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COMPOSITIONAL ANALYSIS AND CROSS-CULTURAL EXAMINATION OF BLUE AND BLUE-GREEN POST-FIRE COLORANTS ON TOLITA-TUMACO CERAMICS

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by

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DEDICATION

Dedicated in loving memory to Kirk K. Reiss.

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ABSTRACT

Blue and blue-green ceramic colorants are an uncommon occurrence in the ancient Americas. This paper explores blue and blue-green post-fire colorants used by the coastal Tolita-Tumaco culture of ancient coastal Ecuador and Colombia through compositional testing and cross-cultural comparison. Using X-ray diffraction and scanning electron microscopy coupled with energy dispersive spectroscopy, one sample each of blue and blue-green colorants were tested to identify the mineral composition present. Though the colorants were thought to likely originate from copper carbonates like azurite or malachite, or perhaps even similar to other Mesoamerican pigments like Maya Blue, the blue-green pigment, collected at La Tolita, was determined to be either celadonite or glauconite. No mineralogical component responsible for the blue colorant, from a site along the Rio Mataje, could be determined. Cross-cultural comparison provides insight on how ancient coastal Ecuadorian groups used these colorants and exemplifies the innovative nature behind their creation.

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I: Introduction

Blue is the most rare color in nature and one of the more difficult colors to produce in a form stable enough to be a paintable substance. To make the vibrant blues that decorated ceramics and architecture, ancient artists relied on their own ingenuity and what was naturally available, such as hard to find blue minerals. In ancient Mesoamerica, examples of blue colorants were relatively widespread on ceramic and mural creations, but blue and blue-green in the same context in ancient South America were almost non-existent.

Coastal Ecuador during the Regional Development Period (RDP), dating from around 500 BCE to 600 CE, may be the one of the only places in South America where blue and blue-green colorants were used on ceramics. Their presence raises various questions. How might the coastal Ecuadorians have learned to create the vivid blues and blue-greens seen on their ceramics? Does their occurrence indicate a relationship with other known instances of blue colorants in the ancient Americas? To address these issues, my research undertakes laboratory testing of samples from collections at the University of New Mexico's Maxwell Museum of Anthropology.

An archeologically retrieved sample set with blue and blue-green colorants from the Tolita-Tumaco culture dating around 600 BCE to 400 CE served as the focus of a multidisciplinary methodology. First, X-ray diffraction (XRD) and scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) were used to determine the mineral composition of these colorants. Secondly, cross-cultural comparison offered insight into the uniqueness of ancient Ecuadorian ceramic colorant technologies.

Blue-green and the more rare blue are found on figural ceramics from the Tolita-Tumaco and other northern groups, like the Jama-Coaque and Bahia cultures. This study's focus, the Tolita-Tumaco culture (600 BCE-400 CE) inhabited the mangrove forests and river basins across coastal northern Ecuador and southern Colombia. This cultural group is given emphasis in the academic literature for its large ceremonial center, known as La Tolita, and through the culture's intricate, often miniature metalwork (Fig. 1), and naturalistic ceramic figurines that are often made from molds (Fig. 2).

It was hypothesized that emulation or exchange could explain the appearance of these rare colorants along the Ecuadorian coast. In particular, the colorants of Mesoamerica, like Maya Blue and the copper carbonates azurite and malachite used at Teotihuacan, and popular blue and blue-green stones used for inlays and beadwork in South America, like chrysocolla, lapis lazuli, and sodalite were thought to be possible sources for the colorants.

Searching for parallel technologies as a far away as Mesoamerica and Peru is necessary because of Ecuador's history as maritime traders. For years it has been hypothesized that long distance trade was well established along the Pacific maritime corridor, from at least as far north as Baja California, throughout West Mexico, Central America, and as far south as Peru. Ancient coastal Ecuador is thought to have been an active part of this Pacific exchange network, largely due to their rafts made from the buoyant balsa wood. Coastal Ecuadorians are thought to have provided the ideologically valuable *Spondylus* sp. shell to Peruvian cultures from as early as 3500 BCE and well into the times of European contact (Martín 2010).

The ancient Ecuadorian coast has also long been noted by scholars for its similarities in the production and style of figurines and other wares to those seen in Mesoamerican traditions (Ferdon Jr. 1940; d'Harcourt 1942; Meggers 1966; Reichel-Dolmatoff 1965; Valdez 1987). The use of bright post-fire polychrome paints, mold making, and the methods for presenting information are akin to the ceramic figurines of the Maya, Zapotec, Teotihuacan, and others (Figs. 3-4). They are similar enough in workmanship to raise questions about the ways in which artistic pigment and dye technologies might travel.

The discovery of parallel technology would have important implications in terms of understanding cross-cultural interactions. On the other hand, the independent invention of rare blue and blue-green colorants would exemplify the innovativeness of ancient Ecuadorian technology. Ultimately, analysis of these pigments, combined with close comparison of test results to other pre-Hispanic Latin American blues and greens, ultimately establishes the unique character of ceramic colorant traditions of coastal Ecuador.

Five sections describe these ideas, with additional information on the testing processes and a more in-depth explanation of XRD and SEM-EDS test results provided in the appendices. The following section focuses on an introduction to what is known about Ecuadorian culture in the RDP, and the third section offers a description of samples and their provenance. The fourth discusses the findings through cross-cultural comparison, and the final section contains concluding remarks and areas for further inquiry.

II: Regional Development Period Ecuador and Long Distance Trade

The coastal cultures of this area have longstanding ceramic traditions, most notably small female figurines from the Valdivia culture appearing in the Guayas Province as early as 3500 BCE. Though earlier period styles suggest these cultures were once more uniform, by the RDP the ceramic traditions were similar in form and subject matter, but somewhat disparate in style (Cummins 1992). Archeologists have identified six primary styles along the Ecuadorian coast during this period divided into two larger northern and southern stylistic complexes (Meggers 1966). The northern area contained the Bahia, Jama-Coaque, and Tolita-Tumaco groups, who favor bright post-fire polychromes with more elaborate iconography, whereas the southern cultures prefer heavily burnished and incised figurines with little added color.

This period is characterized by ceramic figurine art elaborately ornamented with symbols of power and prestige, specialized production of luxury goods, and urban centers with earthen platforms (Masucci 2008). Differences in social complexity for the RDP are attributed to the rise of local elites exhibiting unique traits that emphasize iconographic and material examples of power and authority (Meggers 1966; Masucci 2008). The iconography represents a collection of symbols and representations that demonstrate painstaking attention to detail and craft specialization.

All along the coast, human figurines are found dressed in elaborate costumes (Fig. 5) as well as examples of natural and supernatural depictions of animals (Fig. 6). Many figurines are not freestanding, and they were made into whistles, vessels, and other objects with clear functions. Some were attached to vessel forms through a bridge piece, with elaborate whistling apparatuses embedded in the figurine powered by liquid movement.[1]

The use of mold technology as a predominant means of making these polychrome figurines suggests a workshop structure developed, with an emphasis on providing highly decorated elite ceramics (Cummins 1992). It was a detail-oriented method of production, focused on lifelike movement and a stylized naturalism where emphasis was given to a figurine's specific costume and ornamentation, rather than an individualized appearance.

Alongside this diverse collection of figurines, these coastal cultures also had affinities for elaborate bowls and plates on multiple legs or pedestals (Figs. 7-8), globular shaped vessels, and hemispherical bowls. The multitude of these creations and their fine decoration and craftsmanship suggest a cultural importance on large feasting events, an idea complemented by the large feasting buildings known for the earlier Valdivia culture. They also created ceramic stamps, or *sellos,* possibly used for body painting or some other unknown purpose, and a proliferation of small objects made into shell and metal beads, pendants, and other ornaments (Masucci 2008). Figurines and figural imagery were sometimes made into table supports, handles and decorative elements on serving ware, and whistles.

The Tolita-Tumaco culture inhabited an area stretching along the coast of Ecuador from the northern Esmeraldas Province to the port city of Tumaco in the Nariño department of southwest Colombia. The first signs of settlement in the area appeared near the mouth of the Rio Santiago around 600 BCE (Valdez 1992). Explorations of the hinterland area by William DeBoer and others demonstrate stylistic similarities with La Tolita (1996; 1997; Valdez 1992). Archeological evidence points to the island site La Tolita as the ceremonial center for this area, with likely relations to some of the surrounding coastal and highland groups in Ecuador and Colombia.

La Tolita was inhabited between 200 BCE and 400 CE and is located near the northwest corner of the island La Tola in the Esmeraldas Province. It is a low-lying mangrove swamp in a significantly humid environment with at least thirty-one and as many as forty mounds recorded at the site (Fig. 9) (Ferdon Jr. and Corbett 1945; Valdez 1987; Lubensky 1991). The mounds are oriented from west to east, forming a rectangle

[1] See Guterriez Usillos (2013) for example of whistling apparatus design.

that is open-ended facing the northeast (Valdez 1992, 232). Ceramic fragments and cultural debris in the area around the island suggest habitation was much broader than the site itself (Valdez 1987; DeBoer 1996; Tolstoy and DeBoer 1989). In the Cayapas-Santiago river basin, a similar style is persistent, however, for at least two centuries after the abrupt ending of La Tolita around 350-400 CE (DeBoer 1996).

Archeologists interpret La Tolita as a sacred burial ground and a ceremonial center, with evidence of pilgrimage to the site by many local groups (Meggers 1966; Valdez 1987, 1992). Francisco Valdez regards La Tolita as an early, and somewhat short lived, chiefdom representing a major ceremonial center developed out of the earlier local Chorrera tradition (Valdez 1987). The ceramics of La Tolita are similar to those seen elsewhere along the coast during the RDP, with a more focused attention on naturalistic features (Valdez 1992). Ceramics take on an interesting importance as this site, with human remains interred in large stacked vessels and then buried in the mounds (Valdez 1985, 24-7).

The region's rich supplies of titanium, platinum, and most predominantly gold lend some explanation to the attention it has received across time (Scott 2011, 68). With a preference for creating small beads, rings, and figurines from gold and metal alloys, La Tolita has met an unfortunate fate over the years. Many of the mounds and surrounding areas of the site have been ransacked for gold by looters and property owners (Ferdon Jr. and Corbett 1945; Valdez 1985). Similarly, many ceramic figurines that survive have multiple small holes in the ears, nose, and elsewhere that were likely once meant to hold metallic objects, lost or removed from the piece for their value.

Many of the earliest archeologists to publish about their excavations in Ecuador write about the Mesoamerican ceramics as similar to those in the Tolita-Tumaco region (Ferdon Jr. 1940; d'Harcourt 1942; Meggers 1966; Reichel-Dolmatoff 1965; Valdez 1987). Betty Meggers offers a summary of these similarities suggesting that the masks, mold-made figurines, and stamps resemble those of contemporaneous cultures of Veracruz, Oaxaca, and the Valley of Mexico (1966, 116). Citing similarities in production methods and iconography, Meggers explains, "…northern Esmeraldas seems to be the focus of concentration of Mesoamerican traits, which become less frequent and more modified in form with increasing distance to the north and south" (1966, 117).

Reichel-Dolmatoff speculates in length on these connections as well, adding an iconographic interest in felines, and the use of obsidian and greenstone (1965). The use of post-fire saturated polychromes also holds some similarities to Teotihuacan and Maya ceramics. Blue and blue-green colorants in particular demonstrate a similarity in hue and tonality to those produced in Mesoamerica. These scholars rightly note the strong evidence pointing toward coastal trade although the degree of technological exchange remains unclear.

Scholars have suggested Pacific maritime trade between Ecuador and Mesoamerica for over a century. There are many points noted as connecting these regions, including iconographic traits and ceramic formation techniques, sailing expeditions and raft engineering analyses, incidences of similar cultural practices, and wildlife exchange as evidence of interaction as far north as the cultures of West Mexico. The earliest evidence of ancient Ecuadorian peoples traversing the ocean to trade with Peruvian cultures extends back to the Valdivia culture (3500-2000 BCE) and lasts until the times of European contact (Martín 2010).

The availability of balsa wood and bamboo allowed for a flourishing seafaring culture interested in interaction and the trade of ritually significant items with other cultural groups (Zeidler 1991). Lightweight Ecuadorian balsa wood is recounted by early Spanish chroniclers as being held together by vines and made into large rafts carrying trade goods and many people (Samano [1534]1987).

The Spaniards first encountered these rafts in 1525, when Francisco Pizarro's pilot, Bartolomeo Ruiz, set out on the second expedition from the Panamanian coast to what is known Ecuador and Peru (Samano [1534]1987).[2] His account states that they encountered a balsa raft vessel, capturing it and eleven of the twenty people on board. He lists a load for the raft with expressed wonder upon its size and varied contents, including a collection of metal items, beads, cups, and textiles (Samano [1534]1987).

Archeological findings and the de facto presence of particular items support the idea that these boats carried *Spondylus* sp., metal ornaments, emeralds, and other trade goods southward to Peru (Dewan and Hosler 2008). Ancient Peruvians revered the bright

[2] The voyage's written account is attributed to either Samano de Xeres or Pizarro's secretary, Francisco de Xeres (Currie 1995).

red *Spondylus* sp. shell, but these bivalves cannot propagate in the cold water south of the Santa Elena Peninsula, and the Peruvians may have relied on the Ecuadorians to bring the shell from further north.[3] Living at a depth of 15 to 50m, *Spondylus* sp. is also difficult to access, and would require skilled divers to retrieve it (Pillsbury 1996).

Ancient Ecuadorian cultures played a role in the distribution of trade goods and had the ability to travel long distances with their innovative raft designs. Leslie Dewan and Dorothy Hosler's (2008) raft engineering analysis and Richard Callaghan's (2003) software analyses on their maritime travel capabilities offers evidence that long distance journeys were certainly possible, but not without many challenges. In Callaghan's sailing model, six hundred voyages in each direction are simulated in a software program (2003). It is expected that travel from Ecuador to West Mexico would take between forty-seven and fifty-nine days without stops; the return journey from north to south, however, could last anywhere from ninety-seven days to over a year depending on the time of year (Callaghan 2003)

Two noteworthy expeditions have physically attempted long distance travel on balsa craft with mixed results. Thor Heyerdahl's Kon Tiki voyage to Polynesia from Peru in 1947 was considered by Heyerdahl himself to be a success (Heyerdahl 1996). John Haslett's Manteño voyages during the late nineties from an Ecuadorian fishing village in attempts to find a route to West Mexico would, in contrast, end in disastrous circumstances. First, Haslett's raft was eaten away by shipworms, and then trapped in an ever-flowing circular current, or gyre, for sixty-eight days. The final expedition was grounded in 1999 after a hurricane. Haslett and his team never made it past the coast of Panama, but he remains convinced that these rafts are seaworthy for long distances (Haslett 2006).

The extended duration of these journeys may account for the apparent exchange of ideas and technologies. Evidence in these areas includes parallels in the creation of metallurgy and shaft tombs, as well as similarities in iconography and clothing (Anawalt

[3] In particular, this shell was sacred to Andean highland cultures as early as Chavín (900 BCE-200 BCE), with coastal cultures like the Moche and Chimu also demonstrating an interest in the shell in the archeological record. *Spondylus* cannot survive in the cold water off the Peruvian coast as a result of the Humbolt current. However, it propagates in number in the warmer waters from the Gulf of Guayaquil to the Gulf of Mexico (Pillsbury 1996).

1992; Hosler 1988a, 1988b, 1986; Meighan 1969; Mountjoy 1969). The appearance of metallurgy in West Mexico around 700 CE is considered a probable example of maritime trade and interaction between the continents, given that no other cultures in the surrounding region had that ability at the time (Mountjoy 1969). Copper and gold metallurgy techniques in western Mesoamerica are the same as those used in the Peruvian Andes and some Colombian cultures (Hosler 1988a).

Several stylistic choices and iconographic traits show some level of similarities to those in Mesoamerica as early as the first creation of ceramics. In the earlier Chorrera phase, the introduction of red slipped vessels and micaceous clays, and ceramic decoration with color zoning and zoned punctate designs (Fig. 10) had parallel uses in Mesoamerica (Estrada 1958). Repeated iconographic symbols like the *canastero* figures are also representative of this possible connection (Fig. 11). These figurines wear a simple loincloth and head wear and have a large container on their backs. Found in Ecuador and Colombia, as well as Teotihuacan (Fig. 12), these "merchant" figures demonstrate remarkable iconographic similarities to one another (Carot and Hers 2016).

Ethnozoological evidence also supports the longstanding hypothesis of interactions. While some animals migrate instinctively, others were more likely transported by humans. The tufted jay, a non-migratory bright blue bird that inhabits a relatively small mountainous area of West Mexico has its closest taxonomic relative in the white-tailed jay from Ecuador and Northern Peru (Haemig 1979). The hairless dog's earliest appearances in west Mexico and along the South American coast has also been suggested as an indication of these interactions (Carot and Hers 2016).

Long distance trade has been gradually given less attention, as focus has shifted to localized studies on social structures within coastal groups and their interactions, but the debate on connections between West Mexico and Ecuador continues. Patricia Carot and Marie-Aretti Hers called for a renewed study of these connections in 2016. They suggest Tarascan evidence of *Spondylus* divers with cranial deformations indicative of deep sea diving further offers evidence that West Mexico participated in the Pacific maritime trade system (Carot and Hers 2016).

Many of these similarities link to different points in time and areas of contact, making it difficult to know the context behind these interactions. Studies of the ancient

Ecuadorian coast centered on searching for long distance connections can also be problematic. Susan Toby Evans and David Webster point towards a romanticized notion of sea travel as fostered by an American history educational emphasis, “on the deeds of the Vikings and the romance of fifteenth and sixteenth-century European voyages of exploration” (2001, 674). They argue that a lack of indisputable evidence and the dangers of open sea travel northward limit this discussion to nearby locations, with the developments of metallurgy more likely representing independent invention (Evans and Webster 2001). They further warn that this emphasis on long distance trade and interaction over independent invention perhaps implies that the culture is incapable of producing new innovations on their own accord.

III: The Ferdon Collection Samples

Acquired by the Maxwell Museum in 2006 and 2008 from the Museum of New Mexico, the Ferdon collection is a sizable amount of sherds, as well as partial and whole ceramics, stone, bone, metal, shell, and other archeological materials. Pottery sherds make up the bulk of the collection, and examples of figurines that may be from the early Valdivia culture as well as a number of small beads, stone axes and celts, and residue samples all remain in need of further study.

The collection is from one midden excavation and a number of surface excavations from across coastal Ecuador made by Edwin Nelson Ferdon Jr. with help from John Maxwell Corbett on some of the early expeditions. Ferdon made his first trip to Ecuador in 1939 and continued making surface collection in the country until 1943. At that point, he began to help the war effort with missions to retrieve quinine in Ecuador, while still identifying archeological sites in his journeys far into the Ecuadorian highlands (Lubensky 1991, 4). This collection represents one of a handful of attempts to identify and collect samples from lesser known Ecuadorian sites, prior to a point when coastal erosion and looting made this process much more difficult.

Ferdon wrote in unpublished and published reports on his travels within Ecuador (Ferdon Jr. and Corbett 1945; Ferdon Jr. 1940a, 1940b, 1941). He also recorded every item he collected in an organized fashion, a fact reiterated by Earl Lubensky, a graduate student who had access to these records while working on his dissertation (Ferdon Jr. 1940b; Lubensky 1991). Unfortunately, most of the records were not retained with this collection; the pages that do still accompany the collection are recorded in pencil that has faded to an illegible extent over the years.

In determining provenance for the objects in this collection, several factors need to be considered including the records on the ceramics itself and the labels provided by the Maxwell and the Museum of New Mexico. Two scholars who approached cataloguing stylistic traits for their dissertations were also considered: Lubensky (1991) on the Esmeraldas collection and Michael Patrick Simmons on the La Libertad collection (1960).[4] Their records and the personal accounts they record from Ferdon add invaluable information to this process.

Lubensky records Ferdon's shorthand method for object provenance. Ferdon's method for labeling objects used a trio of two letters and one number to record a site, with some objects receiving a label directly on the ceramic body. The first letter represents the country, the number corresponds to the site number applied by Ferdon, and the second letter tells the province. For example, La Tolita is marked as "E-1-e" (Lubensky 1991). These labels were considered the most accurate sources for provenance. Lubensky also offers Ferdon's descriptions of each site and its location on a map.

The following provides a formal and iconographic analysis of each ceramic sample as well as the available site information. Formation techniques for each piece were determined using observations from Prudence Rice (2016) in her comprehensive publication on ceramic analysis. The Munsell Color System is used to identify the closest available color. This system relies on color identification through color chips arranged by numbers. As a notation system, it uses a shorthand approach, identifying color by one or two letters with a number range then associated in the hue, value, and chroma (e.g B2 3/4). Human sight differences, lighting conditions, and available Munsell colors limit this approach, but it provides a general identification for future researchers with the inevitability of color change from digital image reproduction.

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[4] Both Simmons and Lubensky only catalogued and researched pottery and potsherds in their dissertations, which leaves all other materials and ceramic figurines in this collection still in need of examination.

Two colorant samples from different sites (Fig. 13) were used in this study.[5] The first sample was taken from a sherd (Figs. 14-16) identified as originating from La Tolita by a label on the ceramic itself. The clay paste is light creamy grey with larger temper particles. The surface of this rim sherd is incised with deep lines and some hatching. Two parallel running lines form a circle with the outer lines coming together to run straight and parallel away from the circle. Blue green colorant (BG5 5/4) is painted within the narrow surface of this motif. The center of the circle has a small ball of clay pressed onto the surface into a cone with a single punctation into the center. Remnants of red and yellow post-fire paint are also found on other incised sections. Interestingly, the sherd is flat, with evidence in the particle arrangement that this piece was formed from a slab. It may have been a square vessel, a flat handle, or something else entirely. One example (Fig.17) from the Museo Casa del Alabado's collection shows a similar object as the frontispiece for a platform where a figurine stands.

It is rather enigmatic, which may be why it appears to be excluded from Lubensky's dissertation on vessel sherds from this collection. Simmons (1970) appears to have come across a similar problem, with several comparable sherds that did not fit with the Guayas Province ceramic sequence from Ferdon's Las Carolinas collection. Simmons calls these pieces "Bahia Incised Polychrome" with remnants of green, yellow, and red (1970, 159). He wrote to Betty Meggers about these sherds, and she suggested they show stylistic characteristics of the Jama-Coaque culture (Simmons 1970, 160). However, illustrations of Simmons' La Libertad sherds show that the La Tolita sherd is not similar enough to be a miscategorization of one of the "Bahia incised" pieces.

An unpublished report written by Ferdon and Corbett in 1945 offers some contextual insight into the sampling process and expedition itself. On August 3, 1940, Corbett and Ferdon set out from Quito to the Esmeraldas Province with their wives on a joint commission from the Department of Mines and National Academy of History (1945, 1). The group headed by boat to Hacienda La Tolita owned by Sr. Donato Yannuzzelli to report back on a gold mining operation at the site.

They learned that the gold being mined contained archeological materials as well as unworked metal. Though workers had ceased digging in the mounds themselves,

[5] See Figure 13 for map locating sample origins.

Ferdon and Corbett's map and report demonstrate that the damage was already extensive upon their arrival (1945, 3). The excavation lasted ten days and consisted of gathering pottery from the surface that had been discarded by the workers in the gold mining process (1945, 6).

The second sample (Figs. 18-21) was taken from a small figurine head. This piece was likely produced by impression into a mold, as there is a seam on the interior. The figurine demonstrates skilled craftsmanship with naturalistic features characteristic of the Tolita-Tumaco culture. It wears circular earrings, each with a punctation through the center, and a sizable nose ring. The head is elongated in the back, a trait on many of the figurines, referring to the practice of cranial modification among the ancient coastal Ecuadorians (Valdez 1987). What appears to be hair is short with a line down the middle that may represent a part. Though it is difficult to tell exactly where the colorant was applied, it appears that the blue colorant once covered the face from the hairline down to the cheekbone where it curves in towards the mouth.

This sample represents one of the most vibrant blues (B5 5/8) to be found in Ecuador. The clay has a finely ground temper and the paste appears to be high in iron, considering the red color. Images taken with a digital microscope (Fig. 21) show evidence that the figurine may have been originally covered in an off-white slip, likely to keep the red surface from interfering with the post fire paint. However, the use of destructive ceramic thin sections would be needed to confirm this possibility.

Provenance information for this figurine was found on the original accompanying label, which suggests that it was found along the Rio Mataje.[6] The Rio Mataje demarcates the line between Ecuador and Colombia for almost half its distance. There is one known site along the river near the mouth to the ocean, outside the town Mataje. Reichel-Dolmatoff mentions a mound of midden more than three meters long along the

[6] One of identifying notations for this figurine marks it as "C-1." Considering the first letter of Ferdon's shorthand for mapping sites represents the country, it may originate from the Colombian side of the river. On this note, the original label that accompanied this small bag of ceramics and stone lithics was written in what appears to be Ferdon's hand on a torn piece of sturdy paper, perhaps suggesting hasty circumstances behind the collecting. Other locating information included on the label added "Castillo" and "Raspadores" but the importance of these words could not be determined.

Rio Mataje with dates as early as 300 BCE (1965, 114). Julio Cesar Cubillos (1955) also mentions the Rio Mataje as a source of excavation, but does not specify a site. Reichel-Dolmatoff offers radio carbon dates creating phases for this site, with Mataje I ending in 400 BCE, and Mataje II beginning in 300 BCE and lasting until 10 CE, with the sequence unknown for Mataje III (1965). The other objects found at this site include other figurine heads and a small camelid or dog. All of these pieces were reflective of the larger Tolita-Tumaco style.

Though identifying the likely site where the figurine head was found is possible, how it entered the collection remains more puzzling. The closest Ferdon would ever get to the Rio Mataje site was in his travels to La Tolita and the surrounding sites with John Maxwell Corbett. The pair made two excursions northward during their time at La Tolita by boat, and it may be one of seven sites mentioned, but not identified (Ferdon and Corbett, 1945; Ferdon 1941, 7). The only site Ferdon explains in detail is now known as Los Ruanos de La Tolita on southernmost tip of Isla de Santa Rosa, suggesting their journey brought through the mangroves to the northeast, on route to the Ecuadorian border.

The Rio Mataje is still a distance from this location, but Ferdon and Corbett once sailed much further from Esmeraldas to Limones, suggesting they were more than capable of reaching the border to Colombia. However, no indication is made on Ferdon's map of the journey that the Rio Mataje was an area where they travelled, and the two headed southwest to the Guayas Province after their time at La Tolita (1940, 259). This figurine fragment may also originate from one of four additional sites donated to this collection for which the records could not be found, or it could have been collected in Ferdon's later travels (Lubensky 1991, 5).

This collection containing cultural information from over fifty locations offers avenues to ask many questions about Ecuadorian culture. These two ceramics in particular demonstrate the need for further research into technology behind ancient Ecuadorian ceramic production; how did the ancient Ecuadorians create these historically rare colorants?

To determine an answer to this question, several laboratory tests along with some troubleshooting methods were necessary. The tests performed were X-ray diffraction, to identify the crystalline structure of minerals present and scanning electron microscopy using an electron dispersive spectrometer to identify the elemental composition of minerals within the sample.[7] With the help of the University of New Mexico's XRD and SEM-EDS lab managers in the Earth and Planetary Sciences Department, a method for identifying the minerals responsible for the colorant was formulated and presented to the Maxwell Museum. To provide an initial idea of what the blue-green colorant might contain, the whole sherd was temporarily adhered to a mount and tested on a diffractometer capable of testing the surface of a whole sample. This initial information provided signs that a mineralogical identification could be obtained with further testing.

After troubleshooting several methods, it was determined that scraping a small amount of pigment from the ceramic surface would be the best method for analysis. By being placed on a mount meant to lower background interference and a machine that oscillated the samples to capture a wider range of their surface areas, the samples were then separately tested in ten runs. After that, the powder samples were carbon-coated and mounted on carbon tape for SEM-EDS testing. In these tests, specific points were analyzed for their mineral compositions to confirm the XRD data. The XRD and SEM-EDS lab managers graciously provided data interpretation, leading to some interesting and unexpected results.

IV: Cross-Cultural Comparison of Samples

Originally, the Ecuadorian blue and blue-green colorants were hypothesized to come from the main known pigments primarily used in Mesoamerica and elsewhere, like Maya Blue or azurite and malachite. It was also thought that the blue could derive from lapis lazuli or sodalite-based pigments, which are common stones used for beads and other decorative purposes in areas of South America. There are several hues of blue and blue-green in the ancient Americas, and Maya Blue may be the most well known. It is frequently found applied to ceramics, sculptures, and murals created in the height of Maya civilization. The blue was used predominantly during the Classic and Postclassic Periods (300-1519 CE), but appears as early as 150 CE. The earliest known large cache

[7] Summaries on these techniques are available in Appendix A.

of Maya Blue is on ceramics imitating the Teotihuacan ceramic style in tombs at Rio Azul and Copan, suggesting inspiration for the color may have been gained through contact with Teotihuacan in the fourth century CE (Houston et al 2009).

Traditionally ranging in tonality from green to bright blue, Maya Blue (Fig. 22) is generally considered to be made of two main components. The main ingredient is palygorskite, a fibrous phyllosilicate clay mineral. The second ingredient, at only 0.5-2% of the composition is indigo, a blue dye made from the leaves of the indigo plant (*Indigo suffructicosa* and others). Copal (called *pom* in Yucatec Maya), a tree sap, is often considered to a third ingredient, with some examples suggesting ritual preparation of Maya Blue by burning copal with indigo and palygorskite (Arnold et al 2008).

The preparation requires heating at a low temperature (less than 150°C) for a sustained period to fix the color and create unique chemical and physical stability (Arnold et al. 2008, 153). Maya Blue had sacred and secular purposes and its production methods and uses varied through time and location (Domenech-Carbo et al. 2014). These three ingredients all have sacred and medicinal qualities in their own rite, together creating a ritually important substance used in many ways (Arnold et al 2008). Since its rediscovery on murals in the Temple of Warriors at Chichen Itza in 1931, interest in Maya Blue has remained constant, with many questions still remaining. Scholars have also found that Maya Blue had more than one palygorskite source and that various production methods may also yield green and yellow (Arnold et al. 2007; Domenech-Carbo et al. 2014).

Though manmade Maya Blue is found frequently amongst the Maya and occasionally amongst their neighboring groups, other cultures preferred using minerals to color their architecture and objects. Mural artists at Teotihuacan (100 BCE-500 CE) and occasional appearances in Peru used the copper-carbonate hydroxides azurite and malachite (Donnan 1992; Magaloni et al. 1995; Houston et al 2009, 78). At Teotihuacan, these colorants are found using a similar method of application for murals (Fig. 23) and stuccoed polychrome ceramics (Fletcher 2002; de la Fuente 1995). The Maya would also experiment in the use of these minerals, as shown by Diana Magaloni in the murals at Bonampak and elsewhere (Magaloni et al. 1995).

The resin-painted ceramics of the Paracas culture (800 BCE-100 CE) used the sap of either the acacia bush (*Cercidium praecox*) or the pepper tree (*Schinus molle*) to create a post-fire paint (Proulx 2009). Paracas resin paints are highly fugitive, but examples have been found using azurite and malachite to create blue and greens (Donnan 1992). Other examples of azurite and malachite in Peru are found on murals, like those painted onto the Huaca Tacaynamo in Northern Peru (Brooks et al. 2008). These minerals were also used further north. In the ancestral and historic pueblos, these copper carbonates are also found on kiva murals, baskets, stone and wooden objects, but rarely on pottery (Plog 2003).

Despite the similarities in hue of these possible pigments to ancient Ecuadorian colorants, testing showed that neither the blue-green nor the blue colorants contain palygorskite or copper carbonate minerals. The La Tolita blue-green sample was determined instead to be the pigment green earth, a collection of siliceous minerals that are commonly used in many cultures worldwide. Green earth comes in shades of pale green, greyish green, and pale blue-green, with those found in Ecuador ranging comparably.

Originally used to define the typically green pigments used by the Renaissance painters, green earth has many possible mineral sources and a range of color possibilities that are dependent on sources and binders (Grissom 1986). The main sources of green earth are celadonite and glauconite, two phyllosilicate minerals of similar composition. The mineral name celadonite derives from the French *céladon,* meaning sea green. Glauconite originates from the Greek term, *glaukos,* which describes a bluish-green or a green-grey. The difference between these minerals is their formation; glauconite is a mineral of sedimentary origin, whereas celadonite is from altered volcanic origin (Grissom 1986). It is difficult to distinguish between these two minerals with most methods of testing, making the term green earth an unfortunately vague, but necessary term. The term "Ecuadorian Green Earth" is used here to describe the applied pigment specifically found in the Ecuadorian coastal cultures of the RDP, which may include unknown additives and ranges in color. The reader should keep in mind that Ecuadorian Green Earth is closer to pale blue-green or bluish grey with some occasional examples of bright green.

Green earth minerals cannot be heated to ceramic firing temperatures and retain their color, as heated celadonite and glauconite turn a burnt umber (Grissom 1986). Their inability to retain their original color during firing may have made them more desirable in indigenous American cultures as an architectural and rock art pigment rather than a ceramic colorant, with Ecuador being the exception.

Ecuadorian Green Earth is used with some frequency on ceramics. The pigment is often found on figural imagery, though it can also be seen on ceramic house forms and other pieces, like the sherd tested in this study. Its earliest appearance may date back to the Chorrera culture as early as 1500 BCE. The pigment may hold political and ideological significance as it is often found in association with elite status objects, like ceramic figurines. These figures are associated with many different actions and regalia, and are painted in saturated polychrome. Its application often appears as though it is meant to reflect real objects where the color appears. Ecuadorian Green Earth is found on what appears to be beadwork attached to the arms, legs, and necks of figurines, perhaps representing some form of stone or oxidized copper.

Painted on some of the coast's finest ceramic examples, it seems that this pigment held an important role in the representations of particular events and characters. One female figurine (Fig. 24) in particular is commonly found across the Ecuadorian coast. She was frequently painted with green earth in the Jama-Coaque and Tolita-Tumaco traditions. Ancient ceramists utilized several defining features that make this figurine recognizable. She is most commonly represented as a freestanding figurine in a static pose with her hands down by her sides and palms facing outward. Her mouth is often open or displaying a toothy "grin," and her head is occasionally tilted upwards.

The figurine always wears a long skirt and a similar head cloth or headdress, while the jewelry and other ornamentation ranges. Finer examples of these ceramics are frequently painted with the colorant on the skirt, head cloth, and jewelry. In particular, the color is found painted as a striped or checked pattern on skirts, and painted on a diagonal line on the head cloth. Whatever relationship Ecuadorian Green Earth had with the figural form is unknown, but it seems like it was an important addition to figurines in particular.

Because green and blue-green are relatively common on these ceramics, the source, or sources, were most likely local and abundant enough to allow for centuries of use. The closest known source is the Cayo arc, a geological formation that has been found to contain celadonite and glauconite (Morante Carballo 2004; Machiels et al. 2014).[8] Celadonite is also found much further inland in the Fruta del Norte deposit in the Zamora-Chinchipe Province (Lipiec et al. 2016). With the proximity of possible source material, it is probable that the green earth came from local sources within the Cayo Arc.

There are no known sources of these minerals within the Tolita-Tumaco cultural area, suggesting that these pigments or the objects bearing the colorant were obtained from elsewhere. The Jama-Coaque culture further south in the Manabí Province is the closest group with access to the Cayo Arc. With the connections between these cultures seen in the archeological evidence, this finding further demonstrates the likelihood of trade and interaction between these groups.

Ecuadorian Green earth is particularly unique when compared to other artistic applications of the pigment in the pre-Columbian Americas. There are many instances of green earth pigments across North and South America prior to European arrival and after, with painted examples found from the cultures of the Northwest Coast, Illinois, and California, Mexico, Peru, and Argentina. In North America, celadonite and glauconite are found in many deposits along the coasts and in volcanic areas, like the Southwest; its usage as a pigment is however not often documented. The pre-Hispanic site of San Emigidio in California demonstrates that the Chumash culture used celadonite or glauconite on polychrome rock art in their historic past (Scott, Scheerer, and Reeves 2002).

The North American traditions most historically known to frequently use green earth as a colorant are the Tlingit, Haida and Tsimshian cultures in the Northern Coastal regions of British Columbia. Within these groups, celadonite was used with or without fish egg oil as a binder to color wooden carvings (Wainwright et al. 2009). When only water is used with green earth, it tends to produce a pale, powdery substance when dry, making it only suitable for certain applications. When fish egg oil is used, the resulting

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[8] The term "arc" is used here to define a geological formation that is a typically curved chain of volcanic activity cause by the movement of tectonic plates.

hue is much darker, but the colorant is more strongly affixed to the wood (Wainwright et al. 2009).

Ecuadorian Green Earth is not easily removed, and it is likely that a binder other than water was used in its production. It is however unknown what binders, or post-fire surface treatments, may have been used in Ecuador. Fish egg oils are an unlikely binder, as the paint is often found in paler shades.

These clay minerals are versatile and used across a wide range of objects in the Americas, but ceramics are not a popular base for this medium. Green earth is found on some ceramics in North America including at the Moundville in Illinois (1000-1450 CE) (Knight 2004). In elite burials, polychrome sherds were found with green earth decorating their exteriors alongside ceramic containers caked with glauconite on their interiors (Knight 2004). Scholars have theorized that processed pigments are connected with elites at Moundville, and that they held some profound importance in the care taken to inter pigments in various stages of production in mounds and with elite individuals (Knight 2004; Peebles 1977). In addition to this, green earth may also be found on the occasional ceramic of the southwestern Casas Grandes culture, though the colorant has not been tested (Grissom 1974).

In pre-Hispanic Latin America, instances of green earth's usage are somewhat sporadic. Outside the Ecuadorian coast, green earth may be most commonly used in pre-Hispanic Latin America as an architectural colorant. At the archeological site of Copan in Honduras, Rosemary Goodall and her team (2006) found that a green paint covering the exterior of the Rosalila building contains celadonite. The Maya used white calcite stucco underneath the paint to brighten the shade, and added finely ground magnetite to the paint to alter the color (Goodall et al. 2006). A panel holding a stucco mask sampled for Goodall's study showed over twenty layers of paint, demonstrating that the mask had been repainted over the century (520-655 CE) that the Rosalila building was maintained.

The only other area known to use green earth on ceramics in pre-Hispanic Latin America is West Mexico, which is an interesting similarity between the groups. Pseudo-cloisonné decorated ceramics from La Quemada and likely other sites in western Mexico with largely non-figural designs thought to show scenes of Mesoamerican ceremonialism are painted polychrome with green earth among the colorants (Strazicich 2002). The pseudo-cloisonné technique, where wet clay is applied to the fired ceramic surface with powdered pigment on top, is highly fugitive. Mesoamericans also used green earth after the Spanish arrival. In the early Colonial Period of New Spain, examples of yellow-green colorants shown to contain green earth were used in codices from Meztitlan (Haude 1997).

In South America, green earth was similarly used infrequently outside of the Ecuadorian coast. The coastal site of Pachacamac in Peru, for example, is one of the areas where green earth has been identified. Known to have been inhabited at different points by the Wari, Lima, Ychma, and Inca cultures, Pachacamac shows evidence of longstanding pilgrimage centered around a wooden oracle thought to hold great power. Building B15, also known as the Painted Temple (900-1300 CE), has several polychrome murals. A pale green paint there has been identified by researchers as ferroceladonite, an iron rich form of celadonite, but it is sparingly used at the site (Lujan 2018). A green clay that could also be tentatively identified as green earth through its chemical composition was also used on much older murals at Huaca Ventarrón (2300-2035 BCE) in the Lambayeque Valley of Northern Peru (Wright et al. 2015).

Likewise, it is found to have early dates as rock art pigment in South America. In Argentina, green earth has been identified on rock painting in cave shelters at several early hunter-gatherer sites (Aldazabal et al. 2018; Boschin 2011; Rousaki et al. 2017; Wainwright et al. 2000). There is a wide range of dates for these sites, beginning as early as 13,000 BP (Wainwright et al. 2000).

Across the Americas, green earth had a variety of uses, but it seems that coastal Ecuador used it most frequently with a unique focus on ceramic application. Perhaps this frequency is best explained by not just the localized nature of the source, but also other factors like an innovative binder or post-fire treatment allowing for prolonged adherence of the colorant. Examples of Ecuadorian Green Earth often remain long after other colors have eroded from the ceramic surface, as shown in the La Tolita sherd. Investigations into how this pigment was applied will likely further show the innovative nature of this unique colorant tradition.

The Rio Mataje sample would prove to be more elusive; the results for the Ecuadorian blue were inconclusive in both SEM-EDS and XRPD testing. No mineralogical component could be determined as clearly responsible for the color. This may suggest that the colorant originates from an organic source, which would not be detectable with these methods. Despite eluding a clear identification, the available data do help rule out many possible blue colorants, both manmade and naturally produced. The Ecuadorian blue's uniqueness can be demonstrated through comparison to other blues used in pre-Hispanic Latin America.

As stated previously, the absence of copper rules out the mineral azurite, as well as other possible blue minerals and historic pigments. For example, Colanna-Preti and his team tested a blue (Fig. 25) found at Pachacamac's painted temple. Painted on the temple's adobe walls, the blue was made from lavendulan, a copper arsenate mineral (Lujan 2018). Though a much rarer pigment, another copper-based colorant found on objects in the royal tombs of the Maya site Calakmul show the copper-zinc phosphate, veszelyite, a mineral ranging from bright blue to green. Samples found at Calakmul were a light blue-green with a Munsell color of 2.5BG 8/4 (Moreno et al. 2008).

Other examples of blue paints in Peru, used in adobe murals made by the Moche culture and others along the coast, were made of carbon mixed with calcite or magnetite (Wright et al. 2008). When mixed properly, a blue-grey color can be achieved from these seemingly unlikely sources. The color, which Wright and her team record as closer to grey than blue, is not similar enough in color or composition to hold any close connection to the Ecuadoran Blue (2007, 232). Also, low levels of iron and similarly low levels of carbon make them unlikely colorant sources.

Some blue and blue-green colorants in the Americas remain untested, but they can provide some comparative insight. The Bolivian Tiwanaku culture used a blue that has not been tested. Painted on walls in the Putuni Palace complex, it is theorized to be a pigment made of sodalite or lapis lazuli. These minerals are also found inlaid into wooden objects like snuff trays and on beaded jewelry with some frequency (Young-Sanchez 2004). The Puma Punku pyramid at the same site was also once vibrantly painted with red, blue, green, and white colorants (Rodríguez 2000).

In addition to this, blue pigment has also been found inside ceramic bowls in site excavations, described as a "deep royal blue" powder (Young-Sanchez 2004, 147). Areas of Chile, Argentina and elsewhere are sources of lapis lazuli, and sodalite is somewhat common. Limited use lapis lazuli pigment, is also found on murals at Teotihuacan (de la Fuente 1995). Though examples of lapis lazuli and sodalite were sought out as another likely colorant, no minerals with high enough sodium content were identified in the Ecuadorian blue point analyses.

The earliest known example of Mesoamerica blue-green colorant appears in the murals of Oxotitlan Cave with Olmec style and iconography, tentatively dated around 2,500 years ago (Grove 1970). At Kaminaljuyu near the Pacific Coast, ceramics dating to 400 to 500 CE demonstrate experimentation with minty green and slate blue colors (Houston et al 2009). Many of blues and blue-greens known to cultures of the ancient Americas need further research, with the likelihood that more organic and mineral colorants will be added.

V: Concluding Remarks

Pigments, and the minerals from which they originate add important historical context to the iconography and image. This study was originally developed with the theory that the rarity, portability, and cultural value held by blue and blue-green pigments could result in their transfer and exchange. Instead, ceramic testing and cross-cultural comparison demonstrated the ancient coastal Ecuadorian's unique approach to the challenge of finding and creating rare blue and blue-green colorants, exemplifying local innovation and technological skill.

The blue-green sample from La Tolita was shown to contain green earth, made of celadonite or glauconite. Further verification that the green earth identification is correct has been provided by the Museo Casa del Alabado's unpublished research testing several more figurines with the pigment (Romero et al., n.p.). The use of green earth is not commonly seen as a ceramic pigment elsewhere in the Americas, with only a handful of identified examples on both continents. Historically known to be used as a colorant for woodcarvings, rock art, and architecture, this pigment is rarely used on ceramics outside of the northern Ecuadorian and southern Colombian coasts. All across pre-Hispanic Latin America, the only other area that used green earth as a post-fire ceramic pigment was West Mexico. Though there are many differences in iconography, the contemporaneous application of green earth is an interesting connection between these areas where there is other evidence for interaction.

It is evident through cross-cultural comparison and geological data that Ecuadorian Green Earth used localized sources and methods. The frequency in which these ancient groups used the pigment on ceramics may suggest a particular method of application or the addition of a binder that offered strong adherence to the ceramic surface. Within the Tolita-Tumaco and Jama-Coaque cultures, Ecuadorian Green Earth was used to color particular characters and certain aspects of clothing and ornamentation. These polychrome figurines seem to function as elite objects displaying power and prestige, with possible ideological associations.

Though little is known about this rare Ecuadorian blue, it could be a completely new method for producing a blue paint to the ancient Americas as it holds no clear parallels to other historically used blue minerals and pigments. The color produced by indigo, seen in South American textiles and Maya blue, has remarkable similarities in hue to the Ecuadorian Blue, and seems like a possible organic source for the color. Likewise, green earth is a suitable base for many organic dyes, making it an ideal substance for experimentation with many other mineral and organic colorants (Grissom 1974). Searching for possible organic inclusions in these colorants will be imperative in understanding the possible other additives used to achieve the final results. Though further research is needed, this study demonstrates the first known use of green earth in ancient Ecuador, and the identification of a blue colorant that is likely made of a completely new composition previously unknown to academic research.

Appendix A
XRD and SEM-EDS Ceramic Pigment Analysis Introduction

X-Ray diffraction (XRD) identifies clay minerals by their crystalline structure. Aiming X-rays onto a sample, the atomic planes of the mineral constituents inside diffract the waves along certain angles. These angles are recorded by the detector, and the provided information is processed by the associated software. This results in a diffraction pattern with observable peaks. Alongside the wavelength, this information allows minerals to be identified based on their characteristic lattice spacing (Rice 2016). Each resulting diffractogram is shown as a line graph, and the data is interpreted through a software database. Minerals are identifiable by the location and intensity of each peak in the line graph.

The results produced by XRD cannot be solely relied upon when testing archeological ceramic samples. It is difficult to determine what results in a sample are natural parts of the clay paste and what is an added pigment mineral or temper; even when the pigment is removed, elements of the clay paste may still remain (Rice 2015, 296). Also, the software that interprets these peaks may identify similar minerals that are incorrect. It is therefore important to test ceramic sherds in other ways to confirm the XRD results; scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) can be a viable method for comparison.

SEM-EDS allows the chemical constituents of the sample to be analyzed by detecting x-rays emitted from the sample during bombardment by an electron beam. This provides an image of the sample, which can include a back-scattered electron detector to show areas within the sample that have a higher or lower periodic number. Point analyses allow for specific areas of a sample to be tested with quantitative microanalyses providing the chemical composition.

These compositions can be compared to databases and samples of known constituents on the same machine to achieve more certainty in the results. Another technique, electron mapping, shows the general distribution of different elements in a corresponding color, which offers a more general conception of what the sample contains as a whole. These technical methods are useful in the identification of minerals, but searching for organic materials must take several other factors and techniques into consideration.

Appendix B
Experimental Methods and Results

The following explains the experimental methods and results of a research project where two post-fire ceramic colorants from Ecuador (500 BCE-500 CE) were tested for their mineralogical composition using X-ray diffraction (XRD) and scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS).

The project began with attempts in non-destructive analysis of the colorant. After using a temporary adhesive to attach the first sherd from the site La Tolita to a mount, it was tested whole on a Rigaku D/Max Rapid II, a machine intended for testing whole mineral samples. After adjusting the angle to test the surface, shorter time frames were tried, but the sherd ultimately needed to remain in the machine for over twelve hours to obtain clear spectra peaks. The sum of these tests was averaged with ten runs using a powder diffraction device.

These initial XRD tests offered non-destructive data that was useful in sample identification, but more precise methods were needed. Using a micro scalpel, small samples (~20 mg) were scraped off of each ceramic surface.[9] These samples were placed on a quartz zero background holder for XRPD testing on a Rigaku SmartLab diffractometer. To avoid losing any weight on the small amounts of colorant, these samples were not ground; the platform was rotated five times and the results were averaged together in Jade data analysis software. To provide a reading from several angles, the samples and holder were then placed onto a Eulerian oscillator. The La Tolita sample was tested with five runs flat and five on the Eulerian oscillator as well as whole sherd surface analyses. The Rio Mataje sample was tested with ten runs solely as a powder.

The samples were then each attached to double-sided carbon tape on a specimen stub and carbon coated. Using a Joel 5800LV scanning electron microscope, a collection of point analyses was performed using imaging with backscattered electrons and element

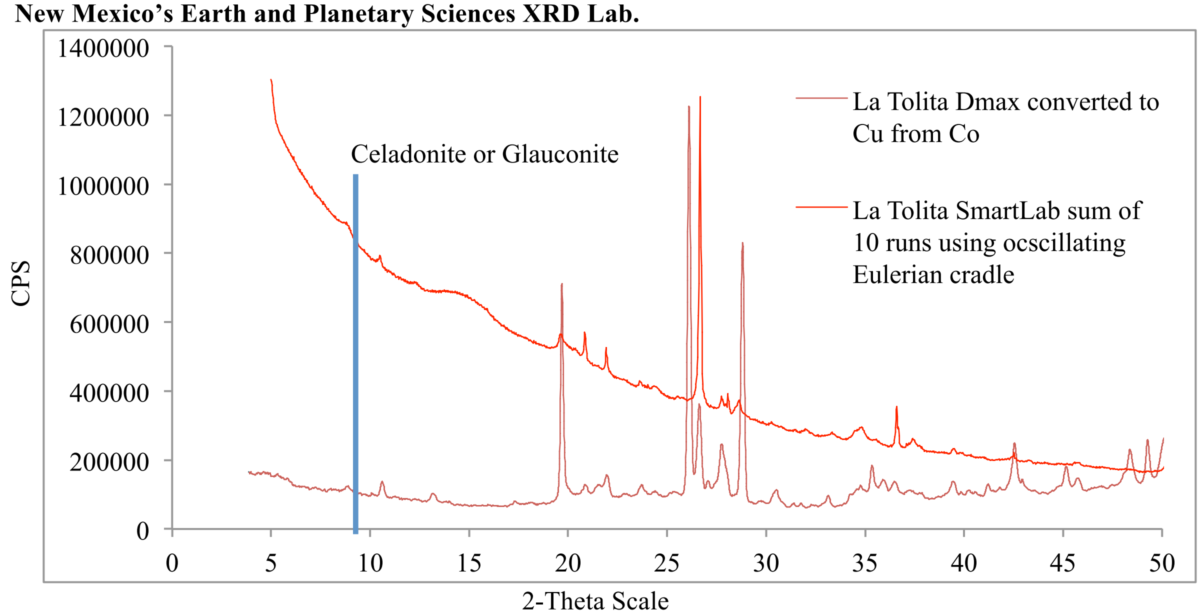
[9] The placement and coverage of the colorants, methods of analysis, and relative levels of destruction were analyzed with the museum's destructive analysis committee. The least destructive and most universal method of testing—scraping small amount from the sherds— was chosen over creating thin sections.

mapping to provide further information on points of interest. Measurements were made with an acceleration voltage of 20 kV and a working distance of 15 mm.

The Munsell Color System was also used to record the closest equivalent in hue, value, and chroma for each colorant.[10] Each sample was examined from the ceramic surface and under white LED light. This system allowed identification of these Ecuadorian colorants in future research.

XRD results for the La Tolita sample demonstrated several clear peaks with high intensity that corresponds to the mineral celadonite or glauconite (Fig. B.1). Along with a few other green clay minerals, celadonite is used to create the pigment more commonly known as green earth. Clay, quartz, and an amphibole group mineral were also found in the sample.

Figure B.1: Diffractogram of La Tolita sample. Provided by Eric Peterson at the University of New Mexico's Earth and Planetary Sciences XRD Lab.

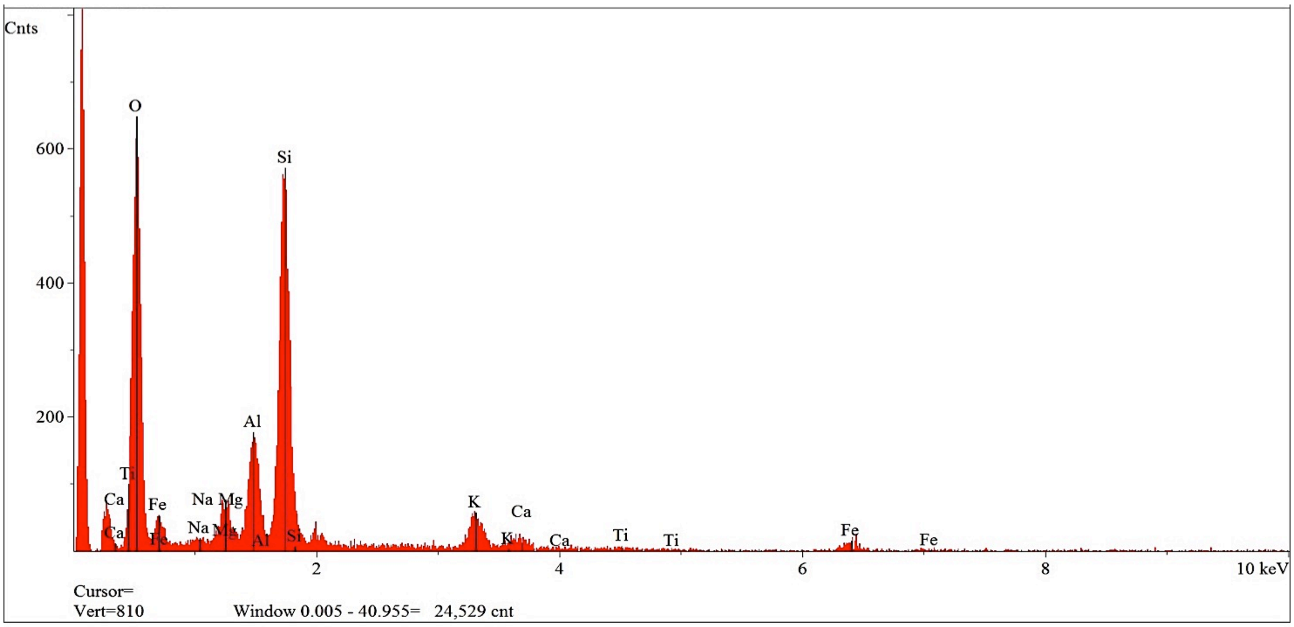


Similarly, the scanning electron microscope point analyses demonstrated the presence of a magnesium-aluminum phyllosilicate with high levels of potassium (Fig. B.2). Quantitative analyses of celadonite and glauconite from databases and publications

[10] A Second Edition Munsell Student Color Set was used in identifying hue, chroma, and value for these colorants. This is by no means a complete Munsell set, and color identification will always vary by person and in different lighting. The application of Munsell System here is simply meant to help clarify the color ranges.

closely correspond to the chemical composition of the sample. Though the samples were carbon-coated, higher than average levels of carbon suggest that an organic substance may have been mixed with the celadonite, but further testing will be necessary to confirm this possibility. Element mapping and imaging with backscattered electrons showed a relatively homogenous sample with one small instance of silver, a mineral from the amphibole group, and some clay inclusions. One instance of iron oxide was also found, and it could have been added to alter the color.

Figure B.2: SEM-EDS Spectra Data on La Tolita sample: Celadonite or Glauconite. Provided by Mike Spilde, University of New Mexico Earth and Planetary Sciences SEM Lab

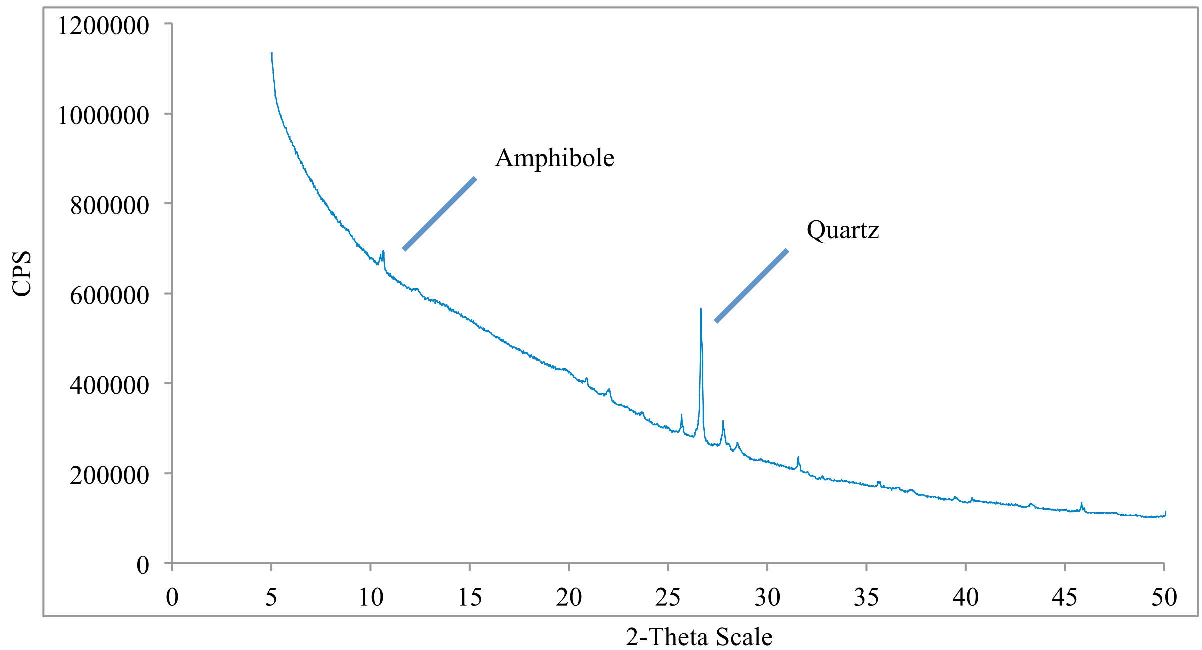


Together, the two tests indicated that the blue-green color originates from celadonite, but there is a distinct possibility that it may be the closely related glauconite mineral as well. Distinguishing between the two minerals requires more in-depth testing.

Reported equivalents of Munsell color hues for green earth range from 2G to 8G, values from 2.7 to 3.0, and chromas from 1.0 to 1.5 (Grissom 1974 145). The sample itself has a hue of 5BG, values ranging from 5-6, and a chroma of 4. These results range more towards the blue-green hue and are lighter in value with more saturation to the color, which may suggest the presence of other unidentified additives to alter the color. However, the recorded ranges offered by Grissom also seem rather low in value in comparison to some green earth samples. For example, both Armenian green earth purchased from Kama Pigments and an Ecuadorian celadonite sample obtained from the Fruta del Norte Deposit had lighter value ranges than those recorded when ground into a fine powder.

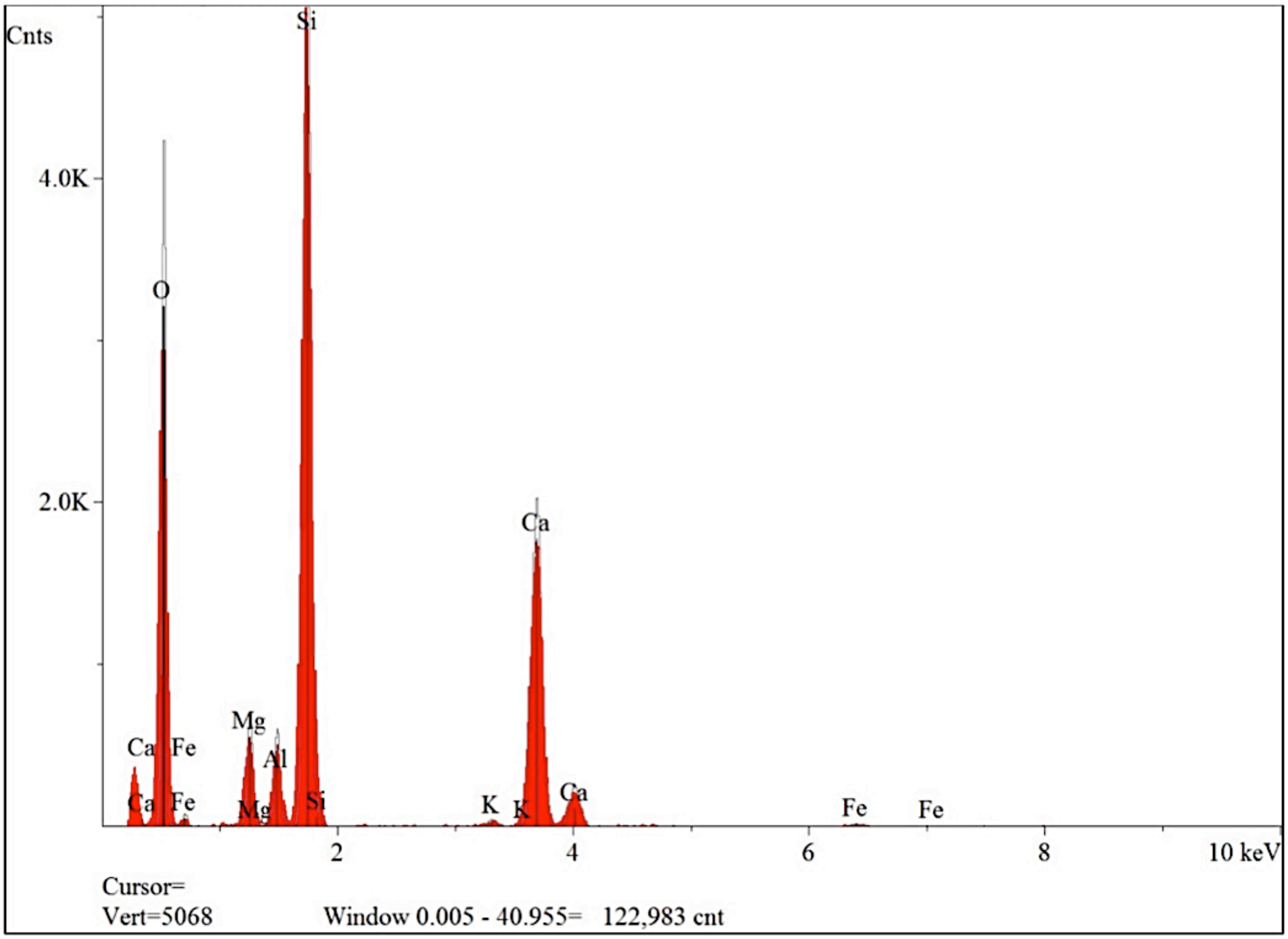
The XRPD and SEM-EDS data for the blue were inconclusive. The diffractogram demonstrates identifications of an amphibole, with its composition similar to the La Tolita sample without the celadonite and higher intensity of the peaks representing the amphibole group mineral (Fig. B.3). This sample also may contain antigorite and cordierite, but these minerals were not located with the scanning electron microscope.

Figure B.3: Diffractogram of Rio Mataje Sample. Provided by Eric Peterson, UNM XRD Lab.



On the SEM, feldspar and amphibole group minerals and clays were commonly found, as well as one instance of a mineral containing the rare earth metal cerium and one pyrite inclusion. Quantitative analyses show that the feldspar present may be albite, which is a common inclusion in both ancient pigments and clay pastes due to its solubility in water. The mineral from the amphibole group remains unidentified (Fig. B.4), but it could have some effect on the color, as a few amphiboles, like glaucophane, are historically known to be used in blue fresco paints. The closest Munsell equivalent to the Ecuadorian blue is a hue of B5, a value of 5, and a chroma of 8. The blue may originate from an unknown organic source, but further testing will be needed to confirm this possibility.

Figure B.4: SEM-EDS Spectra Data on Rio Mataje Sample Amphibole. Provided by Mike Spilde, UNM SEM Lab



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Figures

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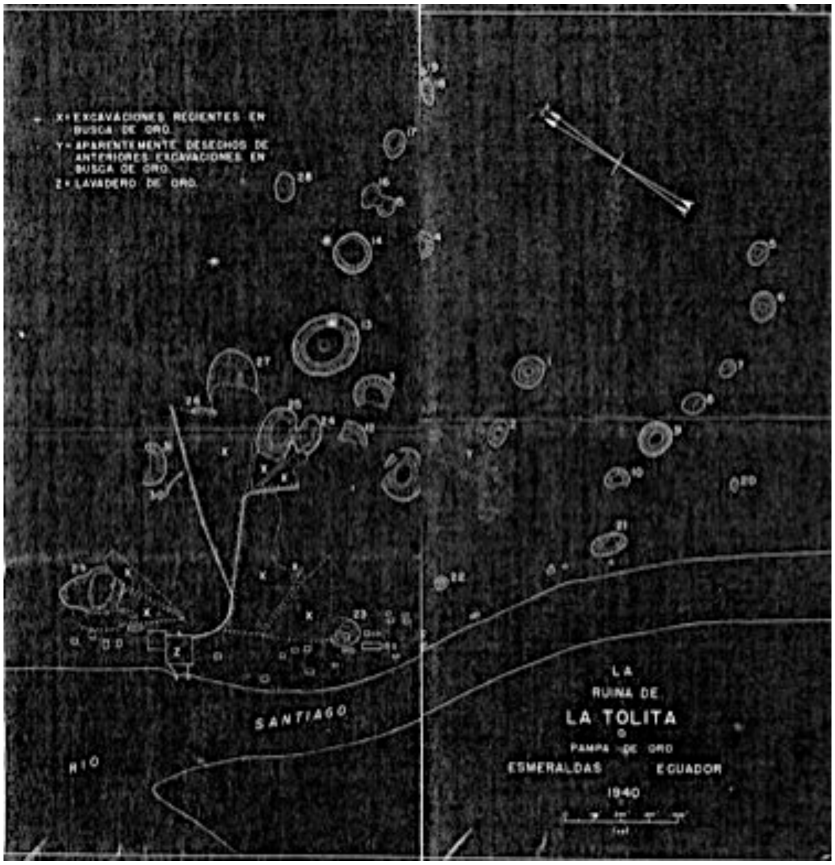

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Figure 12: Vessel-effigy, Ceramic, Teotihuacan. National Museum of Anthropology and History. Taken by Eduardo Matos Moctezuma, Teotihuacan: The Metropolis of the Gods (Barcelona: Lunwerg, 1990).

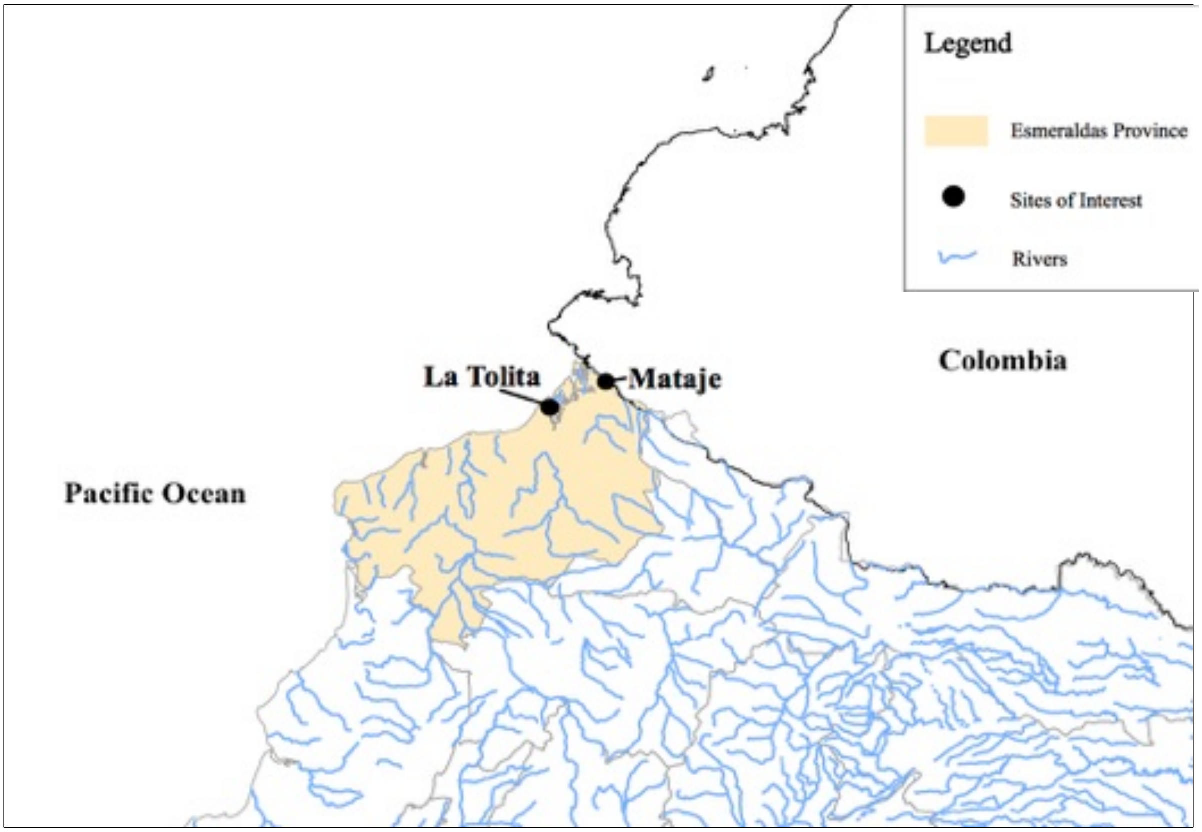

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Figure 15: Incised Sherd (with scale). Tolita-Tumaco. La Tolita Site. 600 BCE-400 CE. Ceramic with Red, Yellow, and Blue-green Post-fire Colorant. Height: 12.4 cm Catalogue No: 2006.111.117. Courtesy of the Maxwell Museum of Anthropology, University of New Mexico.

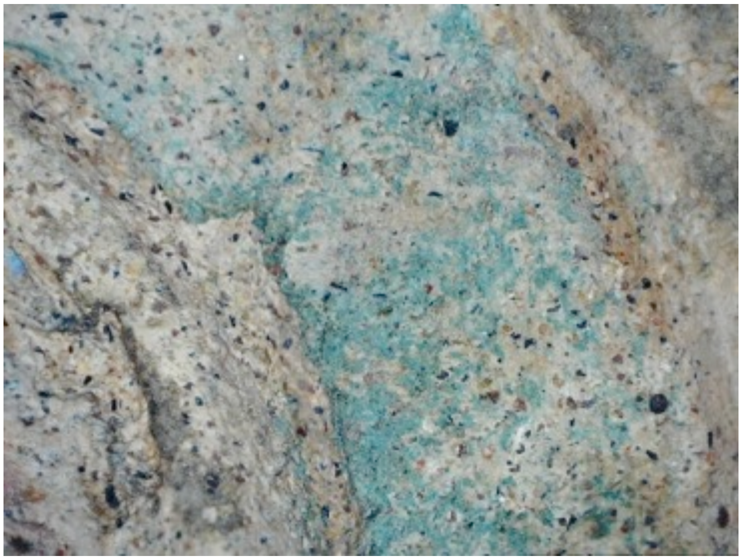

Figure 16: Digital Microscope Image of Incised Sherd, Tolita-Tumaco. La Tolita Site, Ceramic with Red, Yellow, and Blue-green Post-fire Colorant. Height: 12.4 cm. Catalogue No: 2006.111.117. Courtesy of the Maxwell Museum of Anthropology, University of New Mexico.

Figure 17: Musician Figurine on Platform. Jama-Coaque. 500 BCE-500 CE. Ceramic. Museo Casa Del Alabado, Quito, Ecuador. commons.wikimedia.org Uploaded: 16 March 2016

Figure 18: Figurine Head, Rio Mataje Site, Tolita-Tumaco Culture, 600 BCE-400 CE. Ceramic with Blue Post-Fire Paint. Catalogue No: 2006.56.49. Courtesy of the Maxwell Museum of Anthropology, University of New Mexico.

Figure 19: Figurine Head, Rio Mataje Site, Tolita-Tumaco Culture, Ceramic with Blue Post-Fire Paint. Catalogue No: 2006.56.49. Courtesy of the Maxwell Museum of Anthropology, University of New Mexico.

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Figure 21: Digital Microscope Image of Figurine Head, Rio Mataje Site, Tolita-Tumaco Culture, Ceramic with Blue Post-Fire Paint. Catalogue No: 2006.56.49. Courtesy of the Maxwell Museum of Anthropology, University of New Mexico.

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Figure 23: Piece of Feathered Serpents and Flowering Trees Mural, Teotihuacan, Painted Stucco. From *Teotihuacan: City of Water, City of Fire.* Robb, Matthew ed. 2017.

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Figure 25: Painted Adobe Brick with blue, red, and black pigments. From: *Pachacamac Conservación e Investigación*