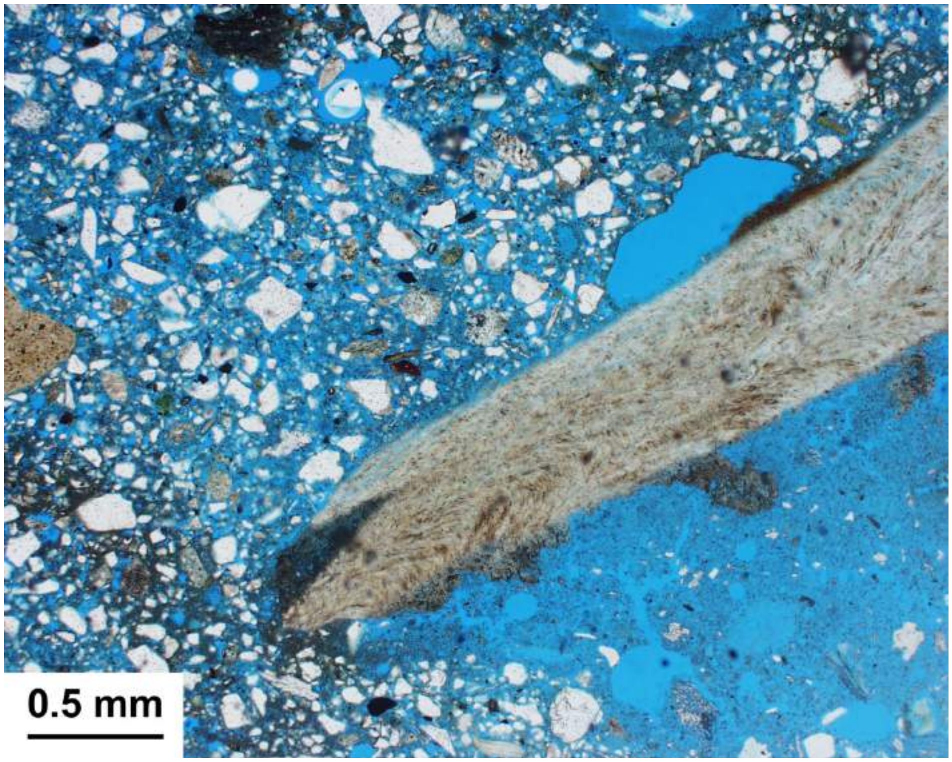


Figure 1. Sample 1132. Unfired shell fragment with laminated texture. Plane polarized light.

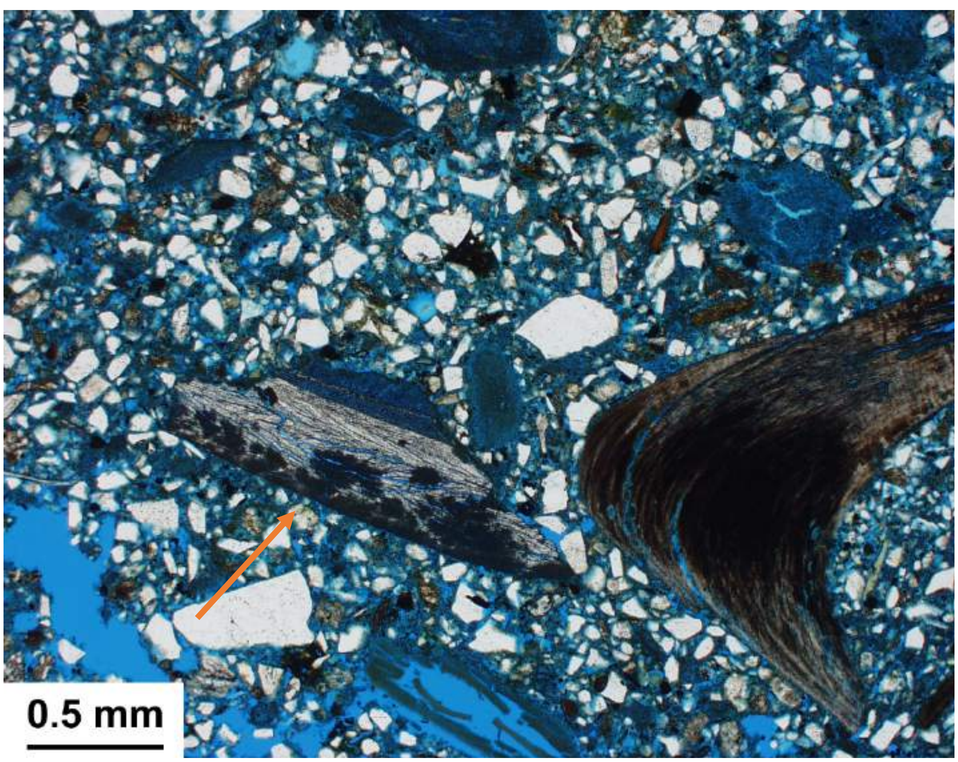


Figure 2. Sample 1652. Shell fragment with zones of incipient calcination. Red arrow. Plane polarized light.

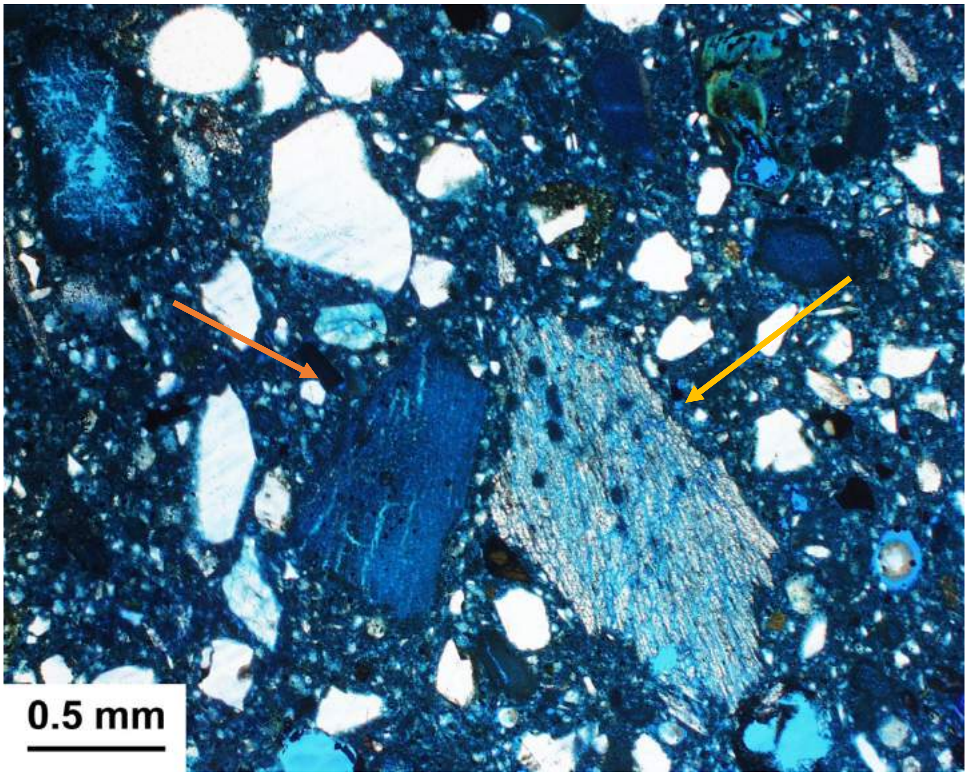


Figure 3. Sample 1657. Laminated shell texture in undisturbed binder lump. Red arrow. Partially calcined shell with prismatic texture. Yellow arrow. Plane polarized light.

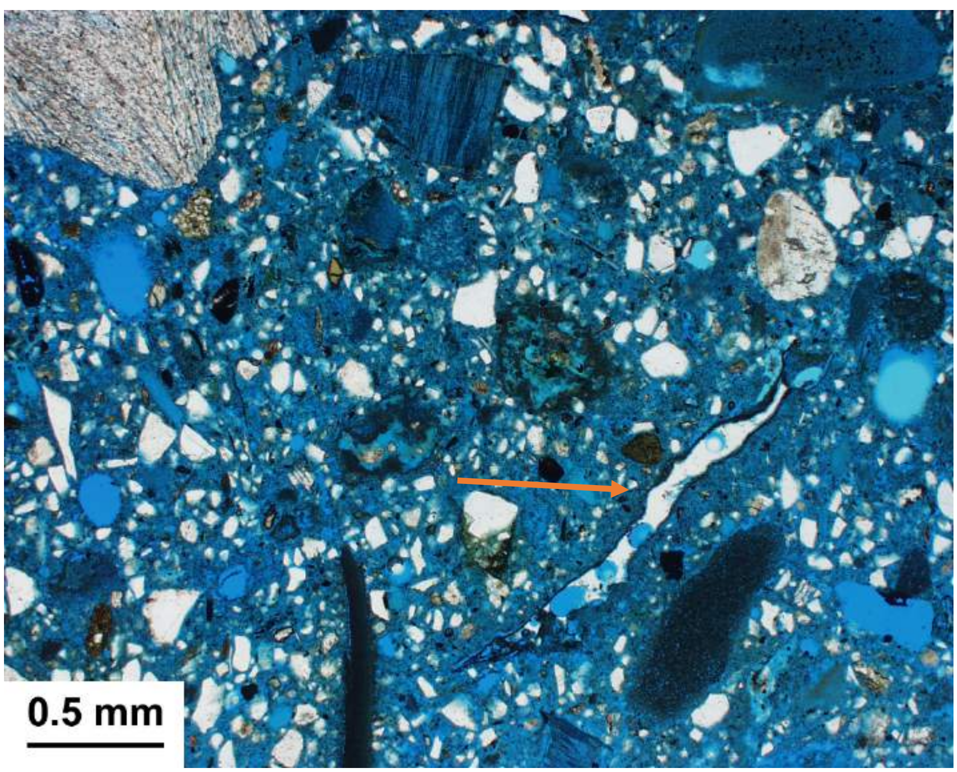


Figure 4. Sample 1766. Glass fragment. Red arrow. Plane polarized light.

**Rock Lime Binders**

In the mortars interpreted to contain a rock lime binder, undispersed lime grains within the paste sometimes have an internal texture that is uniform and featureless. However, it is also common to observe lime grains that have some type of distinctive microstructure. Often the structure is defined as partings or cracks. In other cases, there are variations in the internal degree of carbonation and associated densification that result in other textures. Binder inclusions with random partings and cracks can reflect the expansion that takes place when the lime slakes. [Figure 5] The morphology of the cracks does not appear to be related to any pre-existing structure within the original lime rock. This texture was observed throughout the data set, but was particularly well-represented in Sample 256 as fine irregular lines up to 250 microns in length that are irregularly spaced from one another. In contrast, many of these mortars have lime grains containing distinct geometric patterns. These are representative of the original grain boundaries of crystals in the source rock or internal mineral cleavages that, once fired, can still be observed. Parting along these discrete boundaries can occur in the kiln when the lime is fired or they can develop as preferential weaknesses when the lime is slaked. In relict structures that are defined by carbonation, it is probable that these pre-existing weaknesses were more convenient pathways for carbon dioxide. Importantly, these characteristic binder textures can be used to distinguish rock sources from shell sources. Further, the variability in the observed microtextures reflects a similar variability in the types of rock lime used in the samples investigated in this study.

Lime grains having a mosaic texture consisting of regular, bound polygonal shapes with linear edges was observed in 18 of the samples within the data set, listed in Table 4,

Appendix D. A clear example of this texture was seen in Sample 201 as a grouping of polygons of various shapes fitting together with thin lines of separation between them. [Figure 6] These shapes span a range of sizes, from 100-250 microns in diameter. These shapes make up the entire binder lump. While the texture is clearly relict of a rock source, the specific type of stone is not clearly distinguished. Limestone, dolostone, and marble can all have this type of mosaic texture.

A rhombic texture is a special case of the polygonal texture that was observed in Sample 689. [Figure 7] It is distinguished by sharp linear edges that define randomly oriented rhombic forms. The rhombs are of uniform size, about 100 microns in diameter, at various orientations, making up the entirety of the binder lump. This texture is representative of the original crystal boundaries that are seen in dolomitic rocks. This same texture can be seen in an incompletely fired particle in Sample 1106, which shows that it is representative of the original rock source. Specifically, the texture is associated with a sedimentary dolostone and not a dolomitic marble.

Some of the observed partings within binder lumps are not reflective of crystal boundaries but of internal cleavage texture. This was observed as one or two sets of parallel lines at acute angles to one other, forming rhombic patterns. An example of this texture was seen in Sample 177a as a grouping of three distinctive parallel lines oriented at an acute angle to a group of two parallel lines. These lines ranged from about 250 to 750 microns in length, spaced at varying distances. This pattern is distinguishable from rhombic or mosaic textures as the partings do not meet to inscribe polygonal shapes, and all of the partings are perfectly parallel to another. This texture is instead representative of the three-dimensional cleavage pattern characteristic of calcite and dolomite.

In the characterization of rock lime binders sourced from fossiliferous limestones, there are a wide variety of the fossil textures that one could observe, depending on the type of fossil inclusions included in the source rock. One specific example of a texture that may be representative of a relict fossil texture was observed in Sample 323. A binder lump within this sample contained a spiral texture, about 2.5 mm diameter. Radially disposed lines produce segments within the spiral and these lines are concave toward the center of the spiral. This structure is typical of gastropod shells. One could speculate that this binder was a shell lime derived from a source rich in snail shells. However, other binder grains within the sample contain a mosaic texture indicative of a rock lime. There is also a lack of unburned shell fragments or similar evidence for a shell lime. With that said, the lime in this sample is interpreted to have been fired from a fossiliferous limestone.

In rock lime sources, such as limestone and marble, dolomite and calcite are the components which produce lime upon burning. However, dolomite and calcite are only partially representative of the various mineralogical constituents that may be present within a rock. These may include minerals that do not decompose at the firing temperature needed to produce lime. As a result, the relict mineralogy of a source rock can be seen distributed throughout a lime binder. These mineralogical impurities are indicative of a rock lime.

One example of a relict mineralogy is quartz, which was seen in the binder of twelve samples. These appear as dispersed grains, each surrounded by a faint halo, within the binder matrix. [Figure 8] The quartz is primarily fine-grained. However, coarse-grained quartz with this halo was also observed in Sample 149. This halo is a reaction rim between the quartz and uncarbonated lime. When fired, the quartz undergoes high temperature

phase changes and the silica is then free to react with the calcium oxide in the lime. This could result in the formation of a calcium silicate. With this understanding, one can interpret a halo with no remaining unfired quartz as having undergone the full reaction. These artifacts are distinguishable by the same features described above, but are seen as dark spots with surrounding halos within the binder grain. These were observed in samples 1672, 1675, 186a, and 189. Quartz is a mineral common to both limestone and marble. When these rocks are fired in the process of lime production, the texture of the relict quartz does not distinguish its source. It does, however, distinguish rock lime, as opposed to shell lime.

Another mineral distinguishable as a relic of a rock source is mica. This mineral was observed in Sample 1080b as a tabular fragment with linear, parallel cleavage texture. It is surrounded by a faint halo, which is indicative of firing, and so it is likely a relic of the binder source. Mica may be present in both limestone and marble. However, when it is coarser grained and clustered it is more indicative of a marble source. Additional evidence for marble lime seen in this sample is the presence of undifferentiated burned silicates. These appear as high-relief particles with discreet granules and yellow birefringence surrounded by a faint halo. While the type of silicate is undistinguished, it is some kind of high-temperature forming mineral that is commonly seen in marbles.

Two other types of high-temperature silicates were observed in three of the samples within this grouping. In Samples 641a, 664, and 177a, pyroxene was seen within the binder lumps and in the finish of Sample 664. [Figure 9] In each of these samples, there are pyroxene minerals that have a rounded shape. The pyroxene observed in these samples is representative of a marble source for the lime binder. Olivine was observed within the

binder lumps of Samples 664 and 177a. This mineral is unlikely to be introduced to the mortar as part of the sand because it is unstable in the sedimentary environment and is more susceptible to weathering. Therefore, it is certainly representative of a marble lime binder.

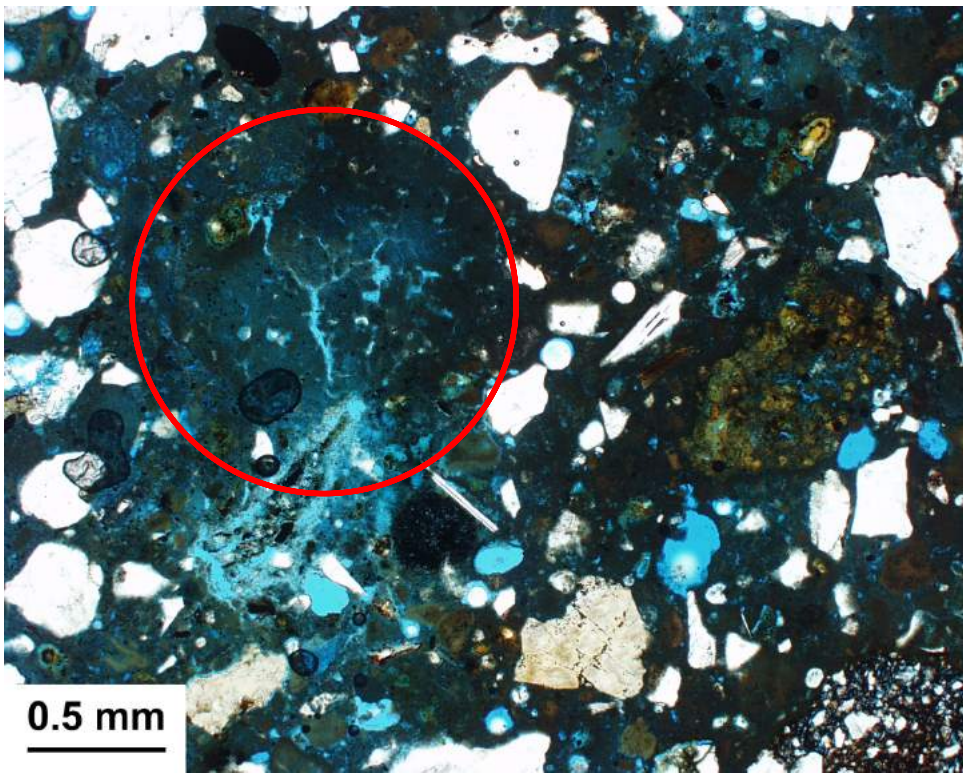

Figure 5. Sample 256. Binder with expansion partings. Circled in red. Plane polarized light.

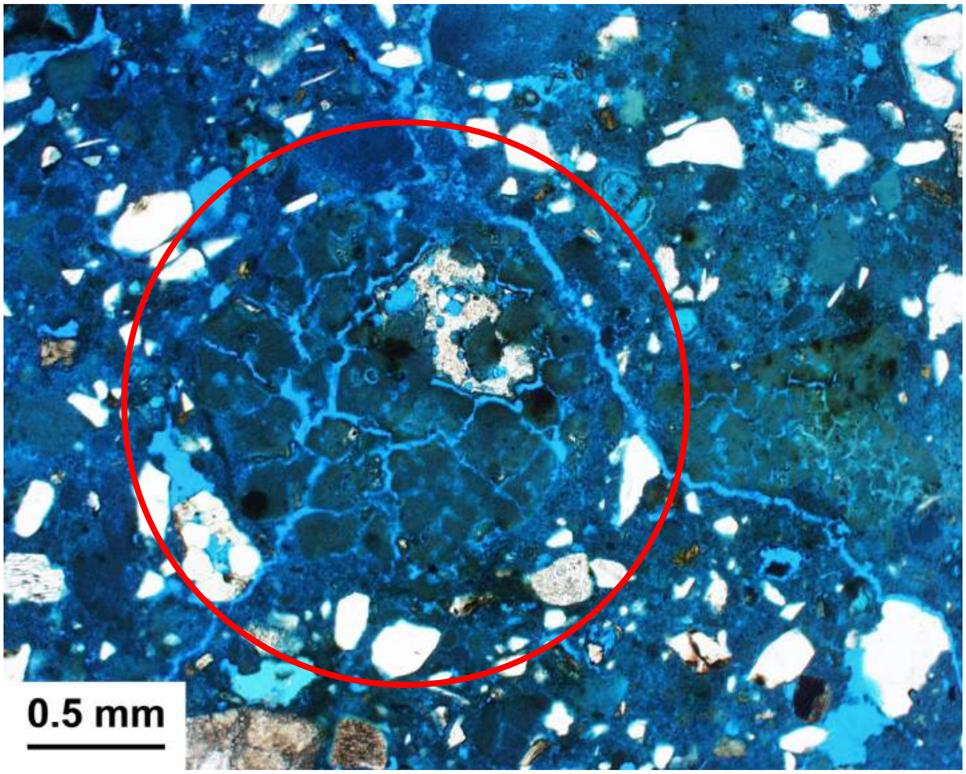


Figure 6. Sample 201. Binder with mosaic texture. Circled in red. Plane polarized light.

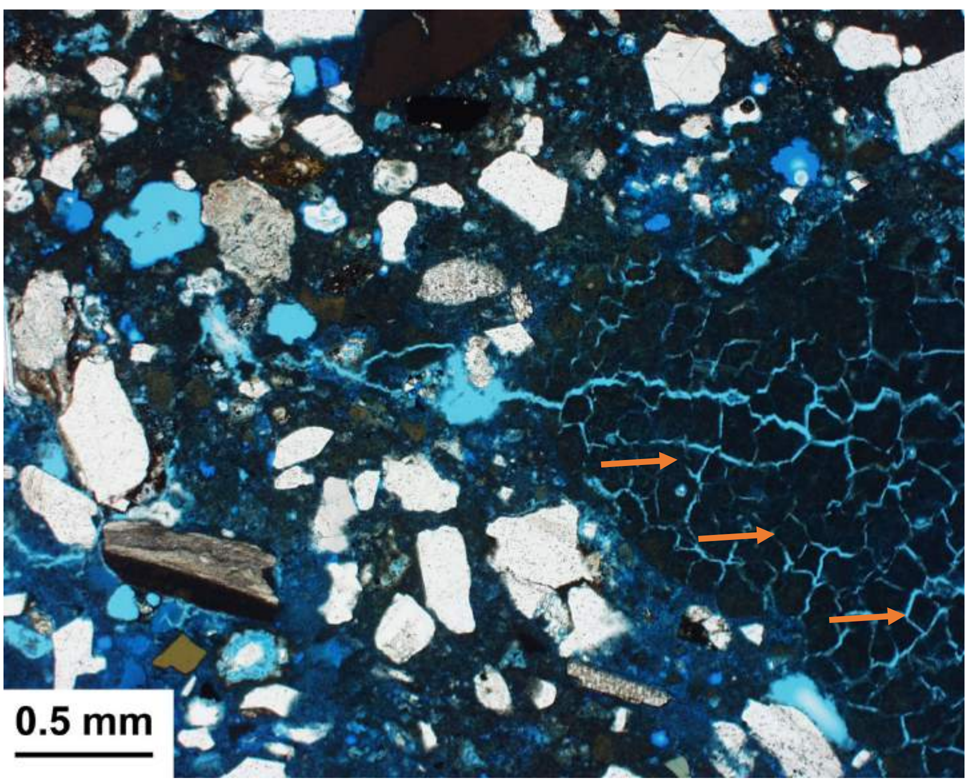


Figure 7. Sample 689. Binder with rhombic texture. Red arrows. Plane polarized light.

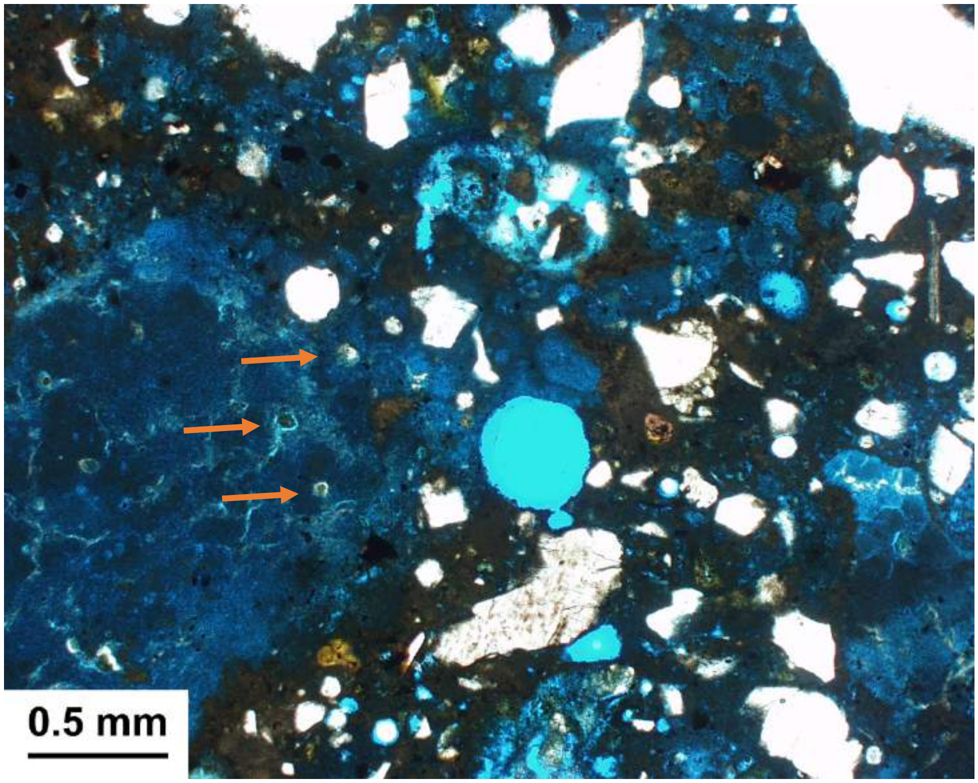


Figure 8. Sample 242b. Quartz grains with halo. Red arrows. Plane polarized light.

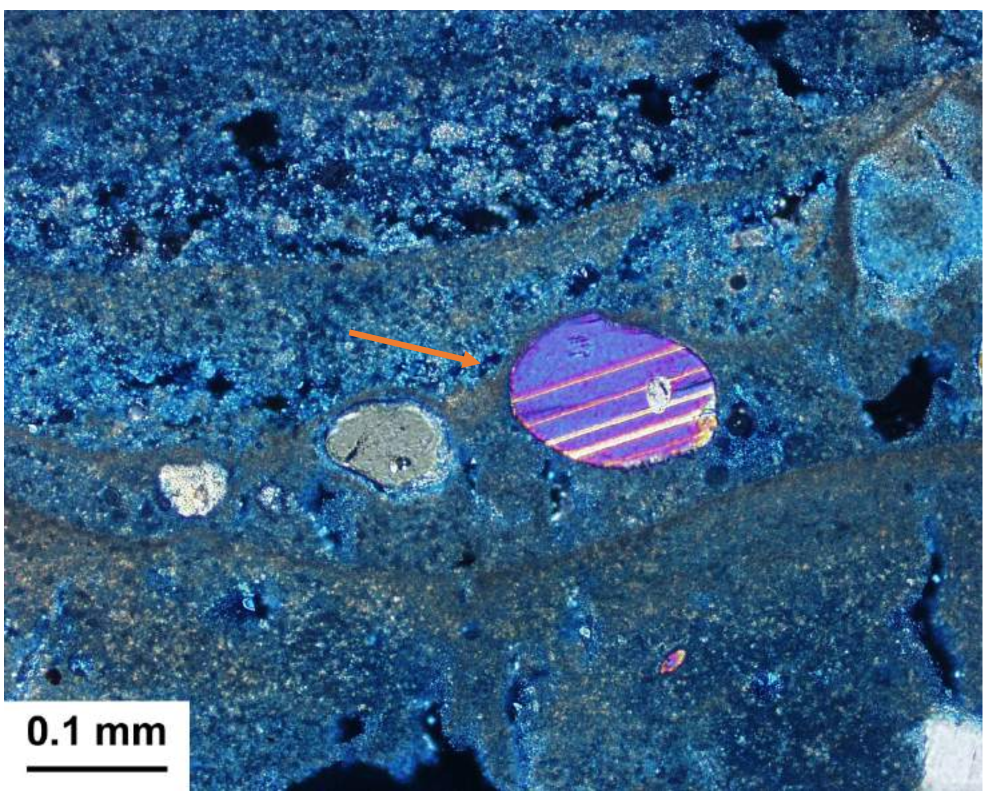


Figure 9. Sample 664. Pyroxene in a finish layer. Red arrow. Cross-polarized light.

**Natural Cement**

In three of the samples within the data set (Sample 628a, Sample 628b, and Sample 1733), binder grains with distinctive features characteristic of natural cement were observed. Natural cements are usually sourced from magnesian carbonate rocks, such as dolostone, that contain a high amount of quartz and clay.[159] The silica and alumina introduced by the quartz and clay, respectively, are responsible for the hydraulic properties of natural cement.[160] When burned, the dolomite in the dolostone calcines while the quartz and clay react to form hydraulic species. With both of these processes taking place, the binder paste appears patchy with dark areas of hydrated material and bright areas of carbonated material. This patchy quality was observed in all of the samples within this grouping. Natural cement grains can also contain the relict mineralogy of the source rock. Unfired quartz was observed within the cement grains of each of these samples.

In Sample 628a, the cement grains have a reddish coloration and a mosaic texture. [Figure 10] These grains are distributed throughout the binder paste and are consistently sized to about 500 microns in diameter. Similar to what is observed in rock lime binders, the texture within a natural cement grain can be representative of the original microstructure of the source rock. This texture is retained because the firing temperature for natural cements is not high enough to clinker and destroy the original microstructure.[161] While this texture can be distinctive, it is highly variable between rock sources. Therefore, natural cements can have a wide range of characteristic textures.

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159 Walsh, 8
160 Ibid.
161 Ibid.

The cement grains in Sample 628a are surrounded by a bright, homogeneous matrix that is characteristic of carbonated lime binder. This indicates that the sample is a mix of both lime and natural cement. In Sample 1733, both a natural cement grain and streak of lime binder were observed within the mortar, indicating that it is also a cement-lime mix.

Sample 628b contains two layers of mortar and a layered finish. [Figure 11] The binder matrix in both of the layers of mortar have a patchy texture that is characteristic of a natural cement paste that is consistent throughout. The finish contains three layers of cementitious washes. The reddish coloration, patchy texture, and relict quartz minerals within these layers indicates that they are natural cement finishes.

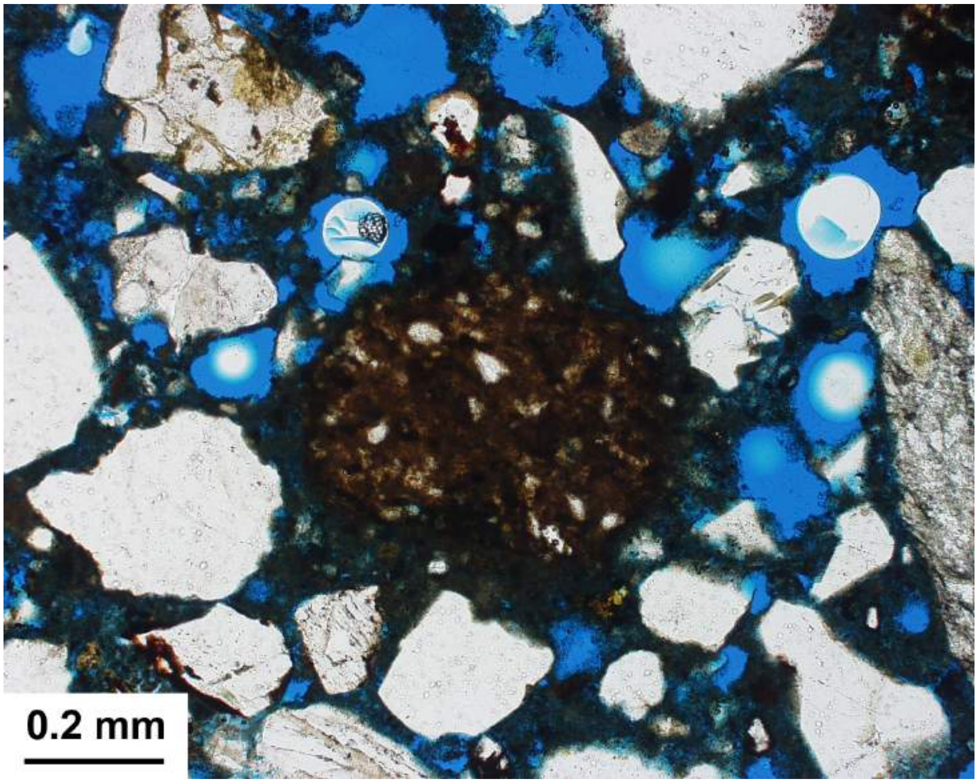

Figure 10. Sample 628a. Natural cement grain with quartz relics. Plane polarized light.

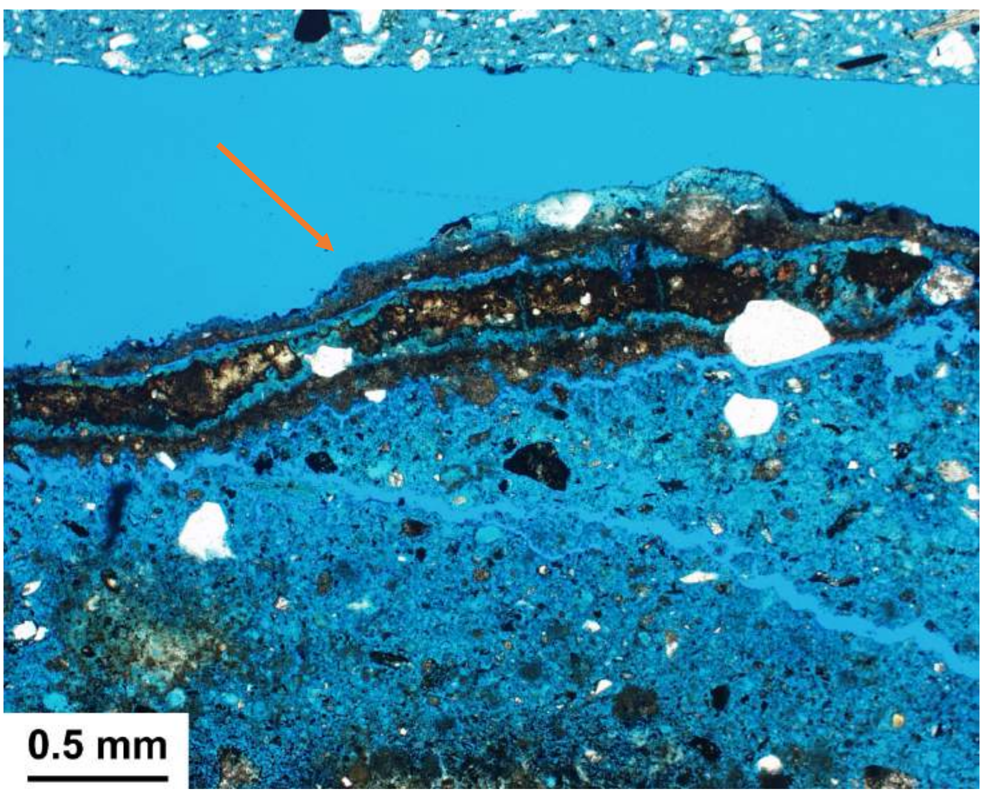

Figure 11. Sample 628b. Natural cement finish. Red arrow. Plane polarized light.

**Portland Cement**

Four samples were observed to have characteristics of portland cement. Portland cement is produced by firing source materials, including ground limestone and shale, at high temperatures in a process called clinkering. This process causes the calcium silicate minerals to become reactive. When hydrated, the minerals dissolve and form calcium silicate hydrate, which makes up the majority of the portland cement binder. Before hydration, ground portland cement consists of calcium silicate agglomerates with an interstitial matrix of iron-bearing ferrite.[162] The residual texture of the hydrated minerals can be visible within the remaining ferrite. These agglomerates are present in all of the samples of this grouping, and can be used to confirm that a binder is portland cement.

Sample 1645 contains a homogeneous dark isotropic matrix of hydrated material. This can be differentiated from the bright matrix in carbonated lime and the patchy texture in natural cement. This sample contains agglomerates with a residual texture of clustered grains that have a rounded shape. This is characteristic of the mineral belite, which is commonly seen in portland cement particles. These belite residuals are regularly sized. [Figure 12] The majority of the agglomerates in this sample fall between 80 to 150 microns in diameter. However, there is also a significant amount larger than 150 microns. These agglomerates are prevalent throughout the binder.

In Sample 200, cement grains were observed within a lime binder matrix. This indicates that the sample is a cement-lime mix. The agglomerates in this sample are consistently-sized between 80 to 150 microns in diameter. The agglomerates also contain regularly-sized residuals of belite minerals.

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[162] Walsh, 4

In Sample 641c, the portland cement paste is fully carbonated. This sample also contains agglomerates of former calcium silicates.

Sample 1784 is a portland cement mortar with agglomerates that are sized similarly to those in Sample 1645. However, this sample has a concrete that is adhered to it. [Figure 13] This concrete has a binder matrix that is characteristic of portland cement. It also has inclusions of glassy material with vesicles. These are identified as boiler cinder. Boiler cinder was commonly used as an aggregate for suspended concrete slabs in the early 20th century. The adhered portland cement mortar was likely a topping layer for a floor construction.

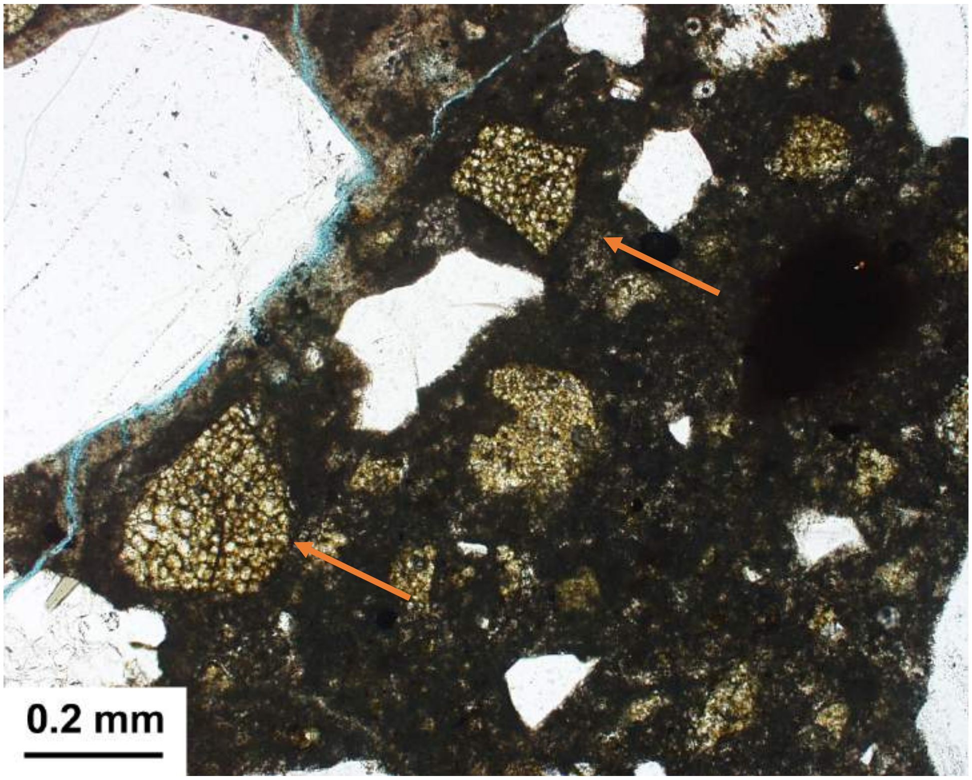


Figure 12. Sample 1645. Agglomerates with belite residuals. Red arrows. Plane polarized light.

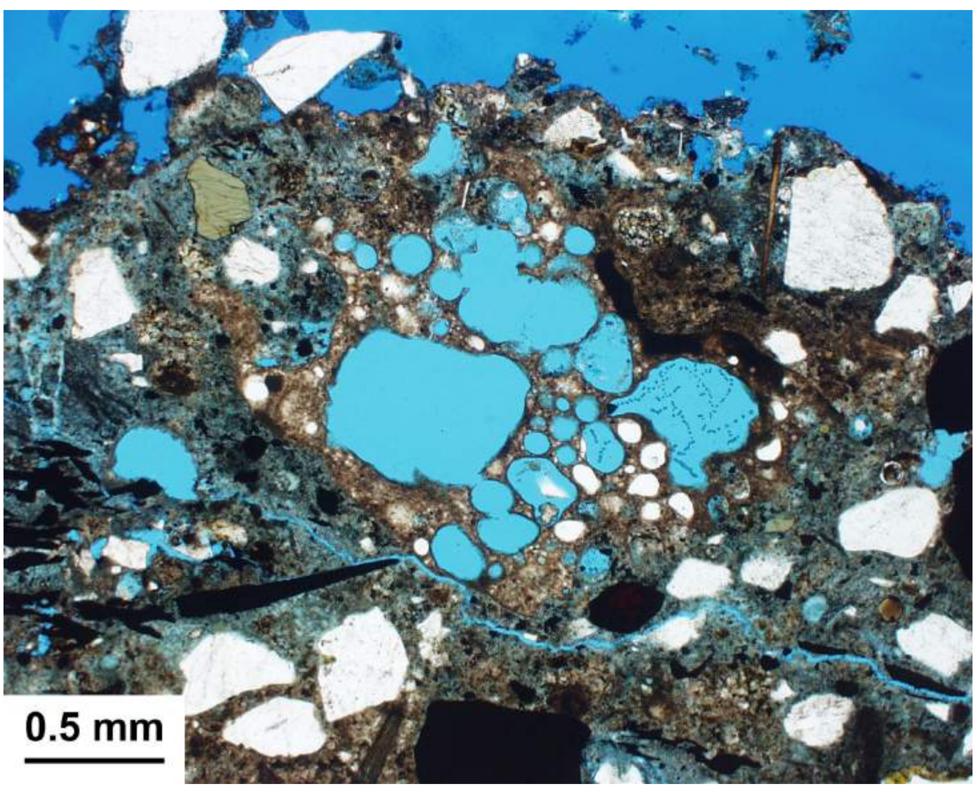


Figure 13. Sample 1784. Concrete with boiler cinder aggregate. Plane polarized light.

**Sand**

Groupings of similar sands were identified through petrographic analysis. This involved the characterization of mineralogy, gradation, and proportion of sand to binder. Aggregates were categorized as silt (less than 60 microns), fine-grained sand (60 to 250 microns), medium-grained sand (250 to 500 microns), and coarse-grained sand (over 500 microns). Sand extractions on a selection of mortars reinforced the groupings that were made through petrographic analysis. [Table 5, Appendix D] Extracted sands were characterized by their color. The sands were then graded using the sieve sizes specified for masonry sands in ASTM C144. Three major sand groupings were identified through these methods.

Group A: 24 samples from the data set were included in this group.  This group can be generally characterized as having a high content of silt and fine sand, consisting mainly of quartz and feldspar. The mortars in this group also contain clay streaks. A moderate amount of claystone was identified in these sands, as well as a low concentration of sedimentary grains rich in iron-oxide, and moderate mica. [Figure 14] Variations in the gradation of the sands were observed through petrography. These are indicated on Table 6, Appendix D. 9 samples with observed to have a high content of silt and fine sand. 4 samples had high content of silt and fine sand with few coarse sand grains dispersed throughout. 7 samples contained a high content of silt with medium and coarse sand grains. Mortars from this group were also matched through their extracted sands, with a Munsell color code of 2.5Y 6/3.

Group B: 17 samples are included in this group. These sands generally contain medium and coarse-grained sand. The sands contain sedimentary grains rich in iron-oxide,

with a high concentration of quartz grains lined with iron-oxide. These sands also contain pyroxene, diabase, and chlorite. [Figure 15] There are slight variations in the sand proportioning within this grouping. Most of the samples contain a high to moderate concentration of medium to coarse-grained sand. In 6 samples (1080b, 628a, 307, 195b, 177a, 139) there was a high concentration of coarse-grained sand with medium to fine grains filling in smaller gaps within the binder matrix. The extracted sands from this group varied in their coloration but were all some shade of pink. This is due to the high content of iron oxide in the sands. These characteristics are typical of sands eroded from the Newark Basin geological formations surrounding Manhattan. The Newark basin is a formation of distinct geological rocks from the Jurassic and Triassic Periods.[163] The erosion of these rocks created a set of sand deposits in Manhattan. Mortars with this sand may have some but not all of these characteristics.

Group C: 3 samples (628b, 186d, 177b) were identified within this group. These samples have a low sand content. The sand grains are all similar in size (around 125-250 micron). In Sample 186d, there is an additional layer of mortar packed with fine sand, followed by a finish layer. These characteristics are commonly seen in mortars used for wall finishes.

[163] Kummel

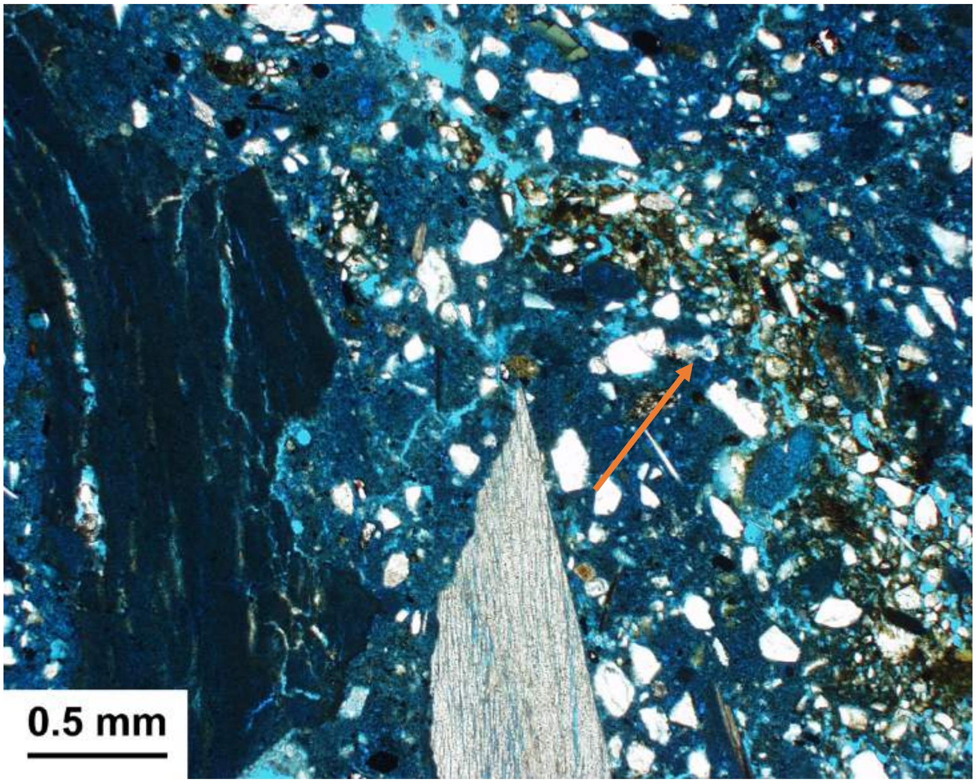


Figure 14. Sample 1799. Streak of clay. Plane polarized light.

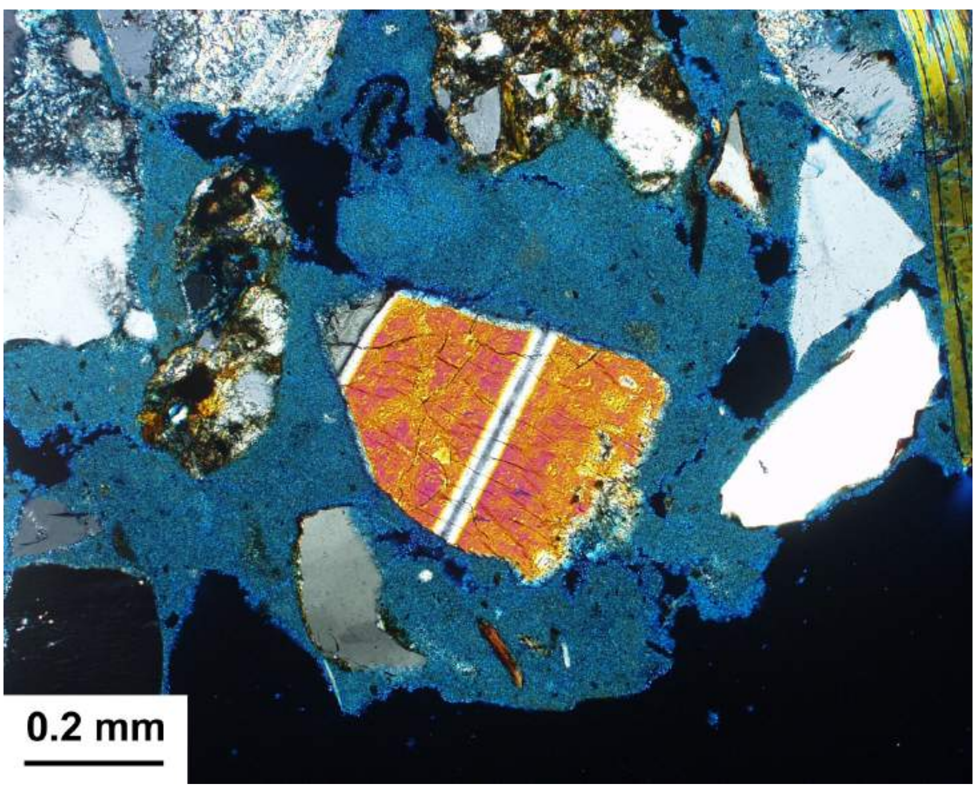


Figure 15. Sample SSSM. Pyroxene. Cross-polarized light.

## Sand Gradation

Graphs 1 and 2 show the sand gradations for some of the mortars from the Stadt Huys and Seven Hanover sites. The percentage of sand passing each sieve is measured by weight and plotted on a semi-logarithmic scale. These gradation curves show general trends for 17th, 18th and 19th century sands. [Figures 16 and 17] In the Stadt Huys mortars, one group (A) contains mortars from stratigraphic contexts dating to the late 18th and early 19th centuries. Another (B) contains two mortars with a nearly identical curve. These mortars are both from deposits dating to the late 18th and early 19th century. The third (C) contains mortars correlating to various dates. However, all mortars from 17th century deposits fall within this grouping. In the Seven Hanover set, mortars from early 19th century deposits follow the same curve as (A) in the Stadt Huys set. Outliers and irregularities in these data make it difficult to identify other groupings. These outliers indicate that sand gradation does not provide a strict characterization, and should instead be used for making general distinctions between sand grouping.

Through petrographic analysis, characteristics of the proportioning of the sands to binder were also shown to follow general trends. A high content of silty and fine sand was commonly observed in mortars from 17th century deposits. Low to moderate sand content with medium to coarse-grained sand was observed in mortars from 18th century deposits. A high content of medium to coarse-grained sand, or a gradation of fine to coarse sand with predominately coarse grains, was observed in mortars from 19th century deposits.

Graph 1: Sand Gradation of Mortars from the Stadt Huys Site


Graph 2: Sand Gradation of Mortars from the Seven Hanover Site

Figure 16. Sand gradation of a 19th century signature (Sample 207)

Figure 17. Sand gradation of a 17th century signature (Sample 1710)

## “Lovelace-style” Mortars

Within the sample set, there are mortars that are distinctive in their visual characteristics, as well as in their sands and microscopic features, that warrant their grouping. Their shared characteristics are associated with those seen in Sample 982, excavated from the deposits associated with the Lovelace Tavern. The mortars grouped as having similar characteristics to Sample 982 will be referred to as the “Lovelace-style” mortars. The mortars identified as belonging to this grouping are listed in Table 7, Appendix D.

In visual analysis, Sample 982 has a buff coloration (Munsell 10YR 8/2) with a dull luster. It is distinctive from other mortars due to its light heft and rounded weathering. It has a soft, white binder, with binder lumps of about 2 to 3 mm in size dispersed throughout the sample. The sample has a low sand content of mostly silt-sized grains, with a moderate amount of fine grains dispersed throughout. The sands contain a moderate amount of mica flakes. This sample contains a moderate amount of shell inclusions, from about 2 to 8 mm in size. It has also has a high abundance of carbonaceous inclusions.

Fourteen mortars in the data set were identified as having many of the same visual characteristics as Sample 982. [Figure 17] Primarily, these mortars were distinguished as having a light heft and smooth rounded weathering, as well as a low sand content, and carbonaceous inclusions. Secondary characteristics of these mortars included the presence of shell inclusions and small dispersed lime clumps.

Through petrographic analysis, Sample 982 was identified as a shell lime binder, with a prominent amount of partially-fired shell fragments and laminated shell texture within undisturbed binder lumps. [Figure 19] This mortar also contained a moderate

amount of glass fragments and wood cinder. The sand is characteristic as belonging to "Group A," which has been described in the "Sand" section above. Mortars that were associated with Sample 982 in visual analysis also contained "Group A" sands. These mortars were also matched by their extracted sands. [Figure 20] The sands had the same buff color (2.5Y 6/3) and their gradation curves were similar in that they contained predominately silt and fine sand.


Figure 18. Sample 1799.

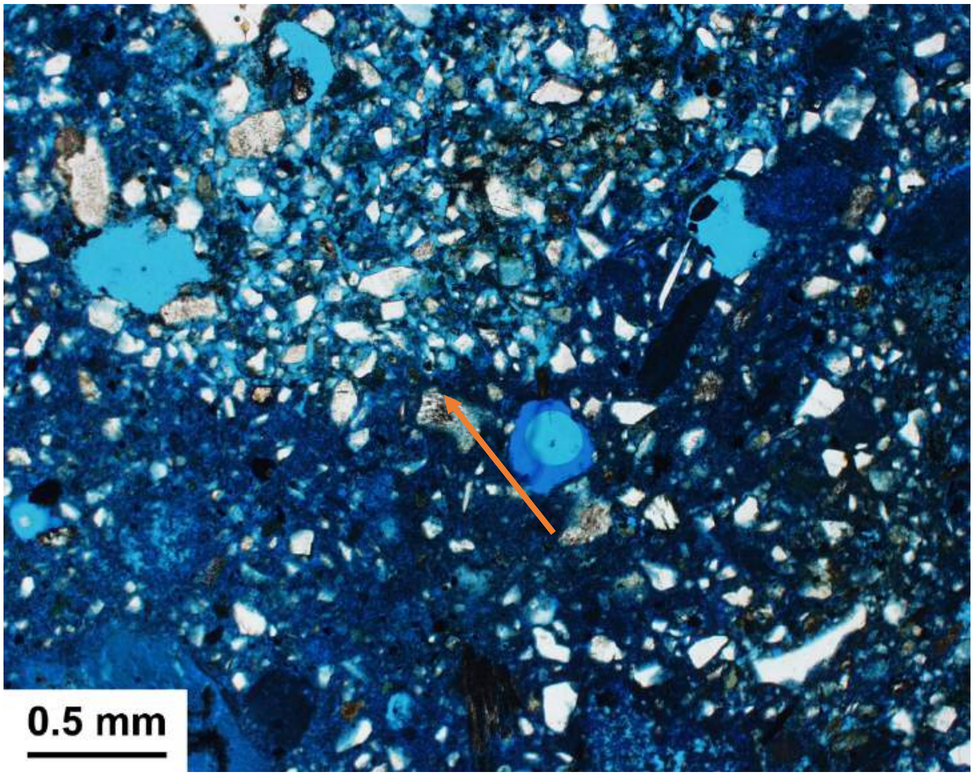


Figure 19. Sample 982. Clay streak indicated with red arrow. Plane polarized light.

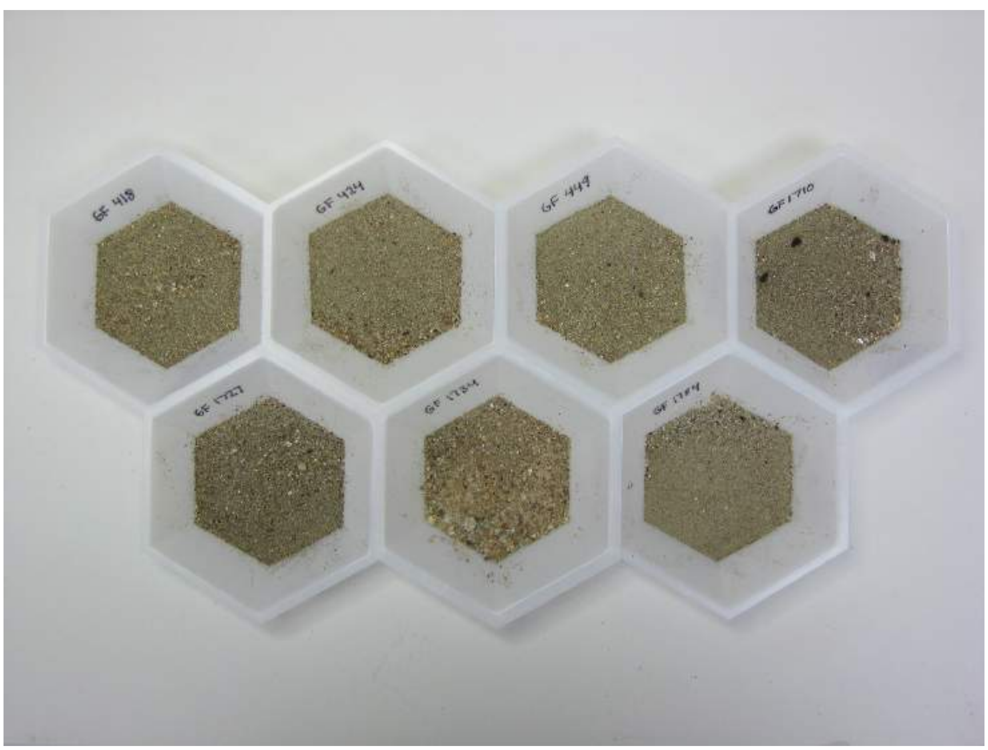

Figure 20. Sand extraction of "Lovelace-style" samples

## Shell to Rock Lime Transition

The mortars analyzed through petrography in this data set offer a potential source of information on the transitions of binder technologies in New York City. The manufacture and use of binders is generally well documented from the mid-19th century. However, earlier transitions in binder sourcing are not well known. Specifically, the period of transition from the use of shell lime to rock lime binder has not been identified for New York. The samples from this data set may be useful for indicating when this transition began. Many of the mortars in this data set were sampled from strata with an interpreted date of deposition. Theoretically, these dated stratified deposits could be used to observe trends over time. The density of artifacts of a particular type can be indicative of its use and production within a given time period. This type of analysis is dependent on a sampling procedure that ensures all collected artifacts are representative of their deposits. It also requires a large amount of data to make a statistically informative interpretation on the transitions in use of an artifact of a certain type over time. Mortars sampled from stratified archaeological deposits could be potentially useful for informing the periods of transition for binder types that are not well recorded. The mortars in this data set, however, were not sampled in their entirety and so they are not fully representative of their deposits. This data set is also limited as it is only representative of two archaeological sites within close proximity to each other. Therefore, these mortars are not representative of building practices throughout Manhattan. Despite these limitations, the mortars in this data set do show general trends in the use of shell and rock lime binders when correlated to dated strata. [Table 8, Appendix D] For example, Lot 28 in the Seven Hanover site has a well-defined stratification with deposits dating from the 17th, 18th, and 19th centuries.

Petrographic analysis identified shell lime in the mortars from the 17th century deposits, rock lime in 18th century deposits, and portland cement in latest deposits. This follows the general trend in binders that is described in Section 2. This could be used as a general indication that shell lime binder was predominately used in the 17th century and then gave way to the use of rock lime by the 18th century. This data set could potentially serve as a guide for a more targeted analysis that can provide a more refined date for the transition of shell lime to rock lime in Manhattan.

## 7a. Discussion – Premise

The main aim of this research is to demonstrate that mortars sampled from archaeological deposits have significant informational potential. The value of mortars as diagnostic artifacts is inherent to the ways in which they are produced, as discussed in previous sections. Mortars are also diagnostic in the ways that they are deposited in archaeological sites. Ultimately, they offer an added resource to contextualize archaeological deposits as well as other artifacts. The diagnostic value of mortars can best be explained through the ways in which they are compatible to methods currently used in archaeological study.

It is necessary to distinguish the research approach in ancient archaeology from historical archaeology. The main difference between the two categories is that historical archaeology involves the study of the remains of events that occurred within the last 500 years.[164] Many of the excavations that take place within the United States can be categorized as historical archaeology. This can involve the study of sites that have long been undisturbed and are preserved within and undeveloped landscape. However, historical archaeology frequently occurs in urban sites. The Stadt Huys and Seven Hanover excavations are examples of this. Urban archaeology has unique challenges in that sites are often occupied at the time of excavation. As opposed to sites in rural areas, urban sites can contain well-defined stratified deposits due to a denser history of construction. However, these strata are often complicated by later intrusions and other disturbances. While urban

[164] Charles, 7

sites tend to be complicated in this way, archaeologists can benefit from a well-documented history of construction episodes.

Urban areas are usually well documented throughout their history of occupation. This documentation can take the form of maps, deeds, tax forms, censuses, and other detailed records on the history of occupation and development. For this reason, methods of analysis in historical archaeology usually involve incorporating documentary research before the start of an excavation. This research is then used to help contextualize excavated deposits and the artifacts within them. In the process of excavation, archaeologists aim to identify spatial patterns. This is done by defining the sequence of deposition for the different "contexts," as defined in Section 2, and assigning dates to the contexts. The combination of both of these processes is used to define a chronology.[165] Archaeological contexts can include architectural features, such as foundation walls, privies, and cisterns. Architectural features play an important role for helping to define a chronology. This is especially true in urban sites with a well-recorded history of building development, as features can be correlated to known dates of construction episodes. Architectural features can also be used to define sequencing, as a feature likely post-dates the strata it overlies.

Mortars have been widely acknowledged by archaeologists as a useful tool for contextualizing architectural features. This is for three main reasons, that have been briefly discussed in Section 2. (1) Mortars are made at the time of construction and at the site of construction, and so their manufacture is directly tied to that event. Therefore, mortars that are original to the building can be used to date the construction of the building. (2) Mortars are not reusable and are generally replaced with every construction episode.

[165] Carver, 267

Therefore, different mortars within the same building can indicate areas of alteration. (3) Mortars can be layered onto, such as in a plaster or repointing, so that one sample can contain several mortars that are directly associated to each other. This layering can be likened to a stratification, and can inform construction chronology.

These features make mortars useful tools for the archaeologist, and they are commonly sampled from architectural remains in archaeological contexts. However, mortars can also be present within archaeological contexts as loose fragments deposited as debris. These mortar fragments are largely ignored and typically discarded in the field. This is because archaeologists currently only implement the analysis of mortars as a way to inform the study of an architectural feature. However, loose mortar fragments sampled from stratigraphic contexts can serve as a unique and valuable tool for placing date constraints on archaeological strata and for reconstructing site formation processes. Mortars have not been analyzed for these purposes, and there are no existing protocols for the sampling of mortar fragments from stratified deposits. The value of these mortars needs to be much more thoroughly researched. This thesis makes the argument that the same qualities sought in artifacts currently used in archaeological study are also found in masonry mortars.

Archaeologists use artifacts to inform site chronology. Artifacts that can be used to place some kind of date constraint on an archaeological deposit, or otherwise inform the context of a deposit, are considered to be diagnostic. The important distinction to make here is that the informational value of these artifacts is inherent to the artifact itself and does not rely on some other context to give it meaning. For example, a ceramic fragment can be diagnostic even if it is not excavated from the kiln in which it was fired, or the shop

in which it was sold, or the kitchen in which it was used. Instead, diagnostic artifacts have characteristic features that can be linked to a cultural practice and can be contextualized within broad cultural trends. Archaeological artifacts are generally characterized by three main features: fabric, form, and style.

*Fabric* refers to the raw materials composing the artifact.[166] This can imply the provenance of an artifact, based on a known history of material sourcing for a specific area.

*Form* refers to the design of the artifact relating to its function.[167] This feature can be used to characterize how the artifact was originally used. This can also be used to distinguish technological developments in the manufacturing of artifacts used for a specific function over time.

*Style* refers to the design of the artifact relating to its aesthetic.[168] This aspect of an artifact's design can imply a specific cultural association. This feature can be contextualized based on a known history of stylistic trends.

Mortars can be characterized according to these features. The *fabric*, or raw materials, of mortars are identifiable through various means of analysis, as discussed in Section 5. The materials that comprise a mortar, including binder, aggregate, and additives, can inform its provenance. This is especially useful when referencing a known history of technological developments in mortar manufacturing, as discussed in Section 2. The *form* of a mortar fragment can be suggestive of its application in construction. There are several features that can be observed in a mortar fragment, such as layers, finishes, and tooling marks, that can be indicative of a method of application in construction. As discussed in

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[166] Carver, 228
[167] Ibid.
[168] Ibid., 227

Section 2, mortars used in different applications may have different mix designs. These can be distinguished in a mortar sample by the gradation of the sand and the proportions of material components. Mortars can also be characterized by their *style*. Mortars used in brick pointing can have a strong influence on a building's overall appearance. Because of this, the choice of sand to be used as an aggregate is often based on the way it affects the color of the mortar. Different pointing techniques are also aesthetic choices that can contextualize a mortar within a time period in which that pointing style was popular.

Mortars characterized by these features have intrinsic informational value even if they have been separated from their original context in an architectural feature. This is not always the case for other building materials. For example, stone that was used in a building and then deposited as a loose fragment can be considered non-diagnostic for several reasons. First, it is not useful for defining a date constraint because stone sources are naturally occurring and so they do not have a date of invention or first manufacture. Stones are typically sourced after the opening of a quarry. However, it is possible for a stone to have been sourced informally before that point. Second, the same stone can be transported and used in various locations, and so it is not necessarily indicative of a local practice. Finally, stone is a recyclable material in that when removed from a building demolition it may be salvaged and reused in another building construction. So it may not be feasible to tie a stone fragment back to an architectural feature. This quality is what mainly distinguishes mortars from other building materials. As mentioned above, mortars are non-recyclable and are replaced, or otherwise modified, with every construction episode. Their deposition in a stratum is then directly associated with a construction or demolition event.

Mortars also have depositional patterns that add to their value for contextualizing archaeological strata. They are likely to be deposited near the building in punctuated discreet periods. Deposition of mortars can occur during the initial construction of a building. Due to their plastic nature, wet mortar can fall as droppings during their application. These droppings can collect at the base of the construction. They may also collect within a builder's trench abutting a foundation wall construction. These droppings accumulate during active construction and can then be leveled over with the installation of a floor or some kind of paving. In later repairs, mortar may be removed and replaced. However, this debris is likely to be cleaned up from the surroundings of a building that is still occupied. Instead, the debris could be deposited in a midden either on or off the site. During a building's period of use, mortar rarely falls off in substantial quantities to be observed in archaeological deposits. In contrast, the final demolition of a building creates a lot of debris. This debris is likely to be built on top of and used as fill or leveling deposits. Based on these activities, the deposition of mortars mainly occurs at the beginning or end of the life of a building. Large deposits of mortars in archaeological strata can then be tied to one of these periods.

Based on the characteristics discussed above, mortars are diagnostic artifacts with informational value that can be used for two main purposes: dating strata and identifying site formation processes. They can be used to refine a possible date range. They can also be used to connect strata from different areas of a site. Ultimately, mortars are another tool for the archaeologist that can be used in conjunction with other artifacts for interpreting archaeological deposits. In order to capitalize of their informational potential, mortar sampling needs to be incorporated into the initial research design. The sampling process

can be targeted to highlight possible connections between strata as well as between architectural features and strata.

## 7b. Discussion – Dating

As discussed above, archaeologists define the chronology of a site through the combined sequencing and dating of contexts.[169] These approaches involve the use of both relative and absolute dating techniques. As the name implies, relative dating techniques establish a relative order of events. In archaeological contexts, the relation of one layer to another is interpreted to reconstruct the sequence in which they were deposited. This process is relatively simple in a well-defined stratification, as the layers are organized in sequential order. Therefore, lower layers will be older relative to the layers above them.[170] This is rarely the case in archaeological deposits, however, which are almost always complicated by later disturbances into earlier layers. Construction projects and natural formation processes can cause these disturbances. Intrusions can be distinguished as older than the layers they cut through. However, it can be difficult to distinguish the extent of an intrusion when only a small test cut is excavated. This can make it difficult to interpret a context sequence, and so archaeologists are constantly supplementing relative dating with absolute dates, when available.

Absolute dating methods can help to define sequencing where the order of deposition is unclear. These methods provide a calendar date, which can be more precise or can be within a constrained range of possible dates. A manufacturer's mark on a ceramic sherd gives a refined absolute date to that artifact, which can then contextualize the deposit from which it was excavated. More often, however, artifacts are given an absolute date, or

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[169] Carver, 267
[170] Ibid., 268

date range, through materials analysis. Generally, ceramics are the most commonly sourced materials for absolute dating in the field of archaeology. Ceramic pipe stem dating is one major example of this. In 1954, archaeologist J.C. Harrington found that the stem bores of ceramic smoking pipes manufactured between the 17th and 18th centuries decreased in size over time.[171] He was able to identify consistent sizing of stem bores within five distinct time periods, ranging from 30 to 50 years.[172] There have been several adaptations to methods of pipe stem dating. However, the basic premise remains the same, that the diameter of smoking pipes excavated from 17th and 18th century colonial sites can be correlated to a particular date range of manufacture.

Archaeologists also commonly analyze fragments of ceramic wares to provide an absolute date. A ceramic fragment can be given an absolute date range by characterizing its type (form, function, and style), which can then be referenced against a known history of manufacturing for that type. Ceramic artifacts are useful for contextualizing the deposits from which they were excavated, but also for interpreting the history of occupation of a site. This is done through a process called mean ceramic dating. The date range of manufacture for each ceramic sherd excavated from a site is calculated as a median.[173] This median date is then compared for artifacts across a site or within a layer. These dates are then calculated as a mean, and can give a general idea of the date of the occupation or deposition.[174]

[171] McMillan, 15
[172] Ibid.
[173] Carver, 98
[174] Ibid.

Absolute dating can be applied not just to artifacts but to the sediments that surround them. Optically Stimulated Luminescence (OSL) uses radioactive dosimetry to determine an age starting from the last time the sediment was exposed to light. This method of dating is not always reliable, however. Archaeologists more commonly use artifacts that establish a TPQ for dating purposes. A TPQ (terminus post quem) establishes a date of earliest possible deposition.[175] Various types of artifacts can be used to define a TPQ. Ceramics are commonly used for this purpose, but this can be done with any object that can be characterized and referenced to a known history.

**Establishing a TPQ**

A common challenge archaeologists face is finding ways to place date constraints on strata. Ceramics and other artifacts may offer a range of possible dates based on their known history of manufacture. An artifact with a TPQ at the end of this range would then offer a tighter date constraint. Mortars can be useful in making these refinements. As discussed above, mortars can be characterized by their fabric. This can be referenced to a known history of invention and commercial introduction of specific binder types. This may not be applicable to mortars made with traditional techniques, as they implement materials used for long periods of time without a clear date of first manufacture. However, some mortars are composed of binders that have a date of invention. In addition to originating within a precise time, binders may also have a punctuated history of technological development. These developments can also be used to establish a TPQ.

[175] Ibid., 99

While the first date of manufacture can be well-established, the last appearances of a binder can be unclear. Also, binders are not always used in construction immediately after their first invention. Certain practices may be more likely to be seen at their height of popularity and less likely once there is a new technological development. For example, after the manufacture of hydrated lime, beginning around 1910, it became much less likely to see job-slaked lime used in construction. This is because it was a fire risk to slake lime on site, and so pre-hydrated lime was safer to use. It was also more convenient as hydrated lime could be packaged and sold by weight, making it easier to order materials for a construction project. The practice of slaking lime on-site did not disappear immediately after 1910. However, one can place a high probability that a structure with job-slaked lime dates from before 1910.

There are several binder types that are useful for providing general time markers, as well as a TPQ. Natural cement was first manufactured in the 1820s and used throughout the 19th century in the United States. While it did not completely disappear, by the beginning of the 20th century the use of natural cement largely gave way to portland cement. Portland cement has a well-documented history of manufacture and defining characteristics that make it a reliable artifact for establishing a TPQ.

An example within this data set is Sample 200 (7 Hanover, T.C. J, Lot 28). This sample was collected from a stratum within a layered deposit of three floor constructions. These deposits were correlated to building records, dating the layers to 1805 (original construction), 1836 (rebuilt after the fire at the Seven Hanover site), and sometime after 1857 (based on the last depiction of the building preceding the latest construction on a map). Each floor was supported by round logs over a layer of fill. Sample 200 is a mortar

sample taken from the fill layer beneath the latest floor. [Figure 21] The binder is identified as portland cement based on petrographic analysis. Belite minerals within the cement grains are consistently fine in size. The texture suggests that it was fired in a rotary kiln. The un-hydrated agglomerates in the sample were ground to between 80 and 150 microns in diameter. This is not as fine as what is seen in portland cements from the latter half of the 20th century. With these combined characteristics, this mortar is likely representative of an approximate date between 1900 and 1950. This would date the latest floor construction in this deposit to sometime in the early 20th century.

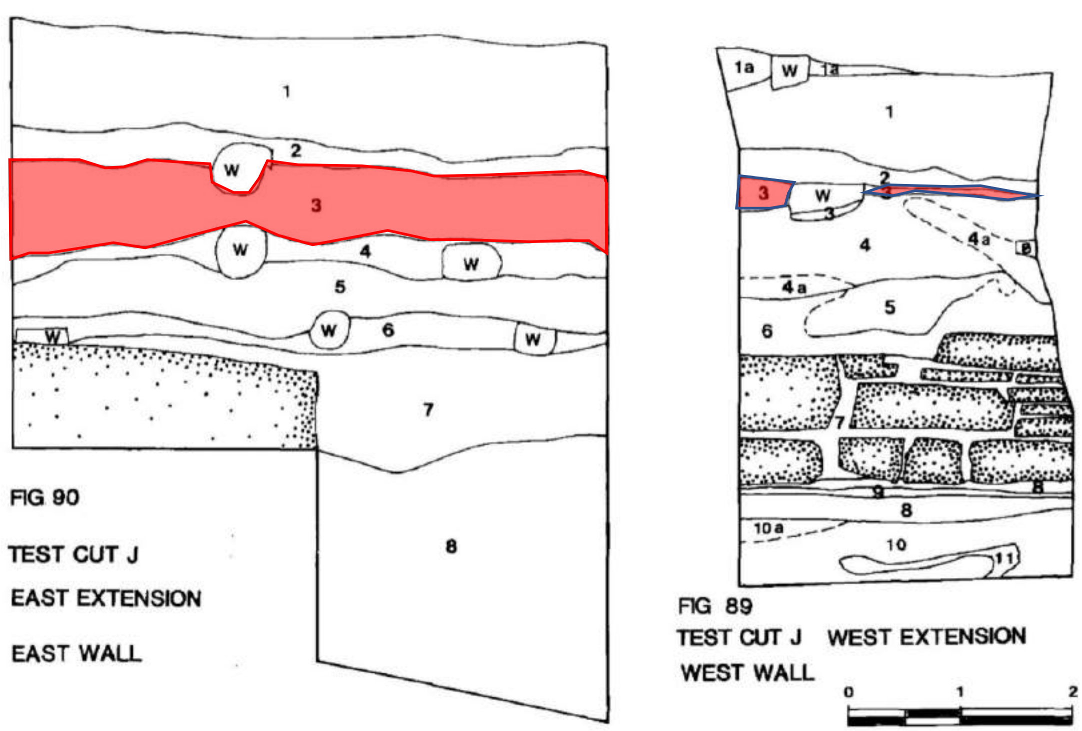



Figure 21. Test Cut J, Lot 28, Seven Hanover. Layer from which Sample 200 was excavated.

**Refining Interpretations**

Archaeologists are often challenged with interpreting complicated stratification. This is especially true in urban sites where the impacts of later construction episodes on earlier deposits may not always be clear. Artifacts that establish a TPQ can be especially useful for identifying whether a deposit has been disturbed. For example, in a well-defined stratification within a test cut, it may be that only one layer contains artifacts that provide an absolute date. When this is the case, that layer may be used to relatively date the layers below it as older. However, if one of these lower layers contains an artifact with a TPQ dating after the upper layer, it could completely reframe the interpretation. This is why archaeologists continually refine their interpretations with every tool for dating that is available to them. Mortars can serve as an additional tool for this purpose. If mortars are sampled in the same way as other diagnostic artifacts, they could be used to potentially inform discrepancies in a sequencing of deposits.

Sample 1784b (Stadt Huys, T.C. CB 24, Stone Street) was excavated from a subsoil layer beneath several strata dated to the early to mid-seventeenth century. [Figure 22] However, petrographic analysis revealed that the sample was a boiler cinder concrete attached to a portland cement-based mortar (likely a topping layer). These characteristics would date this sample to sometime in the early 20th century. This is not compatible with the dates interpreted for the strata above the layer from which this sample was excavated. In the process of the excavation, the archaeologists had noted a modern builder's trench adjacent to the test cut that spanned the full depth of the deposits. The portland cement mortar may have been introduced to the subsoil layer when this builder's trench was created. This does not necessarily mean that all of the strata adjacent to the trench were

contaminated with later material, as the modern trench could have undercut these layers. This finding could have helped the archaeologists to more fully understand the impact of the modern construction on the historic deposits.

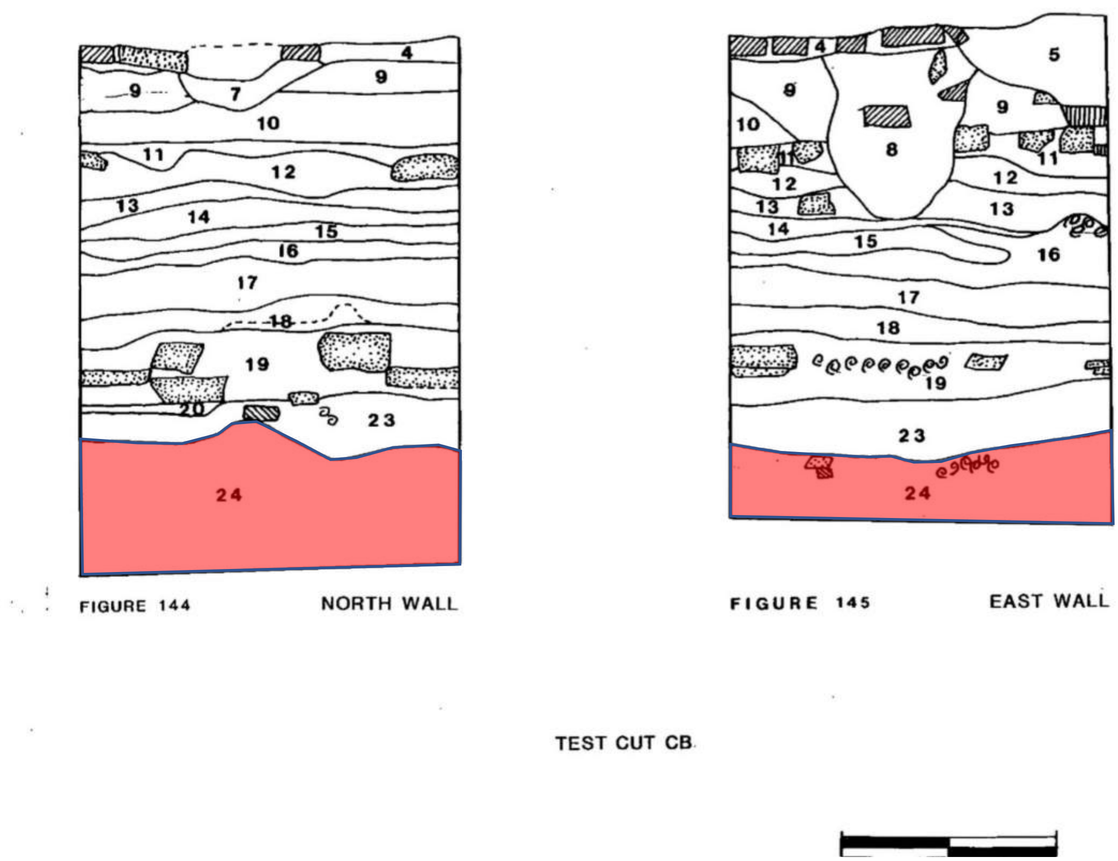



Figure 22. Test Cut CB, Stone Street, Stadt Huys Block. Layer from which Sample 1784b was excavated.

**Connecting Strata Through Mortars with a "Handwriting"**

Archaeological interpretations are often informed by finding correlating artifacts in separate strata throughout a site. Ceramics are often used for dating because they can be matched to the work of a specific manufacturer. A ceramic manufacturer practicing within a given time period will have products that are unique to their design and are characteristic of their work. A particular ceramic may be produced over a period of time up until the manufacturer closes their business or discontinues that style. If a ceramic has characteristics that are distinctive enough to be matched to the work of a single manufacturer, then it can be a useful tool for archaeological dating. The same concept can be applied to mortars. Different masons will produce mortars with intricate variations, even when they are using the same mix design. These variations can be likened to a "handwriting." This can be seen in any materials containing a set of features that is unique to the product of an individual.

Mortars with the same "handwriting" can be useful even if the period in which a certain mason worked is not well known. Any stratum containing mortar with the same "handwriting" can be associated to the same general time period. Then, if just one of these strata is dated, it could be used to provide a possible date for all of the strata that contain this mortar. This can be similarly used for dating architectural features to the same time period.

The "Lovelace-style" mortars, which were described in Section 6, are an example of mortars that have the same "handwriting." Sample 982 is a mortar adhered to a yellow brick that was excavated from a stratum associated with the Lovelace Tavern foundation wall remains. The Lovelace Tavern was first constructed in 1670 and was demolished by

the start of the 18th century. Sample 982 was excavated from test cut AQ along the foundation wall remains of the Lovelace Tavern. The layer from which it was collected included a dense number of artifacts dating to the 17th century, which archaeologists associated with the Tavern. These included several different types of locally-made ceramics.[176] Archaeologists also sampled pipe stem fragments with a mean ceramic date of 1697, some of which had makers marks from the 17th century.[177] Due to the density of 17th century artifacts, it is highly likely that Sample 982 was deposited as demolition debris from the Lovelace Tavern.

Sample 982 has unique characteristics that were matched to other mortars from different areas of the Stadt Huys site. A full description of this grouping, termed the "Lovelace-style" mortars, is included in Section 6. [Table 7, Appendix D] These mortars can be distinguished as having the same "handwriting." The "Lovelace-style" mortars were sampled from test cuts CC, CB, and CA along Stone Street, as well as from test cuts in lots 6 and 9 in the Stadt Huys site. These mortars were also sampled from within lot 9 in the Seven Hanover site. It is possible that these mortars were all made by the same mason, who might have been working on several buildings in and around the Stadt Huys and Seven Hanover sites over a period of time. This is likely to be seen in early Colonial settlements, where there tended to be less skilled workers early on.

The "Lovelace-style" mortars were sampled from strata that archaeologists dated to the 17th century through other methods of analysis. Through mean ceramic dating and characterization of sediments, archaeologists were able to connect layer 23 in test cut CC

[176] *Archaeological Investigation of the Stadt Huys Block: A Final Report*, Appendix C, 6
[177] Ibid., Appendix D, 21

and layer 19 in test cut CB as belonging to the same depositional event.[178] They interpreted this event to be a 17th century ground surface, in which artifacts were deposited slowly over a period of time before the area was redeveloped.[179] The mortars sampled from layer 23 in test cut CC (Sample 1738 and Sample 1747) and from layer 19 in test cut CB (Sample 1766 in CB19) are part of the "Lovelace-style" grouping. The interpretations of the archaeologists using various methods of dating corroborates a 17th century date interpretation for the "Lovelace-style" mortars. It is helpful to have multiple methods of dating that can be cross-referenced to build evidence for interpreting a date of deposition.

The "Lovelace-style" mortars offer a useful method for making connections between strata across the Stadt Huys and Seven Hanover sites. However, there are several limitations to using these mortars for dating. As discussed in Section 6, there are variations between the mortars in this grouping that, while they could be the result of a crude processing of materials, makes it difficult to characterize their similarities. Multiple methods of analysis can be used to reinforce these characterizations. However, interpreting a "handwriting" is still a subjective process. This method of connecting strata is most effective when used in conjunction with other dating methods.

[178] Ibid., 321
[179] Ibid.

## 7c. Discussion - Site Formation Processes

Archaeologists are not only interested in collecting artifacts. They are interested in learning the history of activity on a site. This involves an understanding of site formation processes, in other words, how different events impacted a site. For example, a fire that destroys all the buildings in a lot will result in a large amount of charred material that is deposited on a site. When this site is excavated, any stratum that contains this charred material could then be linked to that event. As mortars are only deposited as a result of a construction episode, they are also representative of an event. Therefore, mortars can be used to make connections between strata. They can also be useful for interpreting a history of activity within disturbed deposits.

**Connecting Strata with Mortars of the Same Construction**

Archaeologists often make connections between strata that contain artifacts from the same period. However, certain artifacts can be deposited over a long period of time. Direct connections are more definitively made when both strata can be linked to the same depositional event. A building demolition can be a useful depositional event, as building materials are often deposited in large quantities in a short period of time. This event can be associated with any other strata containing the same building materials. Mortar samples of the same construction can be identified based on shared characteristics that, while not diagnostic on their own, in combination are unlikely to be seen in two mortars of different construction or different periods.

Samples 242b (Seven Hanover, deposit under floor #3 (ca. 1790-1805), Lot 28) and 256 (Seven Hanover, privy level 1, Lot 28) serve as an example of mortars of the same construction that are present in different deposits. Sample 242b was taken from a stratum associated with the deposition of materials from a building demolition on Lot 28 between 1790 and 1805. Sample 256 was collected from a privy deposit in the backyard of Lot 28. The privy contained a series of layered deposits. Usually, privies have two main levels, the lowermost deposited while the privy was in use. The uppermost level is deposited as a fill once the privy is no longer in service. In this case, archaeologists found through mean ceramic dating that the uppermost level of the privy was deposited around 1790. While the ceramic artifacts place a date for the privy fill that is consistent with the date of the building demolition on this lot, it is not enough evidence to directly associate both deposits to the same event. This can, however, be confirmed through matching the mortar samples.

Samples 256 and 242b have the same visual characteristics. Both have a high sand content (No. 50 and finer) with moderate concentration of lime lumps and the same coloration (Munsell 10YR 8/2). When viewed microscopically, both samples contain large lime inclusions with expansion parting texture and fired relict quartz. [Figures 23 and 24] Their sands include quartz grains that are lined with iron-rich alteration products, as well as heavy accessory minerals such as pyroxene. These characteristics are unique to both samples in their composition and proportions so that it is highly likely that both mortars are of the same construction. This directly connects the demolition debris and the privy fill as part of the same depositional event. This type of direct connection is also useful for contextualizing undated strata. For example, if the privy deposit could not be dated

through the ceramics, the matching mortar could be used to date the deposit to between 1790 and 1805.

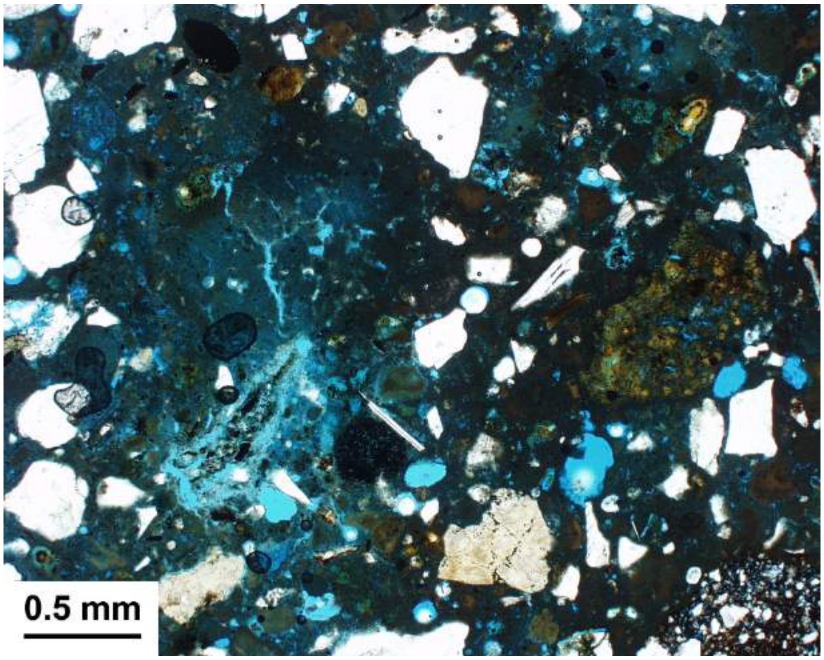



Figure 23. Sample 256. Plane polarized light.

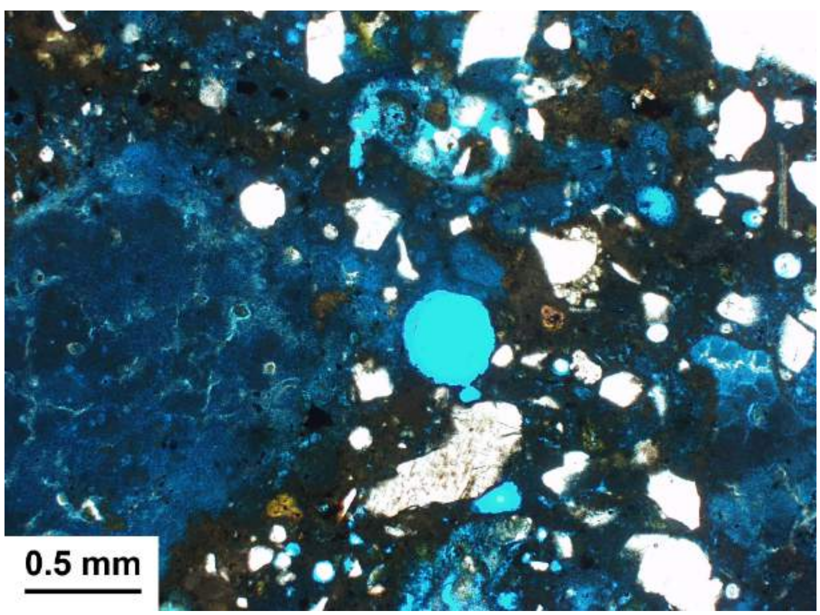



Figure 24. Sample 242b. Plane polarized light.

## Identifying Construction Episodes in Disturbed Deposits

Archaeologists often face challenges when interpreting building records for urban sites with a long history of development. Often times, records do not exist for all of the episodes of construction that have taken place on a building lot. This can complicate the interpretation of the artifacts sampled within that lot. This is complicated even further if the site has been disturbed by later construction. Even in this case, however, mortars can distinguish different periods of construction. If the deposit in a building lot has not been disturbed with fill from other areas of the site, then the mortars sampled from it will be representative of the construction episodes that took place on that lot.

The excavation of test cut CA along Stone Street in the Stadt Huys site revealed a deposit that had been disturbed by new construction. This deposit contained the remains of a foundation wall, which archaeologists associated with building records from 1907. They also found artifacts dating to the 17th century. The mortars collected from this deposit corroborate interpretations for both of these time periods. While the building records were unclear, the archaeologists speculated that there may have been a third construction episode between these two periods.

Sample 1645 was taken from a section within the foundation wall. [Figure 25] The binder is a grey portland cement with consistently sized impressions of former belite crystals and relict cement agglomerates between 80 to 150 microns. This would place this sample to sometime in the first half of the 20th century. This is consistent with the 1907 date of construction for the stone foundation wall. Samples 1646 (T.C. CA, layer 8) and 1652 (T.C. CA, layer 4) were also found within this disturbed deposit and are both shell limes. The sand gradation is also typical of the 17th century. Sample 1653 (T.C. CA, layer 4)

is a rock lime binder, evidenced by fired quartz inclusions in the binder matrix. It also has a high content of well-graded sand that is typical of the 19th and 20th centuries. This sample does not necessarily represent a third construction episode, as it could have been used in a different part of the same construction as the portland cement mortar. However, it could potentially imply another period of construction if corroborated with other evidence.

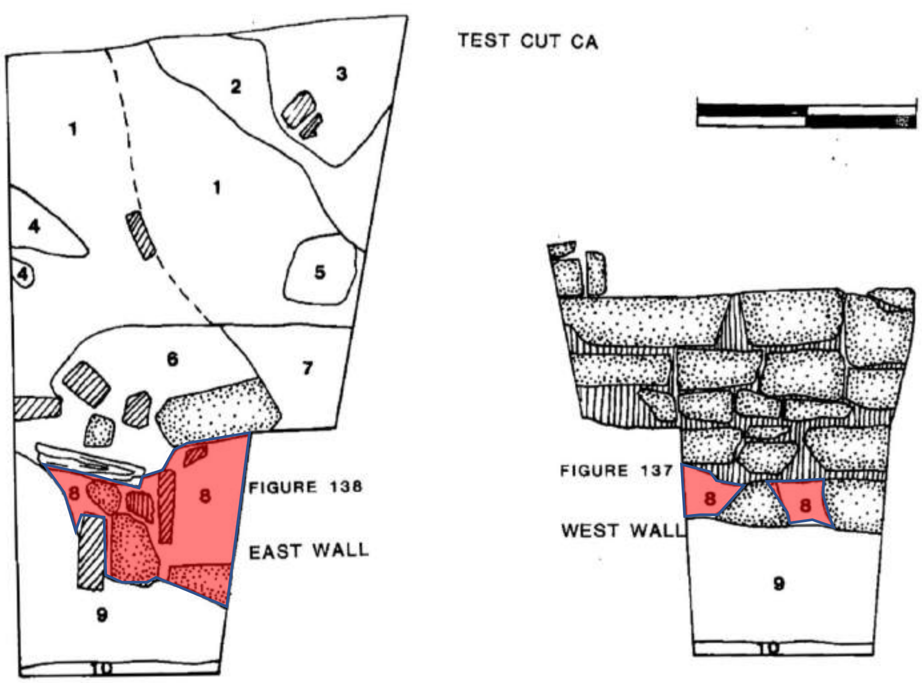



Figure 25. Test Cut CA, Stone Street, Stadt Huys. Layer from which Sample 1645 was excavated.

## 8. Opportunities for Future Study

This section addresses two major avenues for future research projects: (1) Research questions posed at the beginning of this study that were not fully answered. (2) Resources that could serve to build on the findings of this research.

**Research Questions**

→ Lovelace Tavern Mortars

An analysis of all the mortars sampled from the remains of the Lovelace Tavern could provide a more distinct characterization of the "handwriting" described in Section 7. Further identification and sampling of the "Lovelace-Style" mortars could be used to make connections between strata and architectural features.

→ Transitions in Binder Technologies in New York Leading up to the Industrial Revolution

This study addresses only a small portion of the mortar samples collected from the Stadt Huys Block and Seven Hanover Square Sites. An analysis of mortars collected from all of the test cuts within both sites could potentially provide a fuller understanding of the transitions in binder technologies in New York's earlier history.

→ Characterization of Rock Lime Binders

A chemical analysis of rock lime binders from the Stadt Huys and Seven Hanover archaeological sites could help to inform trends in binder sourcing and developments in material industries.

→ Mix Design

A chemical analysis of the compositional proportions of mortars throughout both archaeological sites could confirm trends in mix design throughout various periods. These could then be used as a reference for future mortar analysis in New York City.

→ Imported Materials

There are samples within the data set that include materials that are not native to New York. These samples may serve as an indication that Colonial settlers were importing building materials for use in construction. Further research and materials analysis on these samples may reveal more information on where materials were imported from as well as how they were used.

Sample 1648 contains coral as an aggregate [Figure 26]. An advanced analysis of this mortar could determine whether coral was used as a source for lime.

Sample 1733 contains a layer of chalk whiting, indicated by the presence of foraminifera. [Figure 27] Further research might inform whether chalk was imported to settlements in New York for use in chalk whiting.

Sample 1132 is a piece of chalk that has a thin layer of mortar as well as tooling marks. [Figure 28] These features indicate that the chalk may have been used in some type of construction. The mortar is similar to those within the "Lovelace-style" grouping, which could potentially associate this sample with the 17th century.

## Resources

→ Full Collections of the Stadt Huys and Seven Hanover Sites

All of the research questions listed above could potentially be answered through a more extensive sampling of mortars from both the Stadt Huys and Seven Hanover

archaeological sites. These collections could also provide an excellent sample set for the study of other architectural remains, such as brick and stone. Tables 1 and 2 in Section 4 summarize the full architectural history of both sites along with the test cuts correlated to each building lot.

→Extant Sites from the Dutch Colonial Period

Mortars of the early Colonial period could potentially be characteristic of Dutch building traditions. In order to test this theory, an extensive campaign of mortar sampling would need to be conducted on extant buildings of the Dutch Colonial period. Jeroen van den Hurk's research on original Dutch building contracts is an excellent source for curating a list of potential sites for analysis.[180] This research may need to be localized to a region of interest, however, as local material availability had a significant impact on the building practices developed in Colonial settlements.

As part of an early avenue of research that was not completed in this study, the following list was compiled of extant Dutch sites in New York City with potential for containing original mortar remains:

-Wyckoff House, Brooklyn, ca. 1652 (oldest surviving structure in NYC)

-Bowne House, Queens, ca. 1661

-Conference House, Staten Island, ca. 1680 (English)

-Historic Richmondtown, Staten Island:

-Treasure House, ca. 1700 (additions in 1740, 1790, and 1860)

-Voorlezer's House, ca. 1696

[180] Van Den Hurk

-Billiou-Stillwell-Perine House, ca. 1662

-Hendrick I. Lott House, Brooklyn, ca. 1719 (partially reconstructed in 1792 combining Dutch and English architectural styles)

-Dyckman Farmhouse, Manhattan, ca. 1785

Mortar samples were taken from the Lott House, Billiou-Stillwell-Perine House, and the houses at Historic Richmond Town, as well as from the Dyckman Farmhouse in Manhattan, ca. 1785. A visual analysis was conducted on all of the sampled mortars. Additionally, a petrographic analysis was conducted on the mortar sampled from the Dyckman Farmhouse. [Figures 29-33]


Figure 26. Sample 1648. Coral aggregate, red arrow.

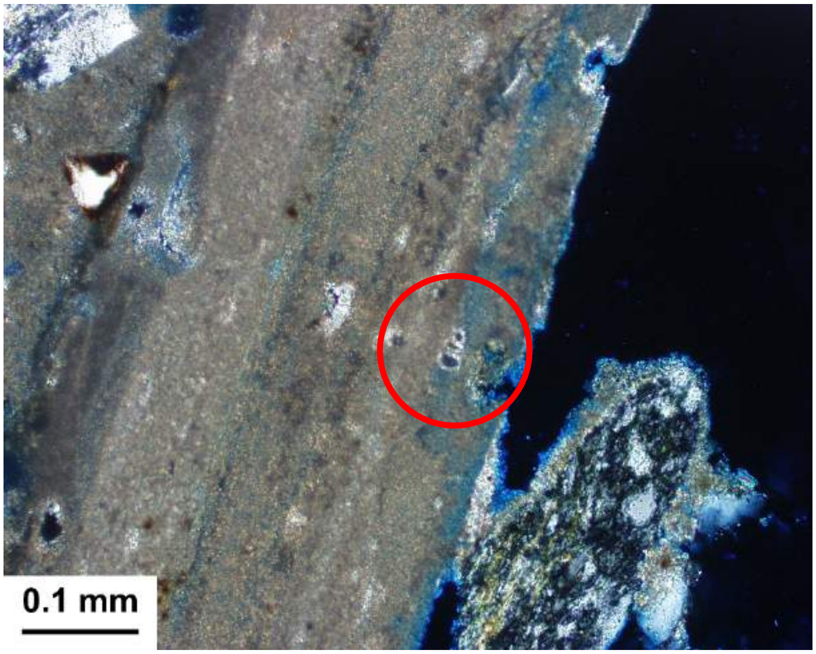



Figure 27. Sample 1733. Foraminifera in chalk whiting. Circled in red. Cross-polarized light.

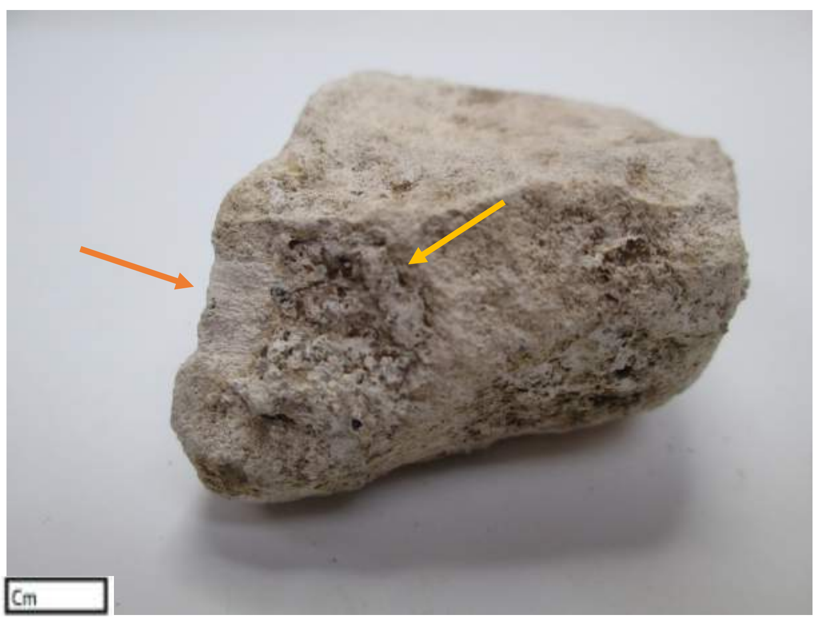



Figure 28. Sample 1132c. Tooling marks, red arrow. Mortar, yellow arrow.


Figure 29. Mortar sample from the Lott House.


Figure 30. Mortar sample from the Billiou-Stillwell-Perine House


Figure 31. Mortar sample from the Treasure House


Figure 32. Mortar sample from the Voorlezer's House

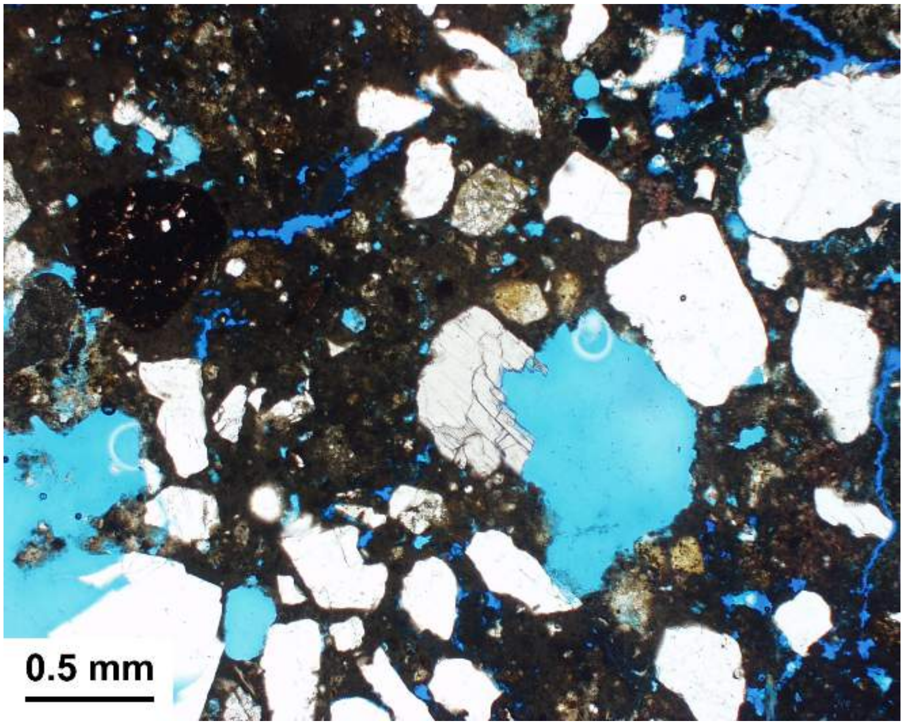



Figure 33. Thin section of mortar sample from the Dyckman Farmhouse. Petrographic analysis showed that the sample contains natural cement binder. This indicates that it is not original to the construction. Plane polarized light.

# 9. Conclusion

The goal of this research was to demonstrate that mortars sampled as loose artifacts within archaeological deposits have informational value for archaeologists. Mortars deposited as building material remains can provide specific information for the study of historic building practices. The unique characteristics and depositional patterns of mortars make them a valuable tool for archaeological research.

The data collected and interpreted as part of this research serves to demonstrate that mortars are diagnostic artifacts and that they can inform interpretations of archaeological deposits. Mortars are diagnostic in the following ways: (1) binders can be characterized and referenced to a known history of manufacture to establish a TPQ in stratified deposits, (2) mortars can be used to refine stratigraphic interpretations and identify contaminated archaeological deposits, (3) mortars can be characteristic of the work of a single craftsperson, which can be used to correlate and possibly date strata, (4) mortars in uncontaminated disturbed deposits can be informative of different periods of construction, (5) mortars can be correlated to the same construction event, which can be used to make connections between strata and inform the interpretation of site formation processes.

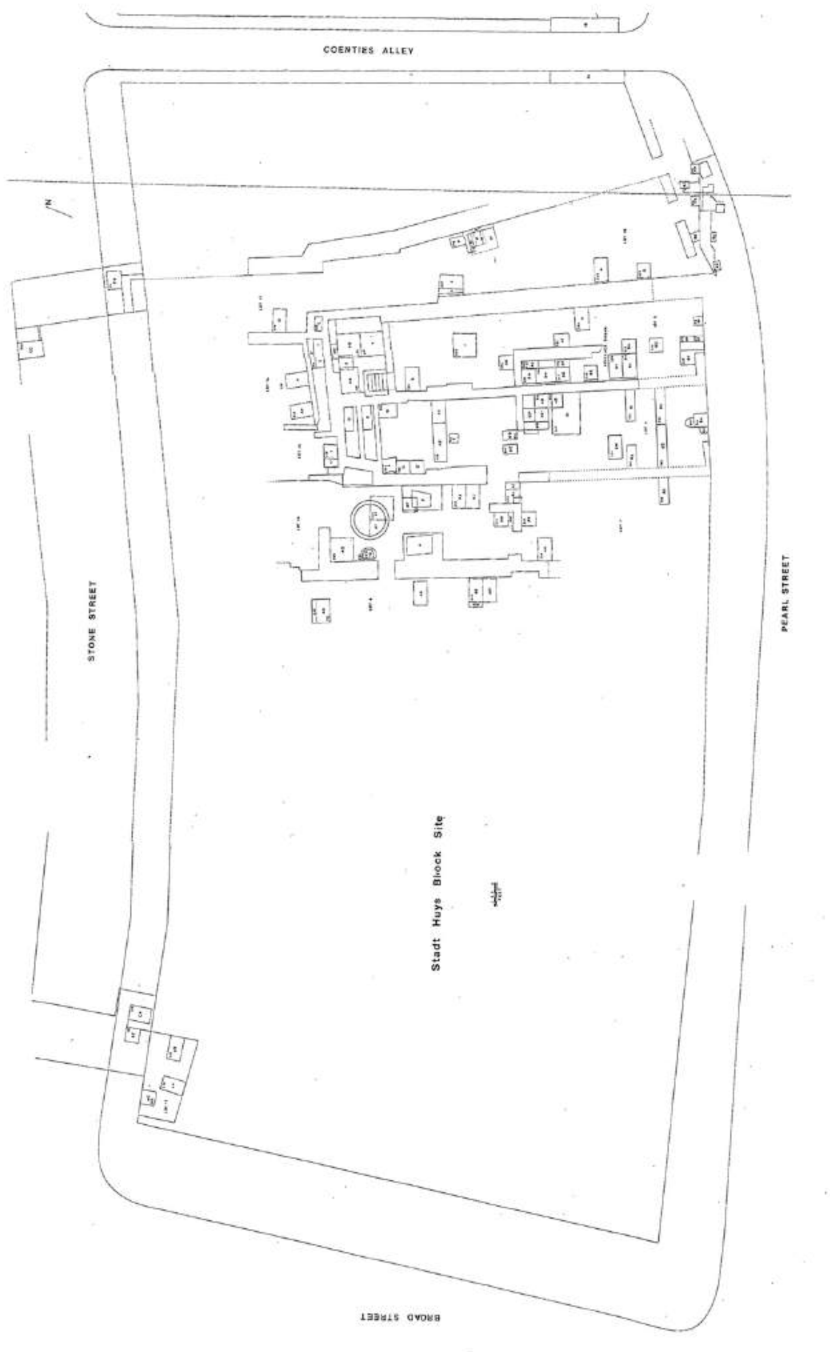
The results of this analysis also provide supplementary information on the history of mortar development in New York City from before the mid-19th century. The characterization of the “Lovelace-style mortars” adds to the current understanding of building practices in New York City from the Colonial period. These mortars could

potentially be identified in other sites in Manhattan. They could then be used to contextualize deposits from the 17th century.

The analysis of mortars included in this study revealed correlatable patterns of binder types to dated archaeological strata. These patterns indicate a transition to rock lime possibly after the 17th century in New York City. These data could serve as a guide for the continued investigation of the transition period for the use of shell lime to rock lime in New York City.

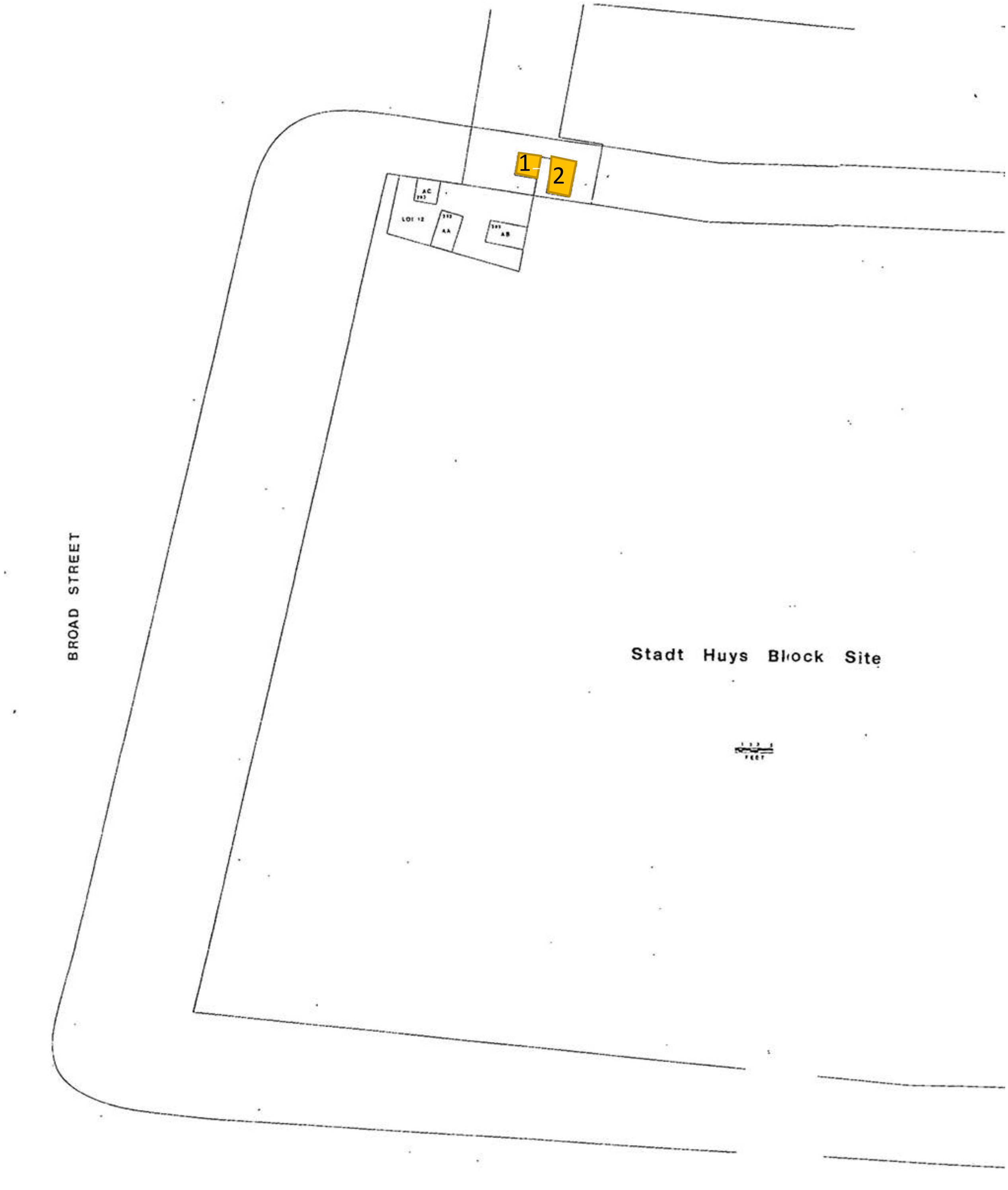
The data collected as part of this study could serve as a reference for the future study of the Stadt Huys Block and Seven Hanover Square archaeological sites. These data could also be built upon to further inform the history of manufacture and development of mortar in New York from before the Industrial Revolution. Ultimately, this research was aimed at contributing to the fields of archaeology and architectural conservation. This study can serve as a demonstration of how both fields can benefit from the informational resources that they can provide each other. Mortar remains from archaeological contexts are a valuable resource, especially in urban sites with a complicated history of development. If the informational value of these artifacts is demonstrated and acknowledged, then more architectural materials will be preserved for use in future study.

# Appendix A – Site Maps

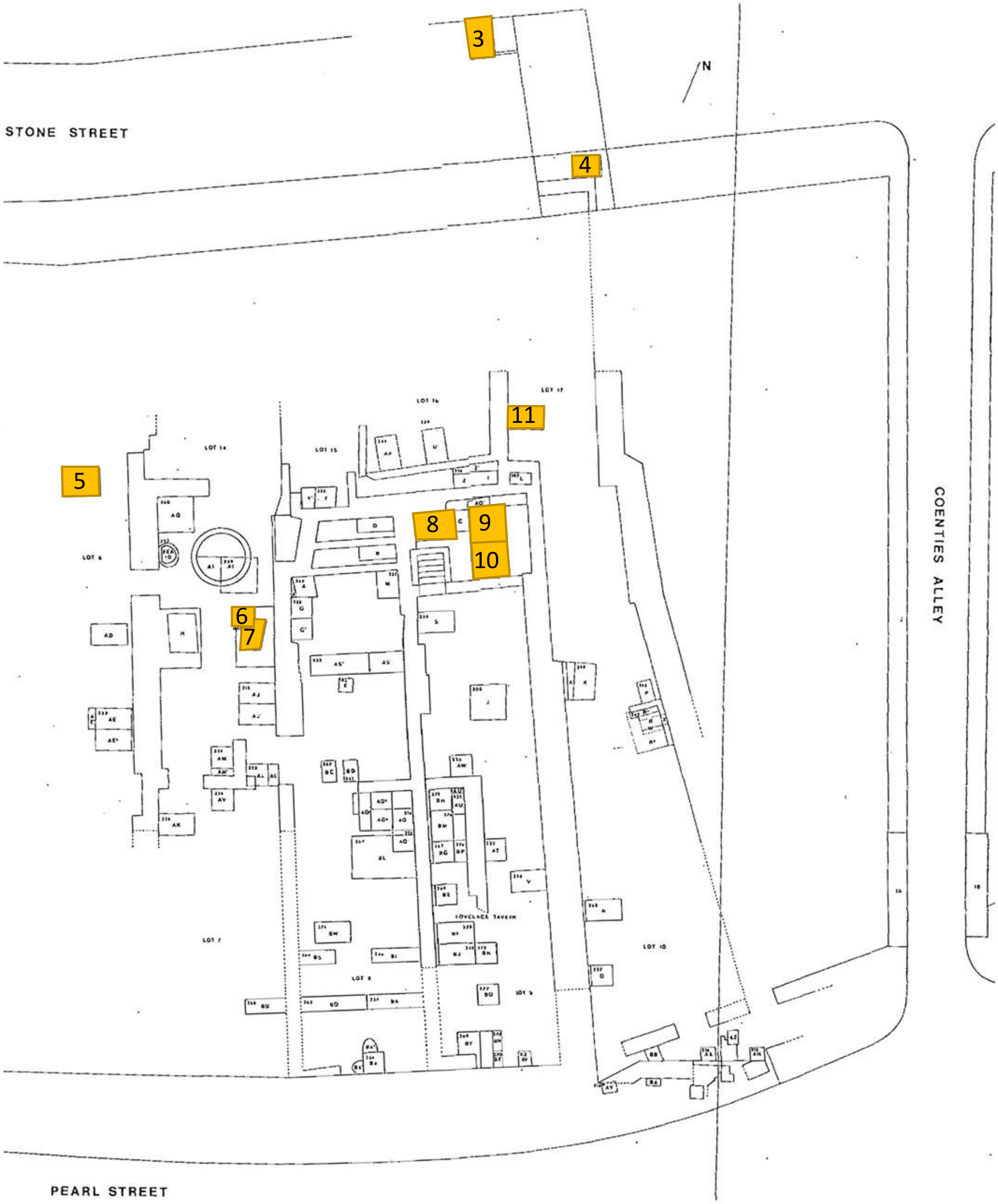



Stadt Huys Site Map, from: *The Archaeological Investigation of the Stadt Huys Block: A Final Report.*

**Key to Test Cuts included in this study:** (1) BZ Stone Street, (2) CA Stone Street, (3) CC Stone Street, (4) CB Stone Street, (5) AH Lot 6, (6) AP Lot 7, (7) F Lot 7, (8) AR Lot 9, (9) AO Lot 9, (10) T Lot 9, (11) O Lot 17

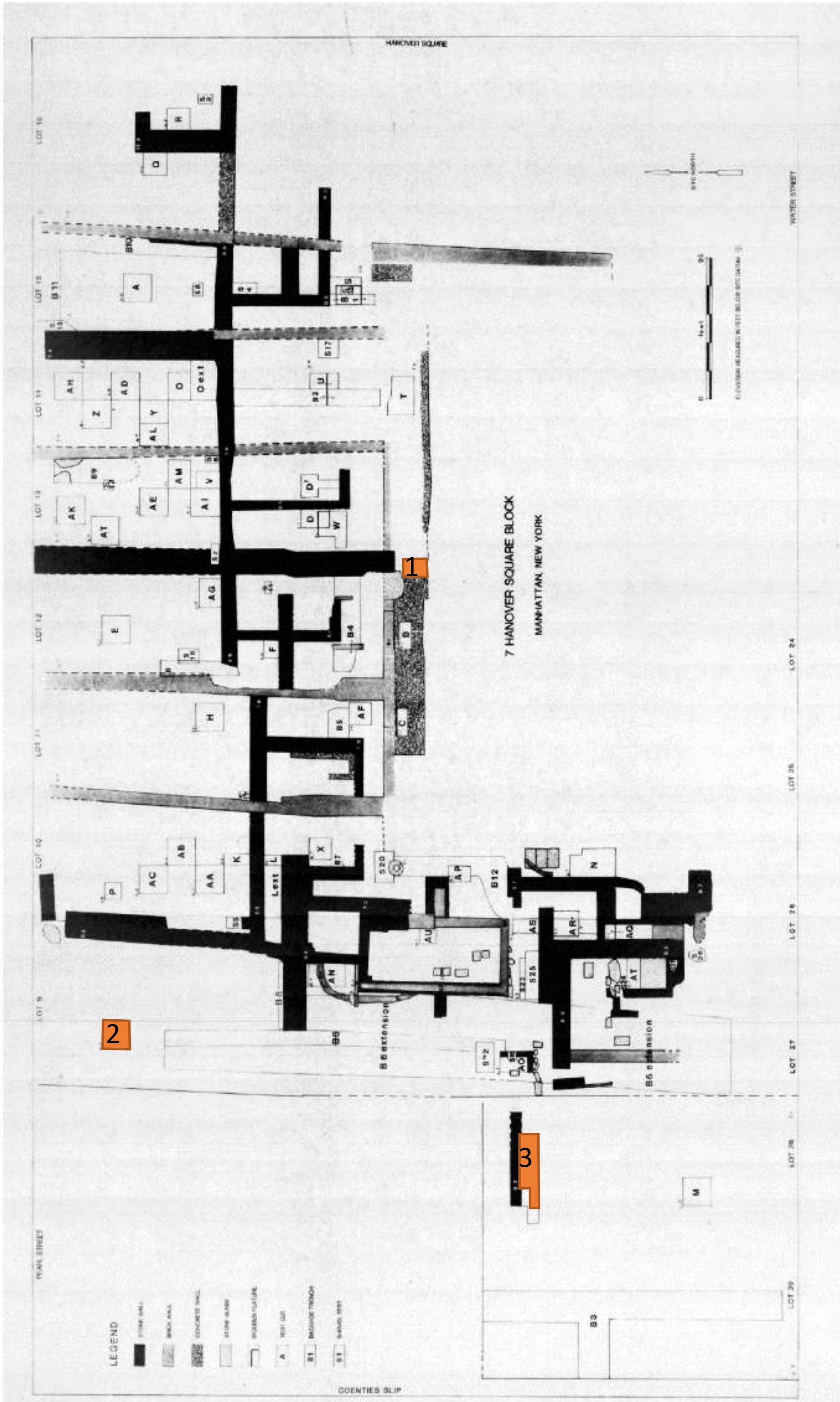



Close-Up Left, Stadt Huys Site Map, from: *The Archaeological Investigation of the Stadt Huys Block: A Final Report.*




Close-Up Right, Stadt Huys Site Map, from: *The Archaeological Investigation of the Stadt Huys Block: A Final Report.*

**Key to Test Cuts included in this study**: (1) G Lot 12, (2) I Lot 9, (3) J Lot 28




Seven Hanover Site Map, from: *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

# Appendix B – Concordance Tables

STONE_STREET

| Test_Cut | Catalog_# | Description | Interpretation |
|---|---|---|---|
| CA | 1618,1621,1625, 1628,1630,1631 | Gray green clay mixed with small amounts of red brown sandy silt | Mixed 19th century deposit plus demolition debris from 1907 structure |
| CA | 1634,1637 | Blue and gray clay | Mid to late 19th century deposit |
| CA | 1622,1633,1636, 1639 | Brown silt | Builder's trench for adjacent stone wall which may relate to 1907 building |
| CA | 1638,1641,1643, 1649,1653 | Dark brown to black clay silt | Mid to late 19th century deposit |
| CA | 1642 | Rust brown silt | Decayed wooden plank |
| CA | 1652,1654,1656, 1657,1658 | Blue clay mottled with brown silt | |
| CA | 1660,1662 | Gray brown silt | |
| CA | 1645,1646,1648 | Stone and mortar from western stone wall | |
| BZ | 1617,1623 | Brown sandy silt | Overburden and demolition debris |
| BZ | 1624,1627,1632, 1635,1644 | Dark brown clayey silt | Builder's trench for stone wall relating to 1907 building episode |
| BZ | 1619,1629,1640 | Red brown sandy silt | Mixed 20th century construction deposit |
| BZ | 1626 | Green clay | |
| BZ | 1647,1650 | Dark brown silt with blue clay | Mixed mid to late 19th century deposit |
| BZ | 1655,1659,1661 | Green/blue gray clay | Subsoil |
| BZ | 1663 | Dark gray silt | |

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Concordance Table T.C. CA and BZ. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 18 – The Strata Excavated in Test-Cut CB

| Stratum | Interpretation | Context Number |
|---|---|---|
| 1. Black top and fill | Modern street, bedding | --- |
| 2. Brown sandy silt | Fill | --- |
| 3. Reddish brown mottled organic silt | Mid-nineteenth century fill | 1669 |
| 4. Bluestone, brick, and black and tan silty sand with red sand | Sidewalk paving and bedding | 1680,1690 |
| 5. Tan and gray silt with red sand | Builder's trench, Lot 18 | 1670,1678 |
| 6a. Gray sandy silt with orange mottling and charcoal | Builder's trench, Lot 17 | 1671,1675,1688, 1692 |
| 6b. Tan sandy silt with gray and red sand mottling | " " | 1702,1718 |
| 6c. Reddish fine sand | " " | 1733,1741 |
| 6d. Light brown silty sand | " " | 1746,1756 |
| 6e. Orange clayey silt | " " | 1770 |
| 6f. Gray clayey silt | " " | 1777 |
| 7. Tan and gray silty sand and red sand | Rodent burrow | 1685,1695,1699, 1712,1721,1731, 1737,1751 |
| 8. Mottled brown silty sand | Eastern refilled hole | 1687,1697,1704, 1711,1720 |
| 9. Tan and orange mottled sandy silt | Later-eighteenth century/ early-nineteenth century fill | 1694,1706 |
| 10. Red fine sand | Later-eighteenth century/ early-nineteenth century fill | 1709 |
| 11. Gray silt with charcoal | Mid- late-eighteenth century ground surface | 1713 |

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Concordance Table T.C. CB. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 18 – The Strata Excavated in Test-Cut CB......continued

| Stratum | Interpretation | Context Number |
|---|---|---|
| 12. Red sand | Late-eighteenth century fill | 1717 |
| 13. Red fine sand mottled with gray silt | Late-seventeenth/early-eighteenth century fill | 1726 |
| 14. Light gray clayey silt with shell and charcoal | Late-seventeenth century/early-eighteenth century middens, fill, ground surface | 1739 |
| 15. Gray and brown mottled sandy silt | Late-seventeenth century/early-eighteenth century middens, fill, and ground surface | 1740 |
| 16. Gray sandy silt mottled with tan and red sand | Late-seventeenth century/early-eighteenth century middens, fill, and ground surface | 1743, 1749 |
| 17. Grayish tan sandy silt | Late-seventeenth century midden/ground surface/fill | 1752,1757 |
| 18. Dark brown organic soil | Late-seventeenth century midden/ground surface/fill | 1753 |
| 19. Dark gray-brown clayey silt with rocks and shell | Late-seventeenth century ground surface | 1760,1761,1766 |
| 20. Gray clayey silt with charcoal and ash | Late-seventeenth century midden/fill/ground surfaces | 1772 |
| 21. Gray-brown clayey silt with charcoal | Late-seventeenth century midden/fill/ground surfaces | 1773 |
| 22. Light gray silty clay with ash and charcoal | Late-seventeenth century midden/fill/ground surfaces | 1779 |
| 23. Dark gray clayey silt with black | Early-to-mid-seventeenth century ground surfaces | 1776,1778,1781 |
| 24. Tan clayey silt | Subsoil | 1783,1784,1785, 1787 |



Concordance Table T.C. CB. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 17 – <u>The Strata Excavated in Test-Cut CC</u>

| <u>Stratum</u> | <u>Interpretation</u> | <u>Context Number</u> |
|---|---|---|
| 1. Blacktop, concrete, and red sand | Modern street and bedding, fill | --- |
| 2. Tan silt mottled trench with brown silt ,1735, | 1674,1681,1685, | Vault 1700,1714,1723, 1725,172 1754,1758,1762, 1767,1774 |
| 3. Brown sandy silt | fill | --- |
| 4. Gray and red brown sandy silt with ash | Utility trench | 1672,1673,1701, 1722,1703 |
| 5. Mortar | Fill | --- |
| 6. Stone with dark brown organic soil | Early-nineteenth century century sidewalk | 1676 |
| 7. Gray sand | Curbstone trench | 1686 |
| 8. Tan silt with red sand | Pavement bedding | 1679 |
| 9. Green sandy silt | Fill | 1691 |
| 10. Rust and gray sandy silt | Fill | 1689,1693 |
| 11. Red sand | Fill | 1682 |
| 12. Green silt | Fill | 1696 |
| 13. Gray and brown sandy silt with | Refilled hole mortar and rubble | 1715,1727 |
| 14. Red sand | Fill | 1698,1705,1707 |
| 15. Rust,red, and gray mottled silt | Late-eighteenth century pavement bedding | 1710,1786 |
| 16. Rust,red, and gray mottled silt | Refilled trench | 1716,1730,1736 1745,1791,1796, 1802,1808 |
| 17. Blackish brown sandy silt | Eighteenth century ground surface | 17 9 |

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Concordance Table T.C. CC. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 17 - The Strata Excavated in Test-Cut CC......continued

| Stratum | Interpretation | Context Number |
| --- | --- | --- |
| 18. Red sand | Late-seventeenth/early eighteenth century fill | 1719,1790 |
| 19. Gray silt with charcoal | Late-seventeenth/early eighteenth century ground surface | 1724,1793 |
| 20. Tan silty clay with gray-green silty sand | Fill/midden lens | 1728,1732 |
| 21. Brown clayey silt with burnt shell | Fill/midden lens | 1794,1797 |
| 22. Red sand | Late-seventeenth/early eighteenth century fill | 1734,1798 |
| 23. Gray silt with charcoal and red sand | Late-seventeenth century ground surface | 1738,1744,1747, 1800 |
| 24. Yellow silt with mortar | Late-seventeenth century fill lens | 1742,1748 |
| 25. Tan silt | Late-seventeenth century fill | 1750,1799,1803, 1804 |
| 26. Gray silt with shell and charcoal | Mid-seventeenth century ground surface | 1759,1763,1807 |
| 27. Tan green silt | Fill lens | 1764,1809 |
| 28. Black silt | Early- to mid-seventeenth century ground surface | 1765,1768,1810 |
| 29. Tan and gray silt | Subsoil | 1769,1771 |

Table 7. Mid-19th through Early 20th century deposits.

| Event and Stratum Description | Test Cut T | Test Cut AD | Test Cut AR |
|---|---|---|---|
| 1. Concrete floor and cinder bedding | 234,270, 235,272 | 618,792 | --- |
| 2. Light brown sand with mortar-fill | 235,272 | 620 | --- |
| 3. Tan silt lens-fill | 237 | --- | --- |
| 4. Dark brown sand with coal and red-brown sand lens-fill | 239,273 245,275 | 622,628 639,629 | --- |
| 5. Light brown sand with mortar-fill | 267,284 302 | 627 cistern:640 647,664,690 815,855 | 696 privy fill: 801,879,829 |
| 6. Dark brown sand with coal and water-worn pebble-fill | 262,278 | --- | --- |
| 7. Privy fill: | | | |
| 7a. Pink sand with mortar | --- | --- | 966,970,978, 980,987,1055, 1078 |
| 7b. Brown and tan clayey silt-lens | --- | --- | 991,996,1052 |
| 7c. Dark brown sandy silt | --- | --- | 1000,1003, 1060,1064, 1092,1080, 1132,1291 |
| 7d. Light brown sand silt-lens | --- | --- | 1089 |
| 7e. Gray-brown clayey silt | --- | --- | 1099 |
| 8. Privy deposit: gray, tan, and brown clayey silt and clay | --- | --- | 1296,1299, 1313 |
| 9. Cistern fill | | | |
| 9a. Medium brown clayey sand with charcoal | --- | 859,864 | --- |
| 9b. Dark brown sandy clay | --- | 867,914 | --- |



Concordance Table Lot 9 Backyard. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 8. Late 18th and Early 19th century deposits and features in the Backyard of Lot 9

| Event | Test Cut T | Test Cut AQ | Test Cut AR |
|---|---|---|---|
| 26. Flagstone paving | 328 | --- | --- |
| 10. Wall of backyard structure | 327,340 | --- | --- |
| 11. Floor and cistern installation - tan and brown mottled silt | 286,291, 303,304 | 631,648, 642,667, 773,795 | 805,850 |
| 12. Lower strata of cistern trench | | | |
| 12a. Dark brown silt | 382 | --- | --- |
| 12b. Tan and reddish-brown mottled silt with brown sand lenses | 384,399, 437,439, 467 | 683,812, 838 | --- |
| 12c. Brown silt | 478 | 854,883, 884,903 | --- |
| 13. The privy wall-stones in brown sandy silt | | 891,958,1009, 1027,1034, 1106,1111, 1118,1308,1324 | |
| 14. The builder's trench | | | |
| 14a. Medium brown sand with mortar, brick, and rubble | 332,335,347, 371,409,427, 450 | | |
| 14b. Brown clayey silt | 418,446,455, 457,459,485, 601 | | |
| Lenses | 418,446,455 | | |
| 14c. Medium brown sandy silt | 313,342 | 643,644,649, 657 | |
| 14d. Medium brown sandy silt with mortar and yellow brick | 368,377,406 424 | 655 | |
| Slumped deposits | | | |
| 16a&b. Tan sandy silt with green and rust mottlin | 16a. 356,361 16b. 392,416 | | |
| 17a. Tan and brown sandy silt | 398 | | |
| 18a&b. Rusty brown sandy silt | 18a. 420,403,419 18b. 463 | | |

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Concordance Table Lot 9 Backyard. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

Table 8. Late 18th and Early 19th century deposits and features in the Backyard of Lot 9 - continued....

| Event | Test Cut T | Test Cut AO | Test Cut AR |
|---|---|---|---|
| 20a&b. Light brown sand with mortar flecks | 20a. 421 | | |
| 21a&b. Medium dark brown clayey silt | 21a. 441,449<br>474<br>21b. 470 | | |
| 22. Brown and orange-tan mottled silt | 479 | | |
| 23a. Orange-tan silt | 479 | | |
| 25. The trench for the Privy in Lot 16 | | See Lot 16 | |
| 25a. Medium, dark, and light brown mottled sandy silt | | | |
| 25b. Dark brown silt with mottles of light brown sandy silt | | | |



Concordance Table Lot 9 Backyard. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

APPENDIX M: title

LOT 6

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| AH,AH(1),AD,AE AE(1), AE(2) | 535,569,536, 543,556,567, 572,584,587 | Reddish brown sand with mortar and rubble | Associated with last construction episode on lot |
| AD,AH,AH(1) | 537,541,573 575,538 | Dark brown organic sandy silt | Early 19th century ground surface (old humic topsoil) |
| AH(1) | 571 | Coal and ash concentration in Dark Brown organic sandy silt | |
| AE, AE(1),AE(2) | 560,574,592 725,728 | Greenish gray clay silt | Late 18th or early 19th century deposit |
| AH,AH(1) | 542,577 | Greenish clay with pockets of charcoal and brown sand | Late 18th or early 19th century deposit |
| AD | 539 | Dark brown clayey silt | Mixed late 18th and early 19th century deposit. Relates to 1835 demolition and construction episode |
| AD | 540,550,551 | Tan sandy silt | Subsoil |
| AE | 708 | Dark brown sandy silt | Builders trench for red brick semi-circular structure |
| AE | 563,597,701, 714,706 | Greenish gray clay silt changing to greenish gray silt | Builders trench for Lot 7/6 stone wall |
| AD | 544,545 | Brown sandy silt with brick rubble and decomposed mortar, mottled with a tan and green clay | Builders trench for Lot 7/6 stone wall |
| AD | 547 | Gray green sandy silt | Builders trench for Lot 7/6 stone wall |
| AD | 552 | Yellow tan silty clay | Subsoil |

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Concordance Table Lot 6. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

LOT 6

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| AH | 549,579,555 | Dark brown sandy silt with pockets of tan sand | Unknown trench |
| AH | 546,548 | Greenish clay with pockets of charcoal and brown sand | |
| AE | 721,735 | Red and yellow brick with mortar | |
| AE | 743,740,738, 733 | Tan green sandy silt changing to clay | Subsoil |
| AH | 554,561,581 | Tan mottled black sandy silt grading to tan sandy silt | Subsoil |
| AE | 741 | Tan silty clay | (Subsoil) Part of red brick semi-circular structure's builder's trench |
| AD | 40 | | Lot 6/7 wall cleaning |
| AD | 45 | | Lot 6/14 wall cleaning |
| AD | 258 | | Lot 6 surface cleaning |
| AD | 553 | Brown sandy silt | Cleaning between brick and stone walls |
| AH | 557 | Brown tan sandy silt | Wall cleaning |



Concordance Table Lot 6. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

LOT 7

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| AM | 760 | Green gray clayey silt | Builder's trench deposit for stone wall |
| AM | 768 | Green gray sandy silt stained with oil | |
| AM(1)<br>AM | 767,769<br>770,761 | Green gray clayey silt | Subsoil |
| AJ & AJ(1) | 578 | Tan gray sandy silt | Subsoil |
| AJ | 588 | Orange brown/gray mottled sandy silt | Builder's trench |
| AJ & AJ(1) | 589,593 | Tan gray sandy silt with yellow and bluish gray mottling | |
| F | 57 | Black brown sandy silt overburden | Demolition of last lot structure |
| F | 60,62,67 | Yellow/tan clay mottled with brown and black sandy silt | Construction pit for Feature 1 |
| F | 72,79 | Yellow and tan clay mottled with brown sandy silt | Pit for Feature 1 (Builder's trench) |
| F | 76 | Black sandy silt | Feature 1 |
| F | 88 | Brown sandy silt | Associated with Feature 1 construction |
| F | 86,92,93,97, 100,311 | Brown clayey silt mottled with greenish clayey silt | Disturbed Late-18th century deposit that contained some debris from Feature 3 |
| F | 89,91 | Brown sandy silt mottled with yellow and green clayey silt | Feature 3 builder's trench |
| F | 316 | Organic brown mottled with brown sandy silt | 'A' horizon, ground surface remnant |

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Concordance Table Lot 7. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

LOT 7

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| F | 321,323 | Tan and green clay mottled with brown sandy silt | 'B horizon' |
| F | 337 | Brown sandy silt | Builder's trench for lot 7/14 stone wall |
| F | 333 | Tan clayey silt | Builder's trench for lot 7/14 stone wall |
| F | 492 | Brown sand with rubble | Feature 3 deposit |
| F | 602 | Reddish brown sand | Feature 3 deposit |
| F | 625 | Cobbles and blackish gray sand | Feature 3 deposit |
| F | 633 | Pink sand with oily green-brown clayey silt veins | Feature 3 deposit |
| F | 917 | Greenish tan silt | Feature 3 deposit |
| AP | 637 | Pink sand | Feature 3 |
| AP | 641,652 | Brown sandy silt mottled with shell, brick and charcoal | Feature 3 |
| AP | 654 | Black clayey silt | Builder's trench for Feature 3 |
| AP | 673 | Brown sandy silt with pink flecks | Builder's trench for Feature 3 |
| AP | 662 | Tan clayey silt | Builder's trench for Feature 3 |
| AP | 676 | Tan silt with brown silt mottles | Builder's trench for Feature 3 |
| AP | 682,687 | Tan and green silt | Feature 3 deposit |
| AP | 685 | Brown and sandy silt | Associated with the brick wall of Feature 3 |
| AP | 689,638 | Bricks and associated pink sand | Feature 3 |



Concordance Table Lot 7. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

LOT 7

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| AP | 811 | Footing stones | Feature 3 |
| AL | 719 | Yellow tan gray clayey silt | Early 19th-century deposit |
| AL | 722 | Brown sandy silt with charcoal and mortar | Builder's trench for stone and mortar wall |
| AL | 723 | Brown clayey silt | Builder's trench for stone and mortar wall |
| AL | 715 | Gray tan clayey silt | Builder's trench for stone and mortar wall |
| AL | 724,734,749 | Green sandy silt with black and orange mottling | Builder's trench for stone and mortar wall |
| AL | 730,726 | Dark brown sand with mortar | Builder's trench for stone and mortar wall |
| AL(1) | 739 | Green sandy silt with tan, rust and black mottles | Builder's trench for stone and mortar wall |
| AL(1) | 742,744 | Green sandy silt with tan, orange and gray mottles | Builder's trench for stone and mortar wall |
| BU | 1486,1492 | Brown sandy silt with rubble | Demolition of last structure on block |
| BU | 1505,1510,1514 | Reddish brown sandy silt | Demolition of last structure on lot |
| BU | 1518 | Red silt | Post hole test |
| AV | 873,880,899 | Dark reddish brown sand mixed with ash | Demolition of last structure on block |
| AV | 885,892 | Light reddish brown sand mixed with ash | Demolition of last structure on lot |
| AV | 902 | Green gray mottled tan sandy silt | |

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Concordance Table Lot 7. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

LOT 17

| Test Cut | Catalog # | Description | Interpretation |
|---|---|---|---|
| O | 169,170,183,181 | Brown sandy silt | Demolition of last structure that stood on lot |
| O | 184 | Light brown clayey silt to light brown clay | 19th century old humic topsoil or 'A' horizon |
| O | 194 | Tan silt | |
| O | 203 | Green and brown mottled silt | Builder's trench for the Lot 16/17 stone wall |
| O | 214,218 | Brown clayey silt | Builder's trench for the Lot 16/17 stone wall |
| O | 217 | Green silt | Builder's trench for the Lot 16/17 stone wall |
| O | 219 | Tan silt | Builder's trench for the Lot 16/17 stone wall |
| O | 248 | Tan silt to green clayey sand | Post hole. Subsoil deposits |
| O | 53 | Cleaning fill | |
| O | 176 | Under floor in cleaning | |
| O | 762 | Cleaning with backhoe | |
| O | 37,65 | Lot wall 11/17 in cleaning surface, brick wall | Tavern walls |



Concordance Table Lot 17. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

## LOT 9 - TEST CUT I

| | |
|---|---|
| (Strata I,II,III)<br>Mortar and hard packed reddish brown sand with yellow mottling below brick floor | 176, 177, 184 |
| (Stratum VI)<br>Red/brown sandy silt lens - NW portion of T.C. - landfill | 195 |
| (Stratum IV)<br>Yellow green sandy silt with yellow mottling - upper landfill | 186, 196, 202, 220 |
| (Stratum V)<br>Intrusive pit - Southeast portion of T.C. | 194, 206 |
| (Stratum VII)<br>Red sand band - landfill | 211 |
| (Strata VIII and IX)<br>Yellow/green sandy silt and green silt with red sand pockets - lower landfill | 215, 218, 225, 229 |
| (Stratum XI)<br>Green sandy silt with pockets of brown and black clay - landfill | 233, 257. 281 |
| (Stratum XII)<br>Brown sand - landfill? | 292, 307, 322 |
| (Stratum XIII)<br>Red sand - river bottom | 333, 3345, 346, |

Concordance Table Lot 9. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

LOT 12
TC G

| | |
|---|---|
| Wall trench east of feature<br>Strata II and V | 66, 75, 116 |
| Deposits outside and above top of feature<br>Strata I, III, IV, VI | 62, 70, 74, 72, 79, |
| Deposits within feature and area above feature - Strata VIIa and VIIb | 87, 94 |
| Deposits outside and below top of feature - Strata IX, X, XI | 109, 117, 122, 125 |
| Brown sandy silt in feature<br>Stratum VIIc - VIIf | 102, 130, 139, 147 |
| Blackish brown sandy silt in feature<br>Stratum XII | 146, 149 |
| Blackish gray clayey silt in feature<br>Strata XIII and XIV | 156, 161, 165 |
| Brown/tan and gray fine sand in feature<br>Strata XV and XVI | 170, 175, 181 |
| South wall trench cutting through south part of feature - Stratum VIII | 105, 136, 178 |
| Gray brown sandy silt within feature<br>Strata XVII, XVIIIa, XVIIIb | 182, 189, 198 |
| Sandstone slabs and brick feature<br>Stratum XVIIIc | 201 |
| Brown sandy silt below feature wall and below slabs - Stratum XIX | 213, 217, 222 |
| Dark brown silty sand at base of feature<br>Stratum XX | 223 |
| Gray silt below feature<br>Stratum XXI | 244 |

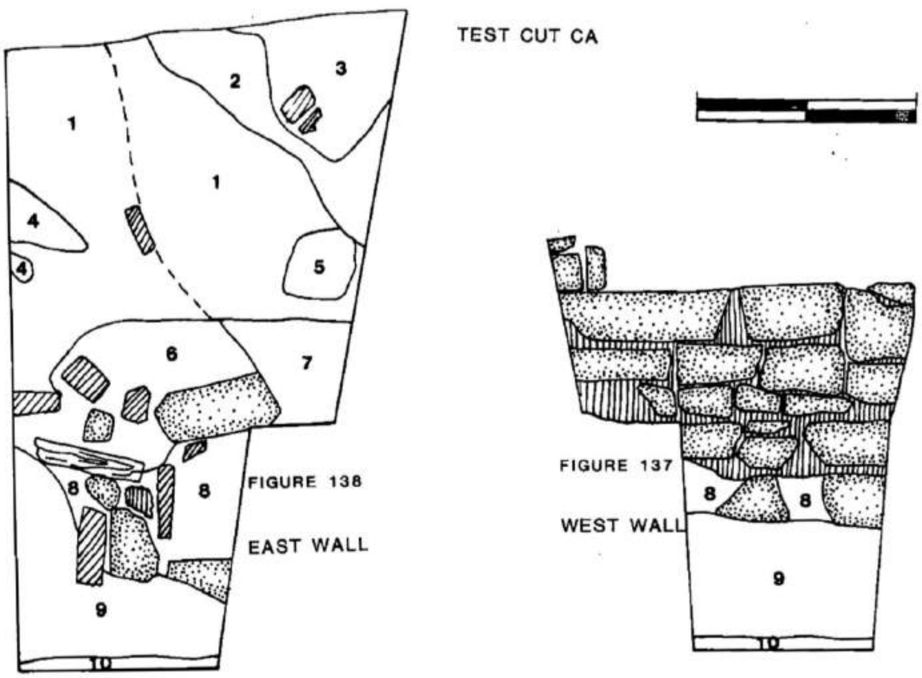
Concordance Table Lot 12. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

LOT 28

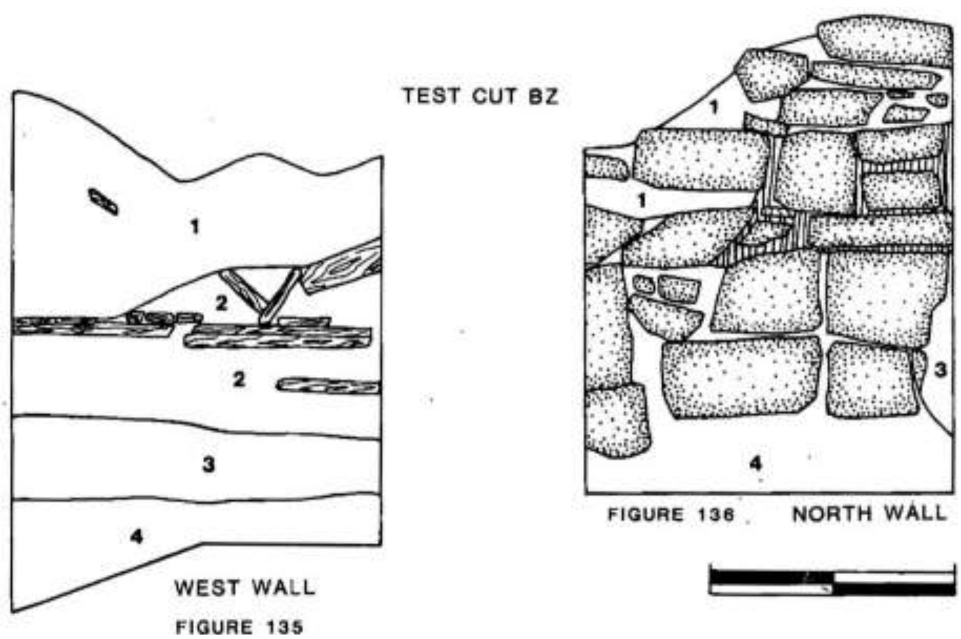
| | TCJ | TCM |
|---|---|---|
| Deposits between floor #12 and floor #2 (rubble) | 197, 200 | 252, 255 |
| Floor #2 | 207 | 260 |
| Between floors #2 and #3 (brown/gray silty sand) | 210, 224, 227, 234,241 | 276, 283 |
| Floor #3 | 230 | 289, (barrels) 294 |
| Deposits under floor #3 | 242, 311, 249, 315, 269 | 299, 305, 310 313, 314 |
| Strip near north wall | 320 | |
| Privy deposit- level 1 west side | 256 | |
| Privy deposit level 2 west side | 261 | |
| Privy deposits levels 1 and 2 - east side | 279 | |
| Privy deposit - level 3 | 293 | |
| Privy deposit - level 4 | 430 | |
| Orange/tan/rust sand below privy | 434, 492 | |
| Mottled red, brown, orange, sand bands (landfill) | 493, 316, 324, 325, 328, 340, 344, 350, 360, 369 | 312, 321, 326, 338, 352, 361, 366, 377, 382, 389 |
| Lens of dark brown/black organic silt (landfill) | 341, 349 | |
| Gray silt (river bottom silt) | 376 | 393 |

Concordance Table Lot 28. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

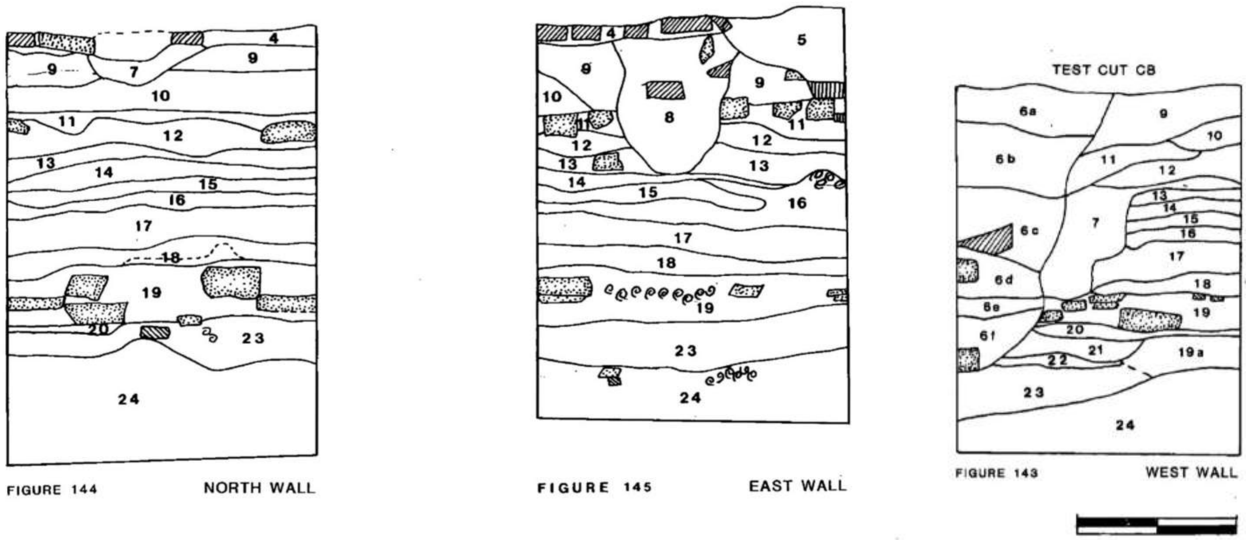
# Appendix C – Test Cut Profiles




Test Cut CA, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

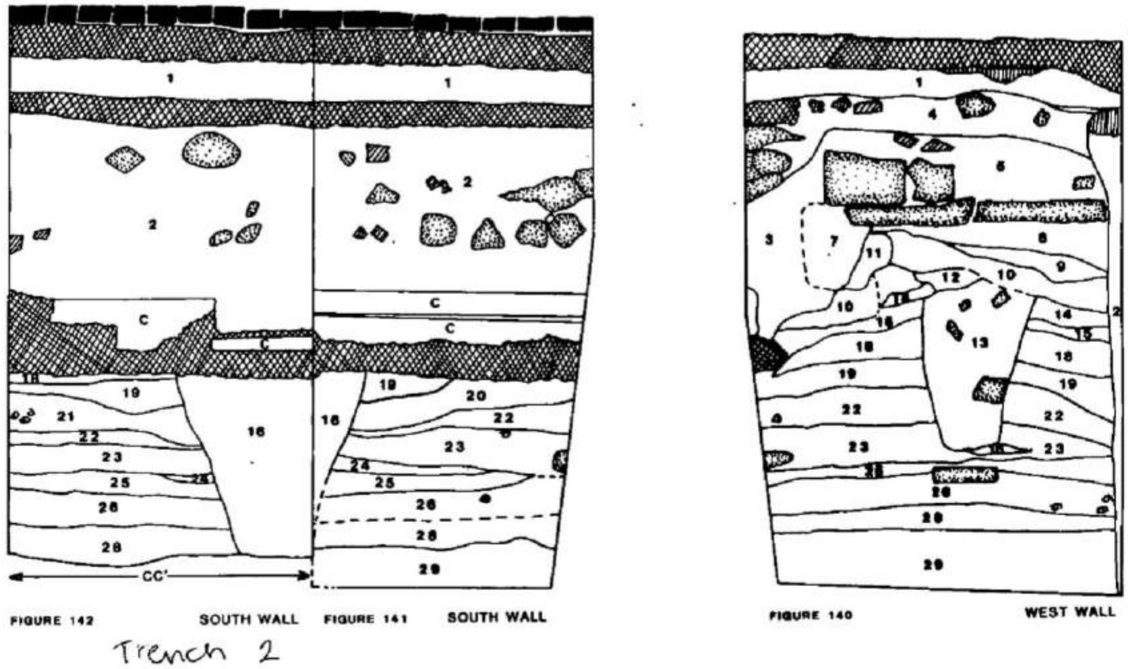



Test Cut BZ, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*




TEST CUT CB

Test Cut CB, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

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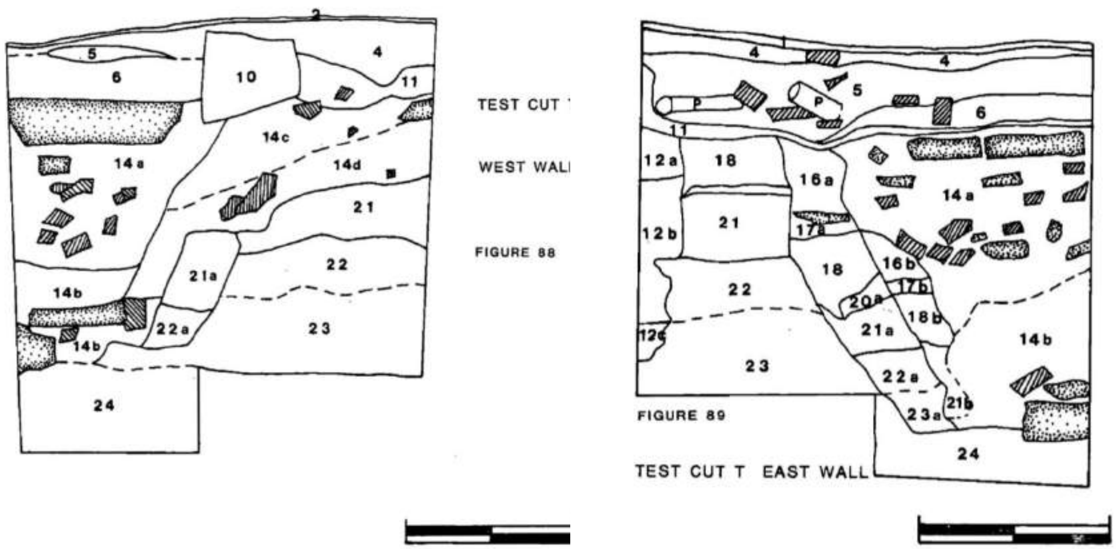
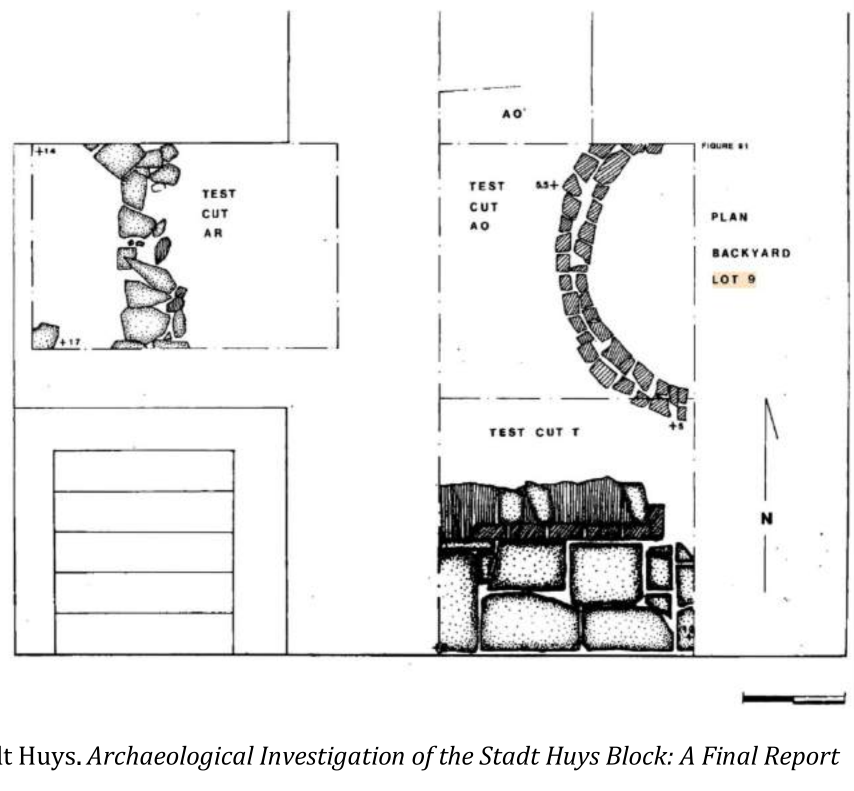
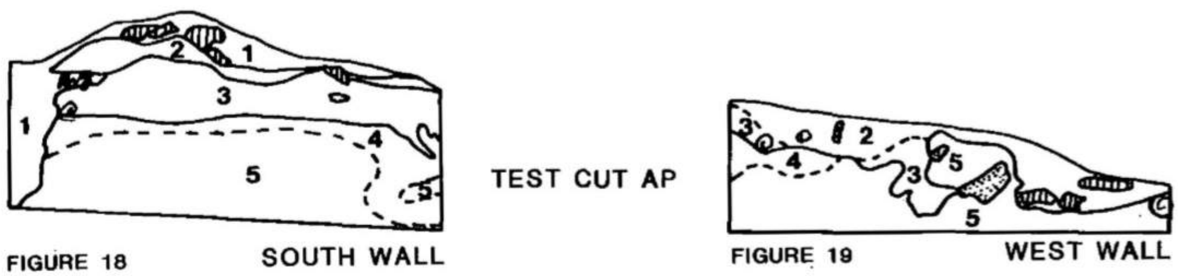



Test Cut T, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*




Plan of Lot 9, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

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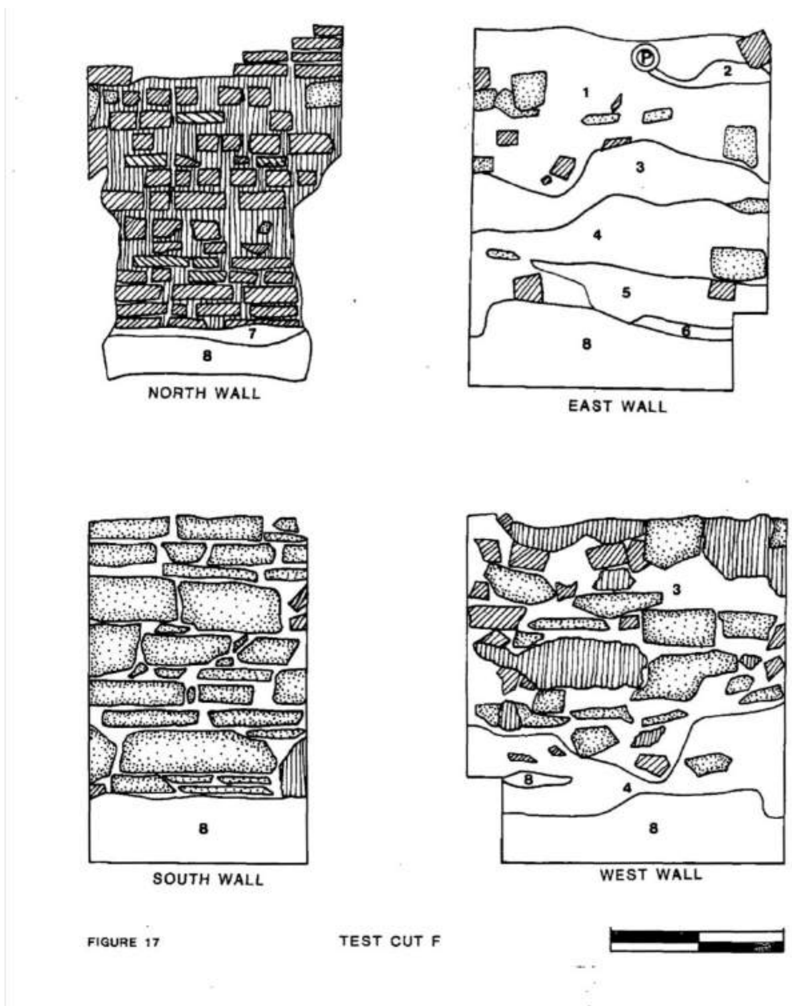



Test Cut F, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

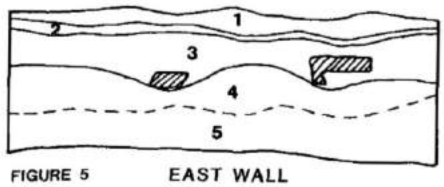



FIGURE 5 EAST WALL

TEST CUT AH AH'

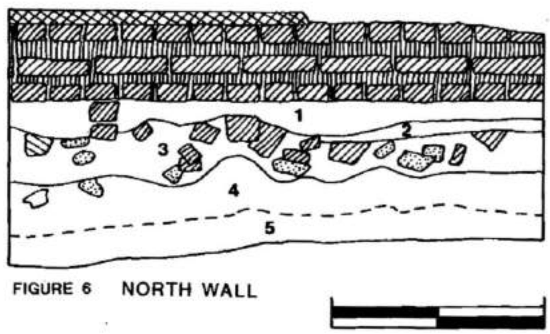



FIGURE 6 NORTH WALL

Test Cut AH, Stadt Huys. *Archaeological Investigation of the Stadt Huys Block: A Final Report*

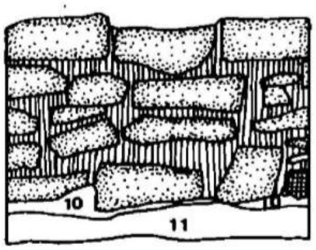
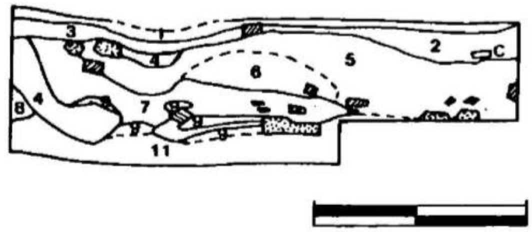



FIGURE 120 WEST WALL

TEST CUT O

FIGURE 119 NORTH WALL

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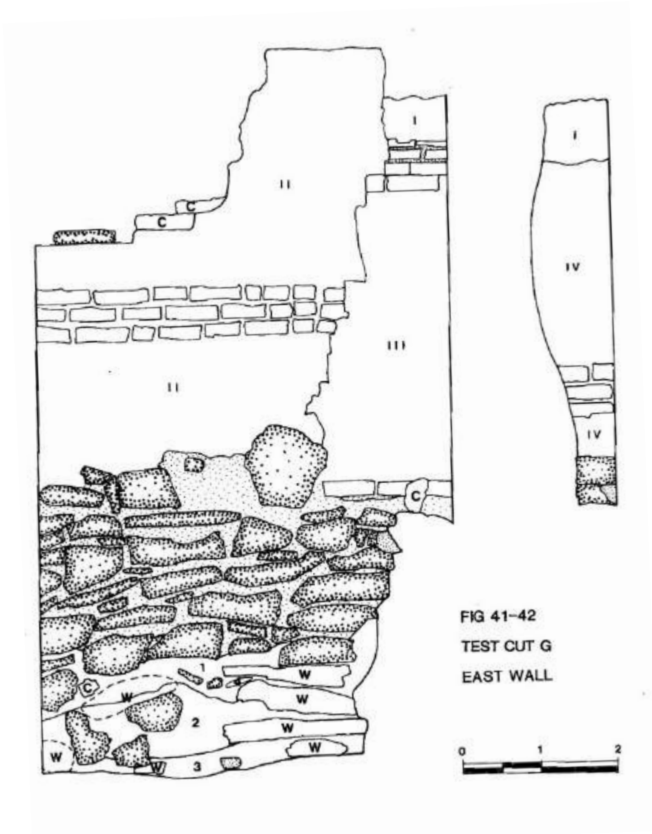
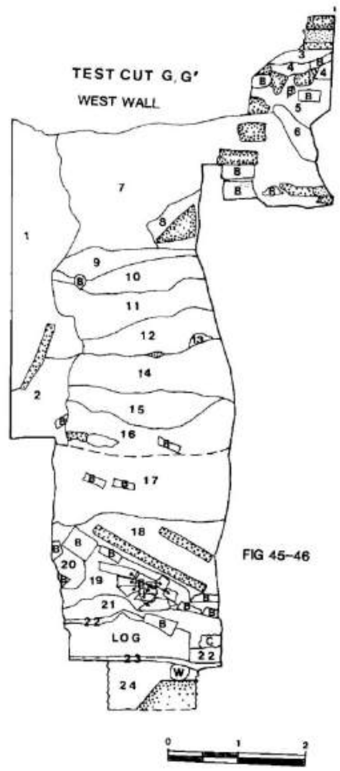
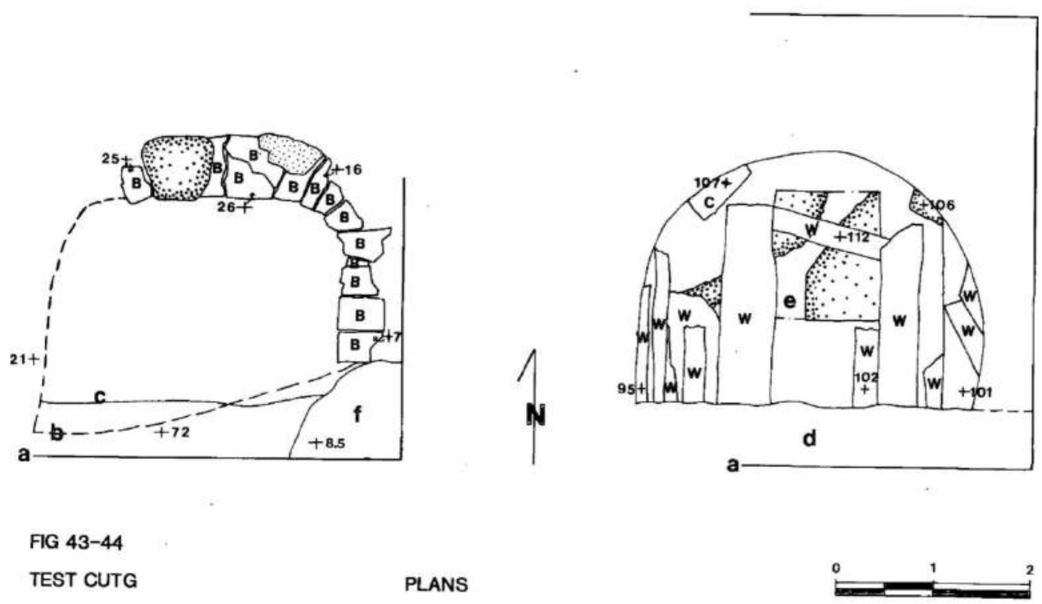
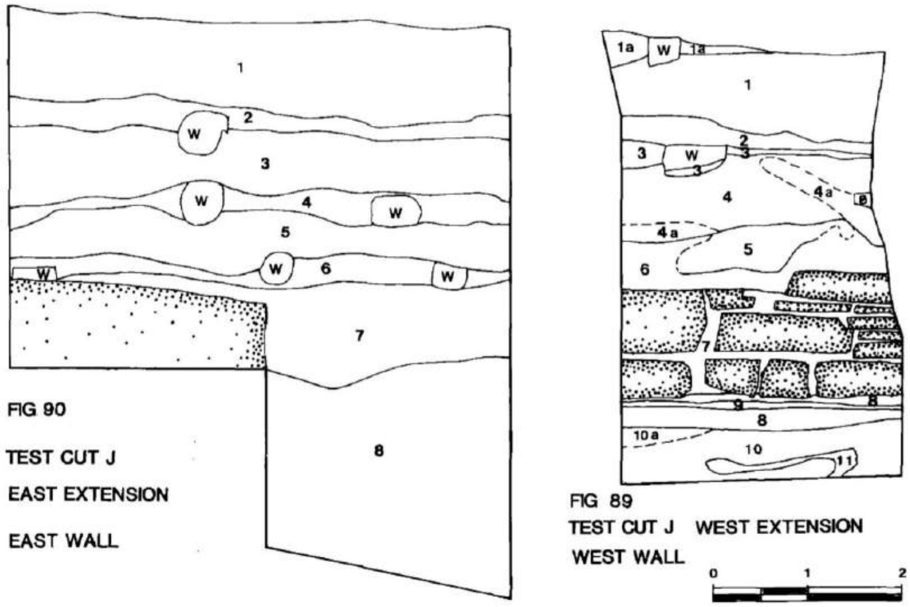


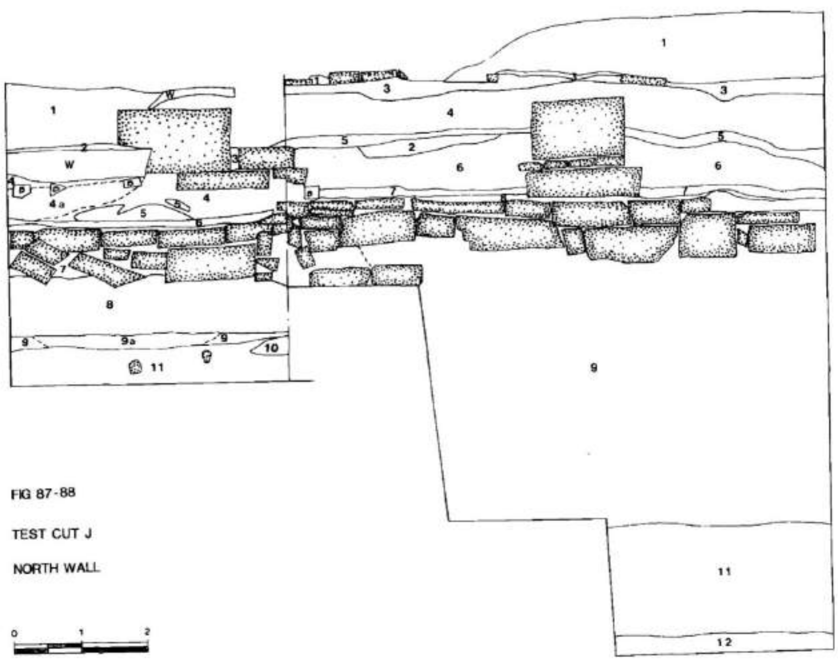

Test Cut G, Seven Hanover. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*




Test Cut G, Seven Hanover. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*




Test Cut J, Seven Hanover. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*




Test Cut J, Seven Hanover. *The Archaeological Evaluation of the Seven Hanover Square Block: A Final Report*

# Appendix D – Data Tables

Table 3: Characteristics of Shell Lime Mortars

| Sample | Site | Stratum | Unburned Shell Fragments | Partially Burned Shell Fragments | Shell Texture in Binder Lumps | Glass Fragments | Wood Cinder | Shell Fines |
|---|---|---|---|---|---|---|---|---|
| 1799 | Stadt Huys | CC25 | X | X | X | X | X | |
| 1747a | Stadt Huys | CC23 | X | X | X | X | X | |
| 1747b | Stadt Huys | CC23 | X | X | X | X | X | |
| 1710a | Stadt Huys | CC15 | X | X | X | X | X | |
| 1710b | Stadt Huys | CC15 | X | X | X | X | X | |
| 1727a | Stadt Huys | CC13 | X | X | X | X | X | |
| 1727b | Stadt Huys | CC13 | X | X | X | X | X | |
| 1727c | Stadt Huys | CC13 | X | X | X | X | X | |
| 1784a | Stadt Huys | CB24 | X | X | X | X | X | |
| 1766 | Stadt Huys | CB19 | X | X | X | X | X | |
| 1657 | Stadt Huys | CA | X | X | X | X | | X |
| 1652 | Stadt Huys | CA | X | X | X | | X | |
| 1631c | Stadt Huys | CA | X | X | X | X | | X |
| 575 | Stadt Huys | AH | X | X | X | | X | |
| 449 | Stadt Huys | T21a | X | X | X | X | X | |
| 424 | Stadt Huys | T14 | X | X | X | X | X | X |
| 450 | Stadt Huys | T14 | X | X | X | X | X | X |
| 304 | Stadt Huys | T11 | X | X | X | X | X | X |
| 332a | Stadt Huys | T11 | X | X | X | X | | X |
| 805a | Stadt Huys | AR11 | X | X | X | X | | |
| 257a | Seven Hanover | Lot 9 | X | X | X | X | | |
| 257b | Seven Hanover | Lot 9 | X | X | X | X | X | |
| 229a | Seven Hanover | Lot 9 | X | | X | X | X | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 229b | Seven Hanover | Lot 9 | X | X | X | X | X | |
| 225 | Seven Hanover | Lot 9 | X | X | X | X | X | |
| 196a | Seven Hanover | Lot 9 | X | | X | | X | |
| 196b | Seven Hanover | Lot 9 | X | X | X | X | X | |
| 196c | Seven Hanover | Lot 9 | X | | X | | | |
| 194 | Seven Hanover | Lot 9 | X | X | X | X | X | X |
| 220 | Seven Hanover | Lot 9 | X | X | X | X | X | X |
| 202 | Seven Hanover | Lot 9 | X | | X | X | X | |
| 186d | Seven Hanover | Lot 9 | X | | X | X | X | X |
| 195a | Seven Hanover | Lot 9 | X | | X | | | |
| 211 | Seven Hanover | Lot 9 | X | X | X | | X | |
| 177b | Seven Hanover | Lot 9 | X | X | X | X | X | X |
| 177d | Seven Hanover | Lot 9 | X | | X | X | | X |
| 369 | Seven Hanover | Lot 28 | X | X | X | X | | |
| 493a | Seven Hanover | Lot 28 | X | X | X | X | X | X |
| 493b | Seven Hanover | Lot 28 | X | | X | | | |
| 242a | Seven Hanover | Lot 28 | X | X | X | X | | X |
| 223a | Seven Hanover | Lot 12 | X | X | X | | | |
| 117b | Seven Hanover | Lot 12 | X | X | X | X | | X |
| LL | Stadt Huys | | X | X | X | X | X | |

Table 4: Characteristics of Rock Lime Mortars

| Sample | Site | Stratum | Notes |
|---|---|---|---|
| 1737 | SH | CB7 | Mosaic texture |
| 1733 | SH | CB6c | Natural cement/lime mix |
| 1672 | SH | CC4 | Mosaic, fired quartz |
| 1653 | SH | CA | Mosaic, fired quartz |
| 1675 | SH | CB6a | Mosaic, fired quartz |
| 1752a | SH | CB17 | Rhombic texture |
| 1752b | SH | CB17 | Rhombic texture |
| 1752c | SH | CB17 | Rhombic texture |
| 1701 | SH | CC2 | Mosaic |
| 1631a | SH | CA | Rhombic, fired quartz |
| 1631b | SH | CA | Mosaic, fired quartz |
| 194 | SH | O | Mosaic, fired quartz |
| 641d | SH | AP | Mosaic |
| 1080a | SH | AR7c | Mosaic, fired quartz |
| 1080b | SH | AR7c | Marble (fired mica) |
| 332b | SH | T14a | Mosaic |
| 323 | SH | F | Gastropod, mosaic |
| 1132b | SH | AR7c | Mosaic |
| 1106 | SH | AR13 | Rhombic, incompletely fired dolomitic rock |
| 958 | SH | AR13 | Rhombic, fired quartz |
| 641a | SH | AP | Marble finish (pyroxene in finish). Substrate rhombic texture |
| 641b | SH | AP | Rhombic |
| 689 | SH | AP | Rhombic |
| 664 | SH | AO5 | Marble lime, finish and substrate, pyroxene |
| 805b | SH | AR11 | Mosaic, fired quartz |
| 186a | 7H | Lot 9 | Mosaic, fired quartz |
| 186b | 7H | Lot 9 | Cleavage and mosaic texture within the same lump |

| | | | |
|---|---|---|---|
| 186c | 7H | Lot 9 | Mosaic |
| 195b | 7H | Lot 9 | Mosaic, fired quartz |
| 177a | 7H | Lot 9 | Marble (pyroxene) Cleavage patterns in lime grain |
| 139 | 7H | Lot 12 | Mosaic |
| 147 | 7H | Lot 12 | Mosaic |
| 256 | 7H | Lot 28 | Expansion cracks, fired quartz |
| 242b | 7H | Lot 28 | Expansion cracks, fired quartz |
| 177c | 7H | Lot 9 | Mosaic, gastropod |
| 117a | 7H | Lot 12 | Rhombic |
| 149 | 7H | Lot 12 | Mosaic, fired quartz (coarse-grained) |
| 189 | 7H | Lot 12 | Mosaic, fired quartz |
| 201 | 7H | Lot 12 | Mosaic, fired quartz |

Table 5: Sand Extractions

| Color | Samples |
|---|---|
| 2.5Y 6/3 | 418 (SH), 424 (SH), 449 (SH), 1710 (SH), 1727 (SH), 1734 (SH), 1784 (SH) |
| 2.5Y 8/1 | 220 (7H) |
| 5YR 7/1 | 186a (7H) |
| 5YR 7/2 | 139 (7H), 147 (7H), 177a (7H), 186b (7H), 189 (7H), 196a, (7H) 196c (7H), 207 (7H), 242b (7H) |
| 5YR 8/2 | 332 (SH), 450 (SH), 575 (SH), 1296 (SH), 1631 (SH), 1675 (SH), 1718 (SH) |
| 7.5YR 7/1 | 1034 (SH), 1106 (SH), 1132 (SH), 1733 (SH) |
| 7.5YR 7/2 | 1027b (SH), 1647 (SH), 1648 (SH) |
| 7.5YR 7/3 | 1756 (SH) |
| 7.5YR 8/1 | 117a (7H) |
| 7.5YR 8/2 | 958 (SH) |
| 10YR 6/3 | 117b (7H), 225 (7H), 256 (7H), 257b (7H), |
| 10YR 7/2 | 194 (7H) |
| 10YR 7/3 | 229b (7H), 257a (7H) |
| 10YR 7/6 | 211 (SH) |

Table 6: Characteristics of Sands

| Sample | Test Cut | Date | Group | Sand Content | Grain Size |
|---|---|---|---|---|---|
| 1799 | SH, CC25 | Late 17th century | A | High | silt and fine-grained |
| 1747a | SH, CC23 | Late 17th century | A | High | silt and fine-grained |
| 1747b | SH, CC23 | Late 17th century | A | High | silt and medium to coarse sand |
| 1710a | SH, CC15 | Late 18th century | A | High | silt and fine-grained |
| 1710b | SH, CC15 | Late 18th century | A | High | fine to medium-grained |
| 1727a | SH, CC13 | - | A | High | silt and fine-grained |
| 1727b | SH, CC13 | - | A | High | silt and medium to coarse sand |
| 1727c | SH, CC13 | - | A | High | fine to medium-grained |
| 1672 | SH, CC4 | - | | Moderate | medium to coarse-grained |
| 1701 | SH, CC2 | - | | High | silt and medium to coarse sand |
| 1784a | SH, CB24 | - | A | High | silt and fine-grained |
| 1784b | SH, CB24 | - | | High | coarse-grained with fine to medium-grained |
| 1766 | SH, CB19 | Late 17th century | A | High | silt and fine-grained |
| 1752a | SH, CB17 | Late 17th century | | High | silt and medium to coarse sand |
| 1752b | SH, CB17 | Late 17th century | | High | fine to medium-grained |
| 1752c | SH, CB17 | Late 17th century | | High | medium to coarse-grained |
| 1737 | SH, CB7 | - | | High | silt and medium to coarse sand |
| 1733 | SH, CB6c | - | B | High | medium to coarse-grained |
| 1675 | SH, CB6a | - | B | High | silt and medium to coarse sand |
| 1646 | SH, CA | - | | High | silt and fine-grained |
| 1645 | SH, CA | (Early 20th century) | | High | coarse-grained with fine to medium-grained |
| 1648 | SH, CA | - | | Moderate | silt and fine-grained |
| 1657 | SH, CA | - | A | High | silt and medium to coarse sand |
| 1652 | SH, CA | - | A | High | silt to fine-grained with few coarse grains |
| 1653 | SH, CA | Mid to late 19th century | | High | coarse-grained with fine to medium-grained |
| 1631a | SH, CA | 19th century | A | Low | fine to medium-grained |
| 1631b | SH, CA | 19th century | | High | silt |

| | | | | | |
|---|---|---|---|---|---|
| 1631c | SH, CA | $19^{th}$ century | A | High | silt and medium to coarse sand |
| 575 | SH, AH | Early $19^{th}$ century | A | High | silt to fine-grained with few coarse grains |
| 323 | SH, F | - | | High | medium to coarse-grained |
| 689 | SH, AP | Early $19^{th}$ century | | High | fine to medium-grained |
| 641a | SH, AP | Early $19^{th}$ century | | High | coarse-grained with fine to medium-grained |
| 641b | SH, AP | Early $19^{th}$ century | | High | medium to coarse-grained |
| 641c | SH, AP | Early $19^{th}$ century | | High | coarse-grained with fine to medium-grained |
| 641d | SH, AP | Early $19^{th}$ century | | Moderate | medium to coarse-grained |
| 449 | SH, T21 | Late $18^{th}$ to early $19^{th}$ century | A | High | silt to fine-grained with few coarse grains |
| 424 | SH, T14 | Late $18^{th}$ to early $19^{th}$ century | A | High | silt to fine-grained with few coarse grains |
| 450 | SH, T14 | Late $18^{th}$ to early $19^{th}$ century | B | High | silt and medium to coarse sand |
| 1106 | SH, AR13 | Late $18^{th}$ to early $19^{th}$ century | B | High | medium to coarse-grained |
| 958 | SH, AR13 | Late $18^{th}$ to early $19^{th}$ century | | High | silt and fine-grained |
| 304 | SH, T11 | Late $18^{th}$ to early $19^{th}$ century | B | Moderate | medium to coarse-grained |
| 332a | SH, T11 | Late $18^{th}$ to early $19^{th}$ century | B | High | medium to coarse-grained |
| 332b | SH, T11 | Late $18^{th}$ to early $19^{th}$ century | B | Low | medium to coarse-grained |
| 805a | SH, AR11 | Late $18^{th}$ to early $19^{th}$ century | A | High | silt and fine-grained |
| 805b | SH, AR11 | Late $18^{th}$ to early $19^{th}$ century | B | Moderate | medium to coarse-grained |
| 1132a | SH, AR7c | Mid $19^{th}$ to early $20^{th}$ century | A | High | silt and fine to medium-grained |
| 1132b | SH, AR7c | Mid $19^{th}$ to early $20^{th}$ century | B | High | medium to coarse-grained |
| 1080a | SH, AR7c | Mid $19^{th}$ to early $20^{th}$ century | A | High | silt and medium to coarse sand |
| 1080b | SH, AR7c | Mid $19^{th}$ to early $20^{th}$ century | B | High | coarse-grained with fine to medium-grained |
| 664 | SH, AO5 | Mid $19^{th}$ to early $20^{th}$ century | | High | silt and medium to coarse sand |
| 628a | SH, AO4 | Mid $19^{th}$ to early $20^{th}$ century | B | High | coarse-grained with fine to medium-grained |
| 628b | SH, AO4 | Mid $19^{th}$ to early $20^{th}$ century | C | Low | fine to medium-grained |
| 203 | SH, O | - | | High | fine to medium-grained |
| 194 | SH, O | - | | High | silt and fine-grained |
| 307 | 7H, I | Late $17^{th}$ century | B | High | coarse-grained with fine to medium-grained |
| 257a | 7H, I | Late $17^{th}$ century | | High | silt and fine-grained |
| 257b | 7H, I | Late $17^{th}$ century | A | High | silt and medium to coarse sand |

| | | | | | |
|---|---|---|---|---|---|
| 229a | 7H, I | Late 17$^{th}$ century | | High | fine to medium-grained |
| 229b | 7H, I | Late 17$^{th}$ century | A | High | fine-grained |
| 225 | 7H, I | Late 17$^{th}$ century | | High | silt and fine-grained |
| 196a | 7H, I | Late 17$^{th}$ century | A | High | silt and medium to coarse sand |
| 196b | 7H, I | Late 17$^{th}$ century | A | Moderate | silt and fine-grained |
| 196c | 7H, I | Late 17$^{th}$ century | | High | silt and fine to medium-grained |
| 194 | 7H, I | Late 17$^{th}$ century | | Low | silt and fine-grained |
| 220 | 7H, I | Late 17$^{th}$ century | A | Moderate | silt and fine to medium-grained |
| 202 | 7H, I | Late 17$^{th}$ century | | High | fine-grained |
| 186a | 7H, I | Late 17$^{th}$ century | | Moderate | medium to coarse-grained |
| 186b | 7H, I | Late 17$^{th}$ century | A | High | coarse-grained with fine to medium-grained |
| 186c | 7H, I | Late 17$^{th}$ century | | High | silt  to fine-grained with few coarse grains |
| 186d | 7H, I | Late 17$^{th}$ century | C | Low | fine to medium-grained |
| 195a | 7H, I | Late 17$^{th}$ century | | High | silt and medium to coarse sand |
| 195b | 7H, I | Late 17$^{th}$ century | A | High | coarse-grained with fine to medium-grained |
| 211 | 7H, I | Late 17$^{th}$ century | | High | silt |
| 177a | 7H, I | Early-Mid 19$^{th}$ century | A | High | coarse-grained with fine to medium-grained |
| 177b | 7H, I | Early-Mid 19$^{th}$ century | C | Low | fine to medium-grained |
| 177c | 7H, I | Early-Mid 19$^{th}$ century | | Low | medium to coarse-grained |
| 177d | 7H, I | Early-Mid 19$^{th}$ century | | Low | fine-grained |
| 369 | 7H, J | Late 17$^{th}$ century | | High | fine to medium-grained |
| 493a | 7H, J | Late 17$^{th}$ century | | Low | silt and fine-grained |
| 493b | 7H, J | Late 17$^{th}$ century | | High | silt and fine to medium-grained |
| 242a | 7H, J | Late 18$^{th}$ century | | High | silt and medium to coarse sand |
| 242b | 7H, J | Late 18$^{th}$ century | B | Moderate | medium to coarse-grained |
| 256 | 7H, J | Late 18$^{th}$ century | B | Moderate | medium to coarse-grained |
| 207 | 7H, J | Early 19$^{th}$ century | B | Moderate | medium to coarse-grained |
| 200 | 7H, J | Post 1857 | | High | coarse-grained with fine to medium-grained |
| 223 | 7H, G | 18$^{th}$ century or earlier | | High | silt and fine-grained |
| 189 | 7H, G | Late 18$^{th}$ Early 19$^{th}$ century | | High | fine to medium-grained |

| | | | | | |
|---|---|---|---|---|---|
| 201 | 7H, G | Late 18th Early 19th century | | Moderate | medium to coarse-grained |
| 117a | 7H, G | Late 18th Early 19th century | | High | fine to medium-grained |
| 117b | 7H, G | Late 18th Early 19th century | | High | silt and fine-grained |
| 139 | 7H, G | Late 18th Early 19th century | B | High | coarse-grained with fine to medium-grained |
| 147 | 7H, G | Late 18th Early 19th century | B | High | medium to coarse-grained |
| 149 | 7H, G | Late 18th Early 19th century | | High | silt and medium to coarse sand |
| SSSM* | - | ca. 1811 | B | High | medium to coarse-grained |

*SSSM mortar sampled from the Schermerhorn Row Block, Manhattan

Table 7: The "Lovelace-Style" Mortars

| **Sample** | **Test Cut** | **Date** | **Methods of Analysis** |
|---|---|---|---|
| 982 | SH, AQ3 | Lovelace Tavern | Petrography |
| 1727a | SH, CC13 | - | Petrography, Sand Extraction |
| 1727b | SH, CC13 | - | Petrography |
| 1727c | SH, CC13 | - | Petrography |
| 1710a | SH, CC15 | Late 18th century | Petrography, Sand Extraction |
| 1710b | SH, CC15 | Late 18th century | Petrography |
| 1747a | SH, CC23 | Late 17th century | Petrography |
| 1747b | SH, CC23 | Late 17th century | Petrography |
| 1799 | SH, CC23 | Late 17th century | Petrography |
| 1766 | SH, CB19 | - | Petrography |
| 1784a | SH, CB24 | Subsoil | Petrography, Sand Extraction |
| 575 | SH, AH | Early 19th century | Petrography |
| 449 | SH, T21 | Late 18th early 19th century | Petrography, Sand Extraction |
| 196b | 7H, I | Late 17th century | Petrography |

Table 8: Binder Summary

Stadt Huys Test Cut CC, Stone Street

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 1799 | CC25 “fill” | Late 17th century | shell lime |
| 1747a | CC23 “ground surface” | Late 17th century | shell lime |
| 1747b | CC23 “ground surface” | Late 17th century | shell lime |
| 1710a | CC15 “pavement bedding” “ground surface” | Late 18th century | shell lime |
| 1710b | CC15 “pavement bedding” “ground surface” | Late 18th century | shell lime |
| 1727a | CC13 “refilled hole” | - | shell lime |
| 1727b | CC13 “refilled hole” | - | shell lime |
| 1727c | CC13 “refilled hole” | - | shell lime |
| 1672 | CC4 “utility trench” | - | rock lime |
| 1701 | CC2 | - | rock lime |

Stadt Huys Test Cut CB, Stone Street

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 1784a | CB24 “subsoil” | - | shell lime |
| 1784b | CB24 “subsoil” | - | portland cement |
| 1766 | CB19 “ground surface” | Late 17th century | shell lime |
| 1752a | CB17 “midden/ground surface/fill” | Late 17th century | rock lime |
| 1752b | CB17 “midden/ground surface/fill” | Late 17th century | rock lime |
| 1752c | CB17 “midden/ground surface/fill” | Late 17th century | rock lime |
| 1737 | CB7 “rodent burrow” | - | rock lime |
| 1733 | CB6c “builder’s trench Lot 17” | - | rock lime, natural cement |
| 1675 | CB6a “builder’s trench Lot 17” | - | rock lime |

Stadt Huys Test Cut CA, Stone Street[181]

| Sample | Stratum | Date Interpretation | Binder |
|---|---|---|---|
| 1646 | "stone and mortar from western stone wall" | - | shell lime |
| 1645 | "stone and mortar from western stone wall" | (Early 20th century) | portland cement |
| 1648 | "stone and mortar from western stone wall" | - | rock lime |
| 1657 | - | - | shell lime |
| 1652 | - | - | shell lime |
| 1653 | "mid to late 19th century deposit" | Mid to late 19th century | rock lime |
| 1631a | "mixed 19th century deposit plus demolition debris from 1907 structure" | 19th century | rock lime |
| 1631b | "mixed 19th century deposit plus demolition debris from 1907 structure" | 19th century | lime |
| 1631c | "mixed 19th century deposit plus demolition debris from 1907 structure" | 19th century | rock lime |

Stadt Huys Test Cut AH, Lot 6

| Sample | Stratum | Date Interpretation | Binder |
|---|---|---|---|
| 575 | "early 19th century ground surface" | Early 19th century | shell lime |

Stadt Huys Lot 7

| Sample | Stratum | Date Interpretation | Binder |
|---|---|---|---|
| 323 | F "B horizon" | - | rock lime |
| 689 | AP "Feature 3" | Early 19th century | rock lime on brick with earlier layer of mortar with shell inclusions |
| 641a | AP "Feature 3" | Early 19th century | rock lime |
| 641b | AP "Feature 3" | Early 19th century | rock lime |

181 Concordance table does not correlate to test cut diagram

| | | | |
|---|---|---|---|
| 641c | AP "Feature 3" | Early 19th century | portland cement |
| 641d | AP "Feature 3" | Early 19th century | rock lime |

Feature 3 is described in the archaeological report as "a semi-circle of red brick" "either a cistern, fire well, or other water storage structure." Archaeologists associated it with the boarding-house that was located on this lot between 1806-1815.[182]

Stadt Huys Lot 9, Backyard

| Sample | Stratum | Date Interpretation | Binder |
|---|---|---|---|
| 449 | T21 | Late 18th to early 19th century | shell lime |
| 424 | T14 | Late 18th to early 19th century | shell lime |
| 450 | T14 | Late 18th to early 19th century | shell lime |
| 1106 | AR13 | Late 18th to early 19th century | rock lime |
| 958 | AR13 | Late 18th to early 19th century | rock lime |
| 304 | T11 | Late 18th to early 19th century | shell lime |
| 332a | T11 | Late 18th to early 19th century | shell lime |
| 332b | T11 | Late 18th to early 19th century | rock lime |
| 805a | AR11 | Late 18th to early 19th century | shell lime |
| 805b | AR11 | Late 18th to early 19th century | rock lime |

[182] *Archaeological Investigation of the Stadt Huys Block: A Final Report*, 71

| | | | |
|---|---|---|---|
| 1132a | AR7c | Mid 19th to early 20th century | rock lime |
| 1132b | AR7c | Mid 19th to early 20th century | rock lime |
| 1080a | AR7c | Mid 19th to early 20th century | rock lime |
| 1080b | AR7c | Mid 19th to early 20th century | rock lime |
| 664 | AO5 | Mid 19th to early 20th century | rock lime |
| 628a | AO4 | Mid 19th to early 20th century | natural cement |
| 628b | AO4 | Mid 19th to early 20th century | natural cement |

Stadt Huys Test Cut O, Lot 17

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 203 | "builder's trench for the Lot 16/17 stone wall" | - | lime |
| 194 | - | - | rock lime |

Seven Hanover Lot 9

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 307 | XI-XIII "1st Landfill" | Late 17th century | shell lime |
| 257a | XI-XIII "1st Landfill" | Late 17th century | shell lime |
| 257b | XI-XIII "1st Landfill" | Late 17th century | shell lime |
| 229a | VIII-IX "1st Landfill" | Late 17th century | shell lime |
| 229b | VIII-IX "1st Landfill" | Late 17th century | shell lime |
| 225 | VIII-IX "1st Landfill" | Late 17th century | shell lime |
| 196a | IV-VI "2nd Landfill" | Late 17th century | shell lime |

| | | | |
|---|---|---|---|
| 196b | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 196c | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 194 | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 220 | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 202 | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 186a | IV-VI "2nd Landfill" | Late 17th century | lime |
| 186b | IV-VI "2nd Landfill" | Late 17th century | rock lime |
| 186c | IV-VI "2nd Landfill" | Late 17th century | shell lime? |
| 186d | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 195a | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 195b | IV-VI "2nd Landfill" | Late 17th century | rock lime |
| 211 | IV-VI "2nd Landfill" | Late 17th century | shell lime |
| 177a | I-III (leveling deposit for brick floor, early-mid 19th cent.) | Early-Mid 19th century | rock lime |
| 177b | I-III (leveling deposit for brick floor, early-mid 19th cent.) | Early-Mid 19th century | shell lime |
| 177c | I-III (leveling deposit for brick floor, early-mid 19th cent.) | Early-Mid 19th century | rock lime |
| 177d | I-III (leveling deposit for brick floor, early-mid 19th cent.) | Early-Mid 19th century | shell lime |

Seven Hanover Lot 28

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 369 | "Landfill" | Late 17th century | shell lime |
| 493a | "Landfill" | Late 17th century | shell lime |
| 493b | "Landfill" | Late 17th century | shell lime |
| 242a | (deposit under floor #3) | Late 18th century | shell lime |
| 242b | (deposit under floor #3) | Late 18th century | rock lime |
| 256 | Privy Level 1 | Late 18th century | rock lime |
| 207 | "Floor #2" | Early 19th century | lime |
| 200 | (deposit between floor #1 and #2) | Post 1857 | portland cement |

Seven Hanover Lot 12

| **Sample** | **Stratum** | **Date Interpretation** | **Binder** |
|---|---|---|---|
| 223a | “Below Feature” | 18th century or earlier | shell lime |
| 189 | VII-XVI (demo feature floor) | Late 18th Early 19th century | rock lime |
| 201 | VII-XVI (demo feature floor) | Late 18th Early 19th century | rock lime |
| 117a | VII-XVI (deposits within and above feature) | Late 18th Early 19th century | rock lime |
| 117b | VII-XVI (deposits within and above feature) | Late 18th Early 19th century | shell lime |
| 139 | VII-XVI (deposits within and above feature) | Late 18th Early 19th century | lime |
| 147 | VII-XVI (deposits within and above feature) | Late 18th Early 19th century | lime |
| 149 | VII-XVI (deposits within and above feature) | Late 18th Early 19th century | rock lime |

The “feature” is a cistern with layered deposits of fill.

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