

# An Analysis of Naturally Derived Marine Clay as a Ceramic Medium

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## Abstract

*This project was conducted to evaluate the use of marine clay as a ceramic medium. Samples of the clay were collected from Kure Beach and analyzed using workability tests, mineralogical analysis, and a chemical analysis. The clay shrank 15.63% after air drying and 17.75% after being fired. Porosity was 26.0% and plasticity was identified by handling the material. It contained 27.43% sand, 55.08% silt, 1.06% clay and also had high concentrations of aluminum and iron. Organic content was 15.79%. The marine clay did exhibit plasticity, was able to be thrown on a wheel and withstood firing. However, the small amount of actual clay present made the material more difficult to control and even after firing, it maintained a certain degree of fragility. The plasticity is likely a result of the high organic content. The clay is not ideal for functional studio work but it can perform as a ceramic medium.*

Ceramic clay has been widely used and studied for thousands of years. As a result, there is a comprehensive understanding of the material and standards for evaluating its potential as a functional ceramic medium. But even as these standards are currently used, the field continues to change as new processes are utilized and the materials are pushed to new extremes. In addition, much of the ceramic making process is still determined by the preferences of the potter. The purpose of this project was to examine the use of naturally derived marine clay as a ceramic medium. It predominantly encompassed the production of creative pieces, but with an emphasis on understanding the characteristics of the collected clay, how

those are defined, and what properties of the collected material influenced its usability in the ceramic studio. The composition of the collected material was analyzed and its functionality was evaluated using existing standards in ceramic studio practice.

## Definitions of Clay

Clay is a naturally formed material derived from igneous rock. Interestingly, clay can refer both to a particle size and to specific compositions of natural materials. Any sedimentary particle that is  $<2\mu\text{m}$  is considered clay. In addition, clay minerals are defined by their similar crystal structures and range of chemical compositions. Because of the

small particle sizes and chemical composition of clay minerals, the material exhibits certain properties that have made it useful in ceramics. Clay particles have a strong affinity for water and when the two substances combine, the material swells. This helps the particles remain adhered to one another and gives them the ability to retain a stable form when wet. Kaolinite, for example, is a common clay mineral. It has a two-layered, hexagonal shape with a diameter ranging from 0.3  $\mu\text{m}$ -0.01 mm and a general thickness of 0.05  $\mu\text{m}$ . This particular structure has a high surface area that is able to interact with water molecules. The interaction between water and clay particles actually gives the material the characteristics that make it usable as a ceramic medium.

A clay's origin and whether it has been transported from the spot in which it formed affect its properties. Clays that are found at their origin are considered "residual" while those that have been moved by natural forces-water, wind, erosion, etc.- to another depositional area are considered "sedimentary." Transportation of sedimentary clays increases the potential amount of impurities present. This difference in composition may change the plasticity and color of the material. A high level of organic matter also tends to increase plasticity and occasionally the stickiness of a clay.

Marine clays are likely the most common source of sedimentary clay. Generally, they form when fine clay particles found in freshwater systems are deposited in brackish water. The clay particles absorb various impurities as they are transported from their place of origin by water movement. Marine clays, like most sedimentary clays, exhibit a higher level of homogeneity and tend to have a high percentage of organic content. They can be grouped into three different categories based upon their location in various marine habitats. Pelagic clay is found in deep water and tends to have very fine particles. Littoral clay is found between the high and low watermarks of a shore and contains coarse particles with a high percentage of organic matter. Estuarine

clay similarly exhibits coarse particles and organic-rich content.

Marine and aquatic clays are also known to create clay balls. These sedimentary formations occur when the fine particles of clay suspended in the liquid are rolled back and forth due to wave and current action. The particles naturally adhere to one another when water is present so the formation can become significant, forming lumps or balls of material. These formations will occasionally roll up on shore and often exhibit relatively homogenous contents.

Generally, any kind of raw clay used in the studio can be categorized into five different groups: china clay, ball clay, fire clay, stoneware clay, and surface clay. China clay is formed at the base of mountains and has minimal impurities. It is rare, exhibits minimal plasticity, and is also the most refractory, or resistant to heat. Ball clay exhibits the highest plasticity and has always been moved by water from its primary spot of formation. This sedimentary clay has a finer particle size that results in a high amount of shrinkage. Fire clay is found in mountain or desert areas and has varying, coarse particle sizes. It is a strong clay that has good standing strength and is usually colored beige, red, gold, or red-brown when fired. Stoneware exhibits properties similar to both ball and fire clay. These characteristics make it a very workable material that also fires to a high density. Surface clay is the most prevalent. Because it has experienced years of movement, the level of impurities is high which increases the workability of the material. It tends to fire a rust-red color, but this can change depending upon the presence of various metallic oxides. Surface clay is also the material most commonly used by indigenous cultures to create ceramic ware.

Raw clay exhibits characteristics that are indicative of its origin and its qualities when wet. The creative process, however, usually involves additional steps such as firing and glazing. Fired clay becomes ceramic ware and it exhibits specific properties that influence its utility and its aesthetic. Ceramic

ware is generally categorized into three separate groups. Earthenware is very porous and lightweight. It fires at a low temperature range and has commonly been used among tribal societies. It will absorb 10-15% of its unglazed weight in water. Stoneware is a very hard and durable clay that holds liquids and is not easily broken. It will absorb 2-5% of its unglazed weight in water. Porcelain is a dense and vitreous clay. It is known for its generally white color and translucency. It will absorb 0-1% of its unglazed weight in water. Since the collected material was assessed as a ceramic medium, understanding the categorization of clay and ceramic ware was necessary for describing the collected clay and for comparing it to other clays commonly used in the studio.

### **Workability Definitions**

The quality of clay used in the studio is a somewhat ambiguous characteristic that cannot always be easily identified. Most often it is based upon a potter's specific preference or upon the qualities needed to produce a particular piece of work. Even so, certain properties have been identified that generally indicate the workability of clay when used in a studio setting. Fortunately, most of those have been given a quantifiable method of measurement. Shrinkage, porosity, and plasticity are three of the most common characteristics used to determine the workability of a clay body.

Shrinkage is a natural process that occurs as the clay dries, or as it is bisque-fired and glaze-fired. It is also an easy characteristic to measure. Clay at the desired plasticity is rolled out into a slab, a measurable block is cut from the slab, and then its length is recorded. The length of the block is then re-measured after drying and again after being fired. Using these measurements, the percent of shrinkage can be calculated. Although this characteristic does not necessarily define the quality of a clay, it is an important property of which to be aware. Understanding how much the material shrinks allows a potter to

estimate the size at which the piece needs to be created when wet so as to be the desired size after being fired and glazed.

Porosity refers to the percentage of empty space, called pores, found in the material. This characteristic is important because the number and size of pore spaces influence the hardness of the clay and its ability to vitrify. Porosity can also be indicative of the type of clay body being used. Porcelain clay has 0-3% porosity while stoneware has 1-6% and earthenware has 4-10%. Measuring porosity is difficult because some of the pore spaces are sealed within the clay. To overcome this obstacle, testing the percentage of water absorption is one of the most common methods for testing porosity. This measures the amount of water absorbed by a bisque-fired piece of clay. There are multiple procedures, including some that require the bisque-fired clay to be boiled for various time periods and others that soak the clay overnight.

Plasticity is an interesting characteristic of clay because there is no quantifiable measurement for it. Although potters will generally agree that plasticity is an important characteristic, it is predominantly determined by a potter's preference. Even so, there are multiple methods to determine if it is present. Simply working with the clay to assess if it can withstand pressure, stretching, and a combination of the two while still maintaining its shape and without tearing are observed characteristics that are indicative of plasticity. A very simple method for identifying the presence of plasticity is known as the coil test, a process in which a pencil-sized coil of clay is looped. If the clay remains smooth, it has good plasticity. However, if excessive cracks appear in the bent coil, there is likely very little plasticity. In addition, if the clay is unable to maintain a tall form, and it begins to fold into itself and sag, the material has low plasticity. Sometimes the percent of water present when the sample is at the desired plasticity is used as a quantifiable method of judging plasticity. Again this measurement, although quantifiable, is still based upon a potter's definition of the appropriate plasticity.

### **Firing and Glazing**

Another desirable characteristic of clay is its ability to be fired. Air drying clay does not make it durable which eliminates its functionality. Firing clay to the appropriate temperature hardens the material and makes the clay body a permanent substance. Once fired, clay is transformed into a more resistant substance. Although it can fragment, the fired material will remain in an unchanged state for thousands of years.

Firing can allow ceramic ware to reach a state of vitrification. This is the point at which the clay material becomes very hard and dense. As the temperature increases, components within the clay begin to melt and fill in exterior pores on the clay. This process creates a durable and permanent substance. Further heating beyond the point of vitrification, however, can lead to complete melting and therefore the destruction of the utility of the clay.

The use of kilns to achieve this state of vitrification and to add glazes was first used by the Chinese. Kilns allow firing to occur in a semi-closed system in which temperature and duration of firing can be controlled and monitored. The high temperatures remove water from the clay body, including those molecules chemically combined with alumina and silica. Kilns must have a heat source that is able to transfer its energy to the clay pieces. The heat needs to be contained in some way so that it is focused on the pottery. This system allows for the clay to be in an enclosed and somewhat controlled environment that reaches the necessary temperatures for vitrification.

Temperatures can be measured in a kiln by observing the reaction of pyrometric cones. These pyramidal indicators serve as a physical representation of the temperatures within the kiln. Their compositions of glaze-like materials are designed to melt at specific temperatures. They have been standardized to range from cone 020-15, or temperatures between 635°C-1430°C. Usually, multiple cones-including one below the desired

temperature, one at the desired temperature, and one above the desired temperature-are placed upright together, in ascending order of melting temperature, on a coil of clay. This is known as a cone pack and it is then placed inside the kiln in an area that is visible to the potter during firing. The cones are monitored throughout the firing process and indicate when the temperature is approaching, has reached, or has passed the desired value.

### **CREATIVE PROCESS AND PURPOSE**

The natural material used for this project was found and collected along the ocean water's edge, predominantly deposited in small clumps or balls that were embedded in or resting on the sand. This specific material was collected because it shared a similar tactile quality to that of the stoneware clay commonly used in ceramic studios. When handled, the particles remained adhered to one another, they did not crumble, and the appearance was smooth. The material had a dark brownish-grey color and was very sticky. Its texture was rougher than the studio clay, but it resembled the consistency of raku clay.

Initially, the clay was found on a barrier island, but a majority of the material used for the project was gathered from the shore at the end of Kure Beach, North Carolina. It was collected over several trips throughout the summer months. Samples were collected in plastic bags and then stored in a 5-gallon bucket to retain their moisture and to ensure that no other materials would be introduced. In addition, a bottle of salt water was collected from the same area to be used during the working and throwing process in the studio. Because clay particles will easily absorb impurities from their surroundings, using salt water from the location of collection helped to replicate an environment similar to where the clay was found. In addition, it maintained the salinity of the material which affected the clay throughout the working and firing process.

Although the use of clay is often influenced

by the preference of the potter, there are still standards used to define the workability of the material in a studio based upon some general properties. Using these basic characteristics of porosity, plasticity, shrinkage, and the ability to be fired, the collected clay was evaluated to assess if it could perform as functional ceramic ware.

## METHODOLOGY

The collected clay was first filtered using a settling method in order to remove any debris. All of the clay was placed in a 10 gallon aquarium, which was then filled with salt water collected from the same area as the clay. The salt water and the collected clay were thoroughly mixed in the aquarium, creating a slurry of material. It was covered and allowed to settle for four weeks. The clear walls of the fish tank allowed the separation between clay and water to be easily viewed.

Once a clear layer of water had formed at the top, it was siphoned off using a turkey baster which minimized the amount of clay particles being collected along with the water. This siphoning was repeated until water no longer appeared on top of the clay. The clay was then allowed to dry to a workable consistency. Only the top layers of clay, those that did not contain the larger debris, were removed and placed in a 5-gallon bucket so as to maintain their moisture content.

The intent of the filtration method was to allow the clay to settle and stratify into layers based upon the weight of the particles and to remove any excess debris which would have settled on the bottom. Even after four weeks of settling, however, there was no evident stratification in the clay. Large pieces of shell and other natural debris did settle out to the bottom but smaller shells and debris still remained in the upper levels of the material. In addition, there was a rust-colored residue evident on the inside of the tank. It potentially indicated the presence of iron in the collected clay.

Use of the aquarium was an innovative addition to the filtration process. Although

there was no stratification evident, it was an effective method of monitoring the settling of clay particles. In addition, it permitted observation of coloration and residues that formed in conjunction with the settling of the material. Despite the filtration, there were still small shells and pieces of debris present in the clay, although not nearly as many as had been present before filtration.

### Workability Tests

Shrinkage was measured using the equation:

$$\% \text{ shrinkage} = \frac{(\text{lengthwet} - \text{lengthdry})}{(\text{lengthwet}) \times 100}$$

Ten blocks were cut out of a slab of the collected clay when it was at the desired wetness. Each block measured 8 inches in length and 1 inch in width. They were each marked to show inches and half-inches. Once the blocks had fully dried, one of them was measured and its length was used to determine the amount of shrinkage. It was bisque fired and then measured again to determine the shrinkage after firing.

$$\% \text{LDS (after air drying)} = \frac{(8.0 \text{ in} - 6.7496 \text{ in})}{(8.0 \text{ in}) \times 100} = 15.63\%$$

$$\% \text{LDS (after bisque firing)} = \frac{(8.0 \text{ in} - 6.58 \text{ in})}{(8.0 \text{ in}) \times 100} = 17.75\%$$

The linear drying shrinkage (%LDS) after air drying resulted in a 15.63% reduction in length while the %LDS after bisque-firing resulted in a 17.75% reduction in length.

Porosity was measured using the equation:

$$P = \frac{(\text{weightsoaked} - \text{weightfired})}{(\text{weightfired}) \times 100}$$

To measure porosity, a fragment of the bisque-fired collected clay was weighed. It was also weighed inside a plastic container with a lid that was later used for transport. The piece was boiled for five hours and then

allowed to cool in the water. It was removed and then the surface water was gently removed. It was placed back in the plastic container and covered to retain all of the moisture during transport. Then it was reweighed.

$$P = (12.40\text{g} - 9.84\text{g}) / (9.84\text{g}) \times 100 = 26.0\%$$

The porosity (P) of the collected clay, which basically equals the amount of water absorbed, was calculated to be 26.0%.

Because there is no quantifiable test for plasticity, the clay was handled and observations were made about its reaction. The coil test was performed to check for cracking. The clay was also compressed and stretched to analyze its reaction. In addition, it was thrown on the wheel to see how well the material retained its shape and if it exhibited signs of sagging. As a final, although less indicative test, the percentage water of plasticity (%WP) was measured using the equation:

$$\%WP = \frac{(\text{weightwet} - \text{weightdry})}{(\text{weightdry})} \times 100$$

The clay did exhibit plasticity. For the coil test, the material looped easily and minimal cracking was evident. Simply handling the clay revealed that it could withstand a certain amount of stretching and compression. While throwing on the wheel, the pieces rarely exhibited any signs of sagging and the clay maintained its form and height.

$$\%WP = (13.30\text{g} - 8.84\text{g}) / (8.84\text{g}) \times 100 = 50.45\%$$

The percentage water of plasticity (%WP) for clay that had reached the desired level of plasticity was 50.45%.

In addition to the workability tests, the collected clay was used in the studio to assess its throwing capabilities and tactile qualities. The material was able to be thrown on the wheel and multiple vessels were created. Although the clay's consistency was rough and contained more grit, it still maintained its

shape and exhibited plasticity. A sponge was used to help eliminate continuous contact with the rough clay. It also helped to keep the outer consistency of the clay smooth.

There were a few particular characteristics that differed from the studio clay. One piece was thrown too thin on the bottom curve. Rather than sag, as would have been expected with the stoneware studio clay, as the weight of the top of the piece pushed down it created a vertical split in the bottom wall of the pot while the rest of the piece maintained its form. This reaction could be attributed to the combination of the stickiness of the clay and its larger particles. The stickiness from the high organic content of the material helped to keep it together. As excess weight pushed down on the clay, however, the organic material could no longer hold the larger particles easily and a tear would form. The collected clay forms also adhered more strongly to the wheel than the studio clay. Again, this could be a result of the increased stickiness due to a high organic content.

Strangely, once the pieces had been thrown and were ready to be moved off of the wheel, they maintained their intended form despite having to be removed more forcibly. This is unexpected because the studio clay deforms easily if too much pressure is applied when being removed from the wheel. The collected clay, however, compressed as it was being removed and then returned to its original form without showing any major signs of malformation. This elastic-like reaction is probably a result of the high concentration of salt and organic matter.

### Mineralogical Analysis

X-ray diffraction (XRD) is used to determine the mineralogical composition in sediments. It is used for clay mineral identification because the particle size is very small, generally falling between 1 and 10 $\mu\text{m}$ . In order for the collected material to be analyzed by XRD, a wet bulk sample was dried at 110°C for 24 hours to remove the moisture

and was then crushed into a fine powder with mortar and pestle. The dried powder was treated for contained organic matter (OM) by applying a 6% Sodium Hypochlorite solution, buffered to pH 9.5 with 10% HCl. The treated sample was then heated in a water bath for 15 minutes to increase the reactivity of the oxidizer, centrifuged and the supernatant decanted. The treatment was repeated until the OM was entirely removed.

For carbonate removal, the sample was washed in an anhydrous Acetic Acid – Sodium Acetate solution. It was then heated in an 80°C water bath to increase reactivity and the supernatant discharged after centrifugation.

After this chemical alteration, the sample was wet sieved with a 125 screen (64µm) to remove the sand particle size fraction. The remaining wet sample was dispersed in a sodium hexametaphosphate solution and further mixed in an ultrasonic bath. This stimulated sample was then settled out, applying Stokes Law for settling particles. After the allotted time interval, it was decanted to separate the silt particle size fraction from the clay particle size fraction. Both fractions were centrifuged, washed with distilled water and after all the dispersant was removed, dried in an oven at 70°C. The finalized samples were mounted on aluminum discs and analyzed using the Rigaku Miniflex II X-ray Diffractometer.

This entire procedure was repeated with a sample of the clay used in the studio. Having both clays sampled the same way allowed for a precise comparison of composition between the two.

The collected material had a particle size distribution of 27.43% sand, 55.08% silt and 1.06% clay with a loss of 0.64% due to the analysis. The major mineralogical component within the material was quartz. The clay mineral, kaolinite was present and there was a trace of montmorillonite (Figure 1). The sample also contained 15.79% of organic material and carbonate material.

For comparison, the studio clay had a particle size distribution of 1.76% sand, 90.39% silt and 4.67% of clay with a loss of 0.10%

due to analysis. The major components within the material were quartz, kaolinite, nacrite, and halloysite (Figure 2). All of those were present in the clay particle fraction. The sample contained 3.08% organic matter and carbonate material.

### Chemical Analysis

Samples of the collected clay were dried and crushed. A mass of 0.2 g of the dry material was measured out into three separate Teflon digestion vessels and a fourth was left empty as a blank. Volumes of 1.2 mL of concentrated HCl and 3.8 mL of concentrated HNO<sub>3</sub> (both trace metal grade) were added to the 4 digestion vessels. All four vessels were sealed and placed in pressure-safe frames and microwave digested for 50 min under increasing pressure and temperature (up to 150 psi and 210°C) using a CEM MARS microwave digestion instrument. After cooling, the samples were filtered and brought to 50.0 mL with high purity water. Samples were analyzed for metals using inductively coupled plasma optical emission spectrometry on a Perkin-Elmer Optima 2100 DV instrument that was calibrated using matrix-matched mixed metal standard solutions.

As the samples were being filtered, the liquid in each vessel displayed a different hue of yellow. The sediment within each sample also appeared to be three different colors. This is unexpected because each of the samples was taken from the same bulk sample. There were no intentional differences between samples when they were collected.

The concentrations of the metals in each solution were measured by the microwave digestion instrument. Those concentrations were then multiplied by the volume of the solution and divided by the sample weight to calculate the concentration (µg/g) of each metal in the dry samples of collected clay. Iron and aluminum had the highest concentrations in the samples and levels of cobalt and cadmium were BD, or below detection (Table 1).

## **KILN CONSTRUCTION AND FIRING PROCEDURE**

Initially, the blocks of collected clay used for shrinkage testing were also bisque fired along with the studio ware in one of the studio kilns. Because the bisque firing only reaches temperatures up to cone 06 (1830°F), this gave a general indication if the material could withstand lower firing. A single, bisque-fired block was then placed-unglazed-in the studio kiln along with studio ware that was being glaze-fired. The glaze kiln fires up to cone 10 (2381°F), so this gave a general indication of the material's ability to withstand higher temperatures.

After the initial bisque firing in the studio kiln, the sample blocks of collected material became a brick-red color. They were very light weight, but also they crumbled and broke apart easily. The block that had been placed in the glaze firing along with the studio ware melted, bubbled, and then adhered to the piece of kiln shelf on which it had been placed. Although the block maintained its general shape, it became hard and lumpy. It also had a metallic grey and rust color when it was removed.

A small kiln was then constructed to allow for the collected material to be fired separately from the studio clay (Figure 3). Cone packs-made of cones 09, 08, 06, 04, 6, 8, 9, and 10-were placed on the kiln shelf along with the ceramic pieces to serve as an indication of the temperature in the kiln. In addition, drawings of the collected material were made in order to monitor the effects of firing on the clay. Drawings are small loops of the clay that can stand vertically in the kiln so that they can easily and quickly be removed in order to monitor the material as it is being fired. The creation of the smaller kiln permitted more control over the temperature of the kiln and the ability to remove the drawings during the firing process.

The kiln was constructed out of firebricks on a base of cinder blocks. An opening below the interior shelf allowed access for the gas-fueled flame which heated the kiln. An additional opening was created level with the interior shelf. It served as a spy hole to check

the progress of the cones and as a channel for removing the drawings while the kiln was being fired. An insulation brick was used to block the opening when it was not in use.

The gas burner was placed parallel to the specified opening. It was attached to the main gas line through a series of pipes. Each joint between pipes was wrapped with tape to form a tighter seal and then securely fastened. To ensure proper sealing, dish soap was dripped onto each joint as the gas was running. Any bubble formation would have indicated a gas leak.

The ceramic pieces made of the collected material, the cone packs, and the drawings were placed on the interior shelf of the kiln. The drawings were positioned in a row directly in front of the spy hole so that they could easily be retrieved using a piece of rebar. The cone packs were positioned so that they could be easily seen through the spy hole. The pottery was then spaced throughout the rest of the kiln.

Two flat kiln shelves were placed on top of the kiln to contain the heat. A gap of about 1.5 inches was left between the pieces to serve as a damper. Once the interior shelf had been organized and the top of the kiln positioned, the gas was turned on. It was adjusted periodically, usually every hour, to increase the heat and the area of fan exposed was adjusted accordingly to allow for the amount of air flow needed to keep the flame burning. Temperature was monitored occasionally with a pyrometer but the cone packs served as the main indicator of temperature.

One drawing was taken out periodically to check the condition of the clay. It was removed through the spy hole with a piece of rebar and then submerged in a bucket of water for rapid cooling. This allowed it to be examined almost immediately and was repeated three times during the first firing. When the drawing that had reached maturation had been removed and cooled, the gas was turned off and the kiln was allowed to cool. The first firing in the small kiln, from ignition to turning off the gas lasted 3.5 hours.

The three pieces fired initially in the kiln

built specifically for this project also melted (Figure 4). The taller piece sagged and collapsed into itself while the shorter pieces just melted down on themselves. The same shiny black, speckled glaze that formed on the latter draw rings was evident on the pieces. Interestingly, although the glaze did form on the outside of the pieces, the brick red color was still maintained on the interior and underside of the pieces, albeit a darker shade. In addition, there was a strange smell emitted from the kiln, however, it went away as firing continued.

The process was repeated a second time with some minor adjustments made based upon the initial outcome. In an effort to reach vitrification without causing melting, the kiln was only allowed to run until cone 04 have fallen but cone 6 was still standing. At this time, the pieces exhibited a shiny surface but also were still maintaining their form. Five drawings were used in the second firing to allow for additional chances to monitor progress. The firing, from ignition to turning off the gas, lasted about 4.5 hours. The additional hour needed for firing likely occurred because of the manual control of the gas burner. The gas was probably increased more slowly than the first firing, thereby the temperature increased more slowly.

During the second firing in the small kiln, a similar smell was emitted, but that time is was more pronounced and lasted a bit longer. It is likely that this smell was caused by the burning off of organic material. Once the material had been removed, the smell dissipated. In addition, the pilot burner was releasing a lot of flame, more than what was usually seen, but there was no way to adjust it. The second set of pieces did vitrify and did not melt. They had a glassy surface and were much more durable. They also were able to hold water without leakage. However, the texture was rougher and the coloring exhibited more reds and even some yellow while the first coloring was predominantly a dark grey (Figure 5). In addition, when the pieces were removed from the kiln, they had an odor similar to that of the wet material.

It is important to take note of some overall observations through the drying and firing process. After air drying, all pieces of the collected clay remained a dark grey color but had also formed a white residue (Figure 6). This residue is likely salt that formed as the water evaporated, causing the salt crystals to precipitate on the surface of the piece. Once bisque-fired, the collected material exhibited a significant amount of shrinkage and its color changed from a dark grey to a brick red. It remained lightweight but was not particularly durable. The single block that was also glaze-fired with the studio ware melted.

For the first firing in the small kiln, the pieces melted, although the progression of drawings did indicate vitrification had been achieved. Even so, the shiny smooth surface that formed with vitrification revealed a natural film of glaze. The pieces in the second firing of the small kiln did not melt, but their appearance was different from those in the first firing. These, too, exhibited a thin film of natural glaze although the texture was much rougher and the coloring was different. The natural glaze was likely a result of the salt precipitating on the surface of the pottery.

## DISCUSSION

The collected clay is sedimentary because it has been moved from its spot of origin and has picked up a number of impurities. Because it was found on the ocean shore between the high and low tide marks and contained a high level of organic matter, the material would be considered littoral clay when categorizing it based on marine clays. In addition, due to its low firing temperatures and the brick-red color it becomes after bisque-firing, the material is likely surface clay. This is further supported in that surface clay has a high level of impurities and is the most common kind of clay found.

The high level of quartz found in the marine clay also had a large impact on the quality of the material as a ceramic medium. Quartz is a free state of silica, which is a common component found in clay. The presence of quartz

can reduce plasticity, lower refractory ability, and limit the crushing and tensile strength of the clay. Sedimentary clay, in particular, tends to have a high concentration of quartz. The low firing capabilities and fragility of the pieces, even after firing, are all possible effects of the high quartz concentration.

Kaolinite and montmorillonite were both

found in the marine collected clay. In general, these tend to increase the plasticity of a clay body. Although the collected material did exhibit plasticity, kaolinite and montmorillonite were found at such low levels that it is unlikely they significantly influenced the overall plasticity. It is most probable that the plasticity was a result of the high organic

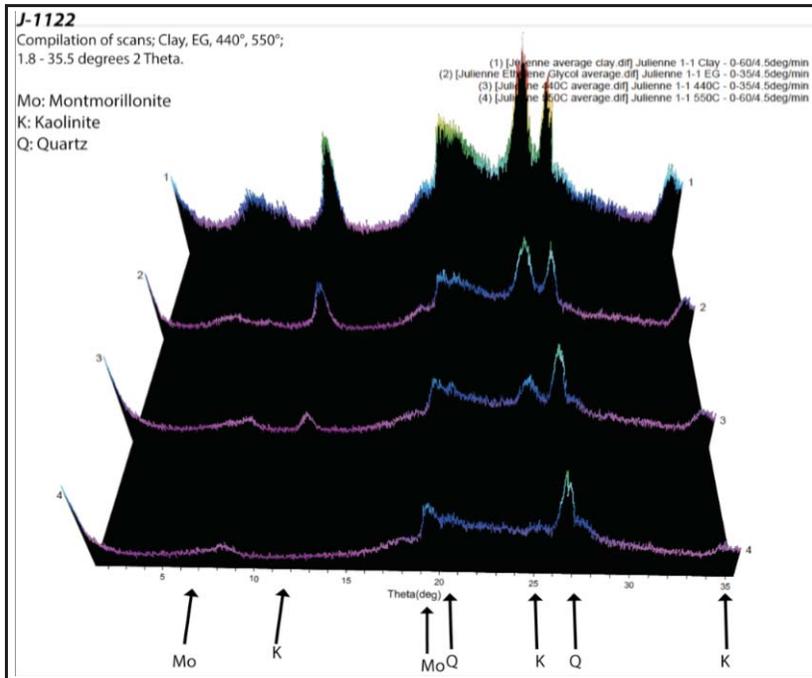
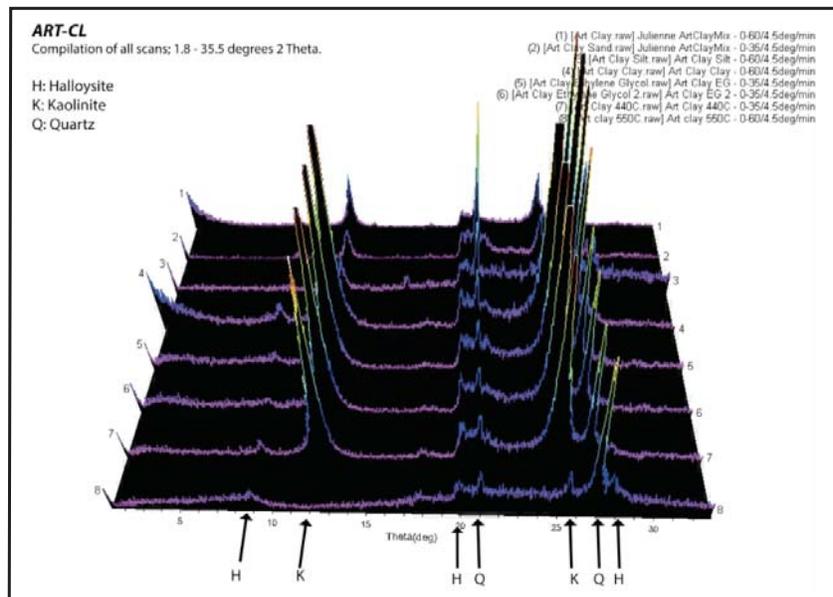


Figure 1: XRD compilation scan of collected clay

Figure shows the XRD peaks indicative of the presence of Quartz (Q), Kaolinite (K), and Montmorillonite (M).

Figure 2: XRD compilation scan of studio clay

Figure shows the XRD peaks indicative of the presence of Quartz (Q), Kaolinite (K), and Halloysite (H).



content, which is known to have a significant effect on this characteristic.

Chemical analysis revealed that there were high concentrations of aluminum and iron in the marine clay samples. Aluminum, in the form of alumina (Al(OH)<sub>3</sub>), may reduce the plasticity and increase the refractory abilities of a clay. Iron, not surprisingly, can affect the color of the material, often producing red or brick-colored clay. In addition, it may form a scum on the fired ceramic ware and reduce the refractory abilities of the clay. The red color of the bisque-fired clay and its low firing temperature were likely affected by the high concentration of iron. The aluminum may have decreased plasticity; it does not, however, appear to have had any additional effects on the material.

### CONCLUSIONS

Ultimately, the collected marine clay did not perform ideally in the studio. It did exhibit several properties characteristic of clay, including critical plasticity. These properties did allow the clay to be thrown on the wheel, creating the shape of functional vessels. It was able to withstand lower firing and it vitrified and hardened to a more durable state. Even so, the excessive amount of sand and

the minimal percentage of actual clay made the material more difficult to control. More than likely, the significant plasticity was a result of the high amount of organic matter in the material. Once fired, and when not melted, the pieces were roughly textured and did not show a consistent coloring. They were also porous and still maintained a certain degree of fragility. Both of these characteristics make the material unsuitable for storing food or liquids. Even so, the collected ocean clay did function as a ceramic medium and the vessels created possessed a unique and aesthetically pleasing quality.

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Extractable <u>NaCl</u> content (5 g of sediment in 10 mL of water, by refractometer):							6.0% by wt.	
	JB1	JB2	JB3	Average	std dev	Rounded <u>µg/g</u> (= <u>ppm</u> by wt.)		
Copper	20.3	21.0	19.6	20.3	0.7	20.3	0.7	
Lead	19.4	19.7	16.6	18.6	1.7	18.6	1.7	
Nickel	15.2	16.3	15.3	15.6	0.6	15.6	0.6	
Arsenic	77.1	91.5	80.1	82.9	7.6	82.9	7.6	
Iron	28700.0	29700.0	26700.0	28367	1527.5	28400	1500	
Aluminum	40000.0	52000.0	46100.0	46033.3	6000.3	46000	6000	
Cobalt	BD	BD	BD			BD		
Cadmium	BD	BD	BD			BD		
BD = below detection								

Table 1: Summary of chemical analysis results



Figure 3: Image of melted pieces after first firing



Figure 4: Image of small kiln built for firing the collected clay



*Figure 5: Image of vitrified pieces after second firing*



*Figure 6: Image of dry, collected clay showing evidence of salt precipitation on the surface*

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