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Assessing Mexican pottery paint recipes using particle-induced X-ray emission

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Abstract

Decorated pottery dating from the Epiclassic through Early Postclassic (*ca*. A.D. 650-1150) was selected for chemical characterisation of pottery slips and paints. Specimens include pottery types commonly occurring across the Basin of Mexico and Tula, Hidalgo. Recipes for slips and paints require training and first-hand knowledge of specialised techniques in production. A high degree of similarity of recipes across the region suggests widespread knowledge in the preparation and use of paint and slip. Distinct patterns in rare elements suggest differentiation in locally available pigments, and clays reflect regionally available sources of materials and differences in recipes. Particle-induced X-ray emission (PIXE) is a nondestructive method of identifying concentrations (in ppm) for 18 chemical elements. Data collection was conducted by the author using the Arizona State University (ASU) ion beam analysis of materials (IBeAM) laboratory. A sample of 136 pottery sherds was chosen and PIXE was conducted on red, black, white paints and slips. Specimens were chosen from a larger sample previously assessed for compositional characterisation of ceramic paste using instrumental neutron activation analysis (INAA). Results indicate that variation in red paints are high in iron-oxide and vary by pottery type. Black paint in Aztec I pottery is high in iron (Fe) and manganese (Mn), indicating a Fe-Mn paint recipe. Cream coloured slips vary by region and pottery type. PIXE characterisation identifies the chemical element concentrations contributing to the colourant pigments, the clay matrix in the binding materials, and trace indicators of localised impurities in clays and minerals contributing to paints and slips.

Introduction

This work presents the characterisation of pottery paints from Epiclassic (*ca*. A.D. 650-850) and Early Postclassic (*ca*. A.D. 850-1150) Central Mexico. Samples were selected from among specimens submitted for instrumental neutron activation analysis (INAA) for paste characterisation (Crider, 2011). Samples were selected from multiple areas of the Basin of Mexico and Tula, Hidalgo, in order to assess regional comparisons in paint recipe and identify shifts in recipe through time. Proton-induced X-ray emission (PIXE) was used to nondestructively characterise the chemical signatures of paint in multiple colours, including red, cream, black and orange.

This study integrates compositional and stylistic analyses to identify shifting regional trends in Epiclassic (*ca*. A.D. 650-850) and Early Postclassic (*ca*. A.D. 850-1150) Central Mexico following the political collapse of the Early Classic Teotihuacan state. The primary goal is to assess the degree of shared technological knowledge in pottery production (Herbich, 1987; Lechtman, 1977; Lemonnier, 1986). Pottery forms and decorative attributes are highly visible stylistic traits that are easily emulated and indicate cultural affiliation; whereas, technical attributes, such as recipe for slips and paints, are low visibility traits that require training and first hand knowledge of specialised techniques in production.

Paint and slip colours differ according to variation in mineral or organic constituents, presence of clay binding materials, technical variation in surface treatment, and firing conditions. Central Mexican Prehispanic pottery technology is consistent with mineral paints, low-fire temperatures [*e.g.* Aztec plain wares between 600-900°C (Garraty *et al.,* 2007)], and a mix of polish and matte surface treatments. The PIXE analysis provides evidence for the detection of spatially discernible microvariation in paint recipes among diagnostic pottery types in each of the cultural complexes. Spatially distinct patterns in pigment recipe reflect differential access to resources for production and local practices in recipe and technique. A high degree of similarity of recipe across the region reflects shared practices in production technology and a high degree of interaction among producers.

Materials and Methods

Samples were selected in order to represent subsequent time periods and decorated types. Each specimen was selected from large chips removed from the original vessel which were subsequently submitted for INAA at the Missouri University Research Reactor (MURR). In many cases, only small fragments were exported from Mexico, reducing the number of eligible samples to contain enough quality surface area for testing. Because INAA is a bulk technique and these samples were to be destroyed in preparation, PIXE was employed to gather additional chemical data prior to sample destruction.

The PIXE was conducted by the author at the

Arizona State University LeRoy Eyring Center for Solid State Science using the ion beam analysis of materials (IBeAM) facility (http://le-csss.asu.edu/ibeam), with training and consultation provided by Barry Wilkens. PIXE is sensitive to impurities in the ppm range for surface and near-surface (0-2 mm) analysis of solids (Feldman and Mayer, 1986; Gosser *et al.*, 1998) and requires no sample preparation. Proton beams were accelerated at both low (1.72 MeV) and high energy (2.89 MeV) using a 1.7 MV Tandetron accelerator (Cockroft-Walton type; General Ionex, Newburyport, MA, USA). The proton beam (1 x 1 mm) crosses a 7.8 μm kapton foil window before entering the chamber containing the

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sample. The chamber was placed under low vacuum to avoid air signal and absorption. Emitted X-rays were detected by a Si(Li) detector (169.8-184.8 eV at 5.9 KeV) placed at a 45° angle from the normal of the sample's surface; the detector has a 2.54 μm beryllium window with a 1.2 μm gold contact layer.

No additional filters were used in front of the detector at low energy (1.72 MeV) to analyse light elements. To control background noise while analyzing the heavy elements at high energy (2.89 MeV), foils of Mylar (300 μm) and vanadium (11 μm) were installed in front of the detector in order to magnify the sensitivity to trace elements by attenuating the signal of elements with atomic numbers lower than Fe. Two data points (one each for high and low energy) for each sample were irradiated for three to five min. The PIXE detector signals were processed with the GUPIX spectrum fitting software package (http://pixe.physics.uoguelph.ca/gupix/main/) and samples were compared with the Buffalo River standard. The low-energy spectra were used to obtain Na to Fe concentrations and the high-energy spectra were used to obtain concentrations of heavier elements. The elements measured in the PIXE analysis include: sodium (Na), magnesium (Mg), aluminium (Al), silicon (Si), phosphorus (P), sulphur (S), chlorine (Cl), potassium (K), calcium (Ca), titanium (Ti), iron (Fe), chromium (Cr), manganese (Mn), zinc (Zn), arsenic (As), rubidium (Rb), strontium (Sr), and zirconium (Zr). However, not all elements achieved the limit of detection (LOD), only those exceeding 2x the LOD are included for the analysis. Extreme outliers were removed as possible indication of errors in data acquisition.

Prior to statistical analysis, all element concentrations (ppm) were Log_{10} transformed. Major, minor, and trace element concentrations can differ by several orders of magnitude and log transformed data reduces the effect of excessive weight on major elements in multivariate statistical analyses (Glascock, 1992; Neff and Glowacki, 2002). The resulting PIXE data was assessed by pottery type and INAA compositional group. Specimens were previously assigned to INAA compositional groups determined for the regional areas within the Basins of Mexico (*e.g.* Northwestern, Northeastern, Southeastern, and Western Basins). INAA compositional groups were identified by the author implementing a combination of multivariate statistical techniques described elsewhere (Crider, 2011; Neff, 2000; Neff and Glascock, 1998).

Results and Discussion

The means of concentration for each element provides univariate comparison for the
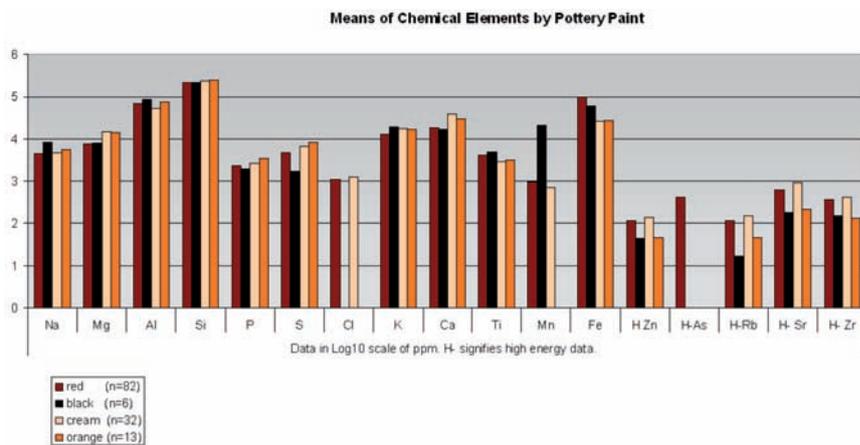
Figure 1. Comparison of means of chemical element by paint or slip colour. Red and black are paint colours, while cream and orange are slips. Concentrations are log_{10} transformed (scale in ppm). H-, high energy data.
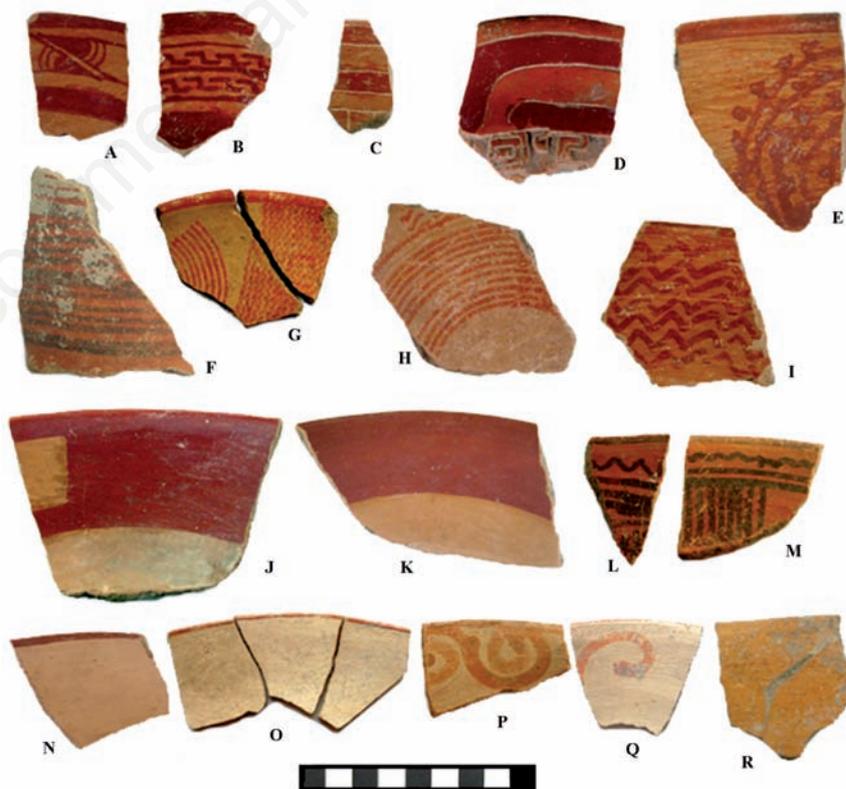
Figure 2. Selection of pottery types used for particle-induced X-ray emission analysis of paints and slips: A-B) Coyotlatelco red-on-natural; C) Zone Incised red-on-natural; D) Tezonchichilco red-on-natural; E) Sloppy red-on-natural; F) Ink Stamp; G-H) Wavy Line matte variant with multi-prong brush; I) Wavy Line burnished variant with single brush; J-K) Macana red-on-natural; L-M) Aztec I black-on-orange; N-O) Proa cream slip; P-Q) Joroba cream slip; R) Jara Pulido cream slip. Scale in cm; photographs all by Author.

general trends across the paint and slip colours (Figure 1). This comparison includes all pottery types for both the Epiclassic and Early Postclassic periods (Figure 2). For all colours, Al and Si have the highest concentrations, as is expected for clay and mineral composition. It is the heavier elements that most contributing to pigment colour that are of interest for comparison among paint and slip colours, these include Ca, Ti, Mn and Fe. Other lighter elements, collected in the high-energy beam, are highly variable among paints and slips and may contribute to the identification of regional patterns in trace elements present in the clay and minerals. Each paint colour is discussed in sequence.

Red paint is highest in Fe which is consistent with colourant from iron oxides (*e.g.* hematite, limonite, magnetite, ilmenite). Hematite, the prominent mineral mixed with clay in red ochre is an abundant and easily obtainable mineral in Mexico. Ochres occur as a product of metamorphism in crystalline schist and can carry impurities of calcium and magnesium carbonates, aluminum hydroxide, manganese compounds and phosphates. Ochre formed from spring deposits can include traces of copper (Cu), arsenic (As), nickel (Ni) and cobalt (Co) (Shepard, 1956). Another possible contributor to red pigment, ilmenite, is a titanium oxide similar in structure to hematite with parts of Mg and Mn. Overall, the red paints in this study indicates presence of several expected impurities including As, which is only identified above the level of detection in a subset of samples with red paint (n=27) and is expressed with a high variance among samples.

Red paint occurs on several pottery types assessed in this study for the Epiclassic period (Coyotlatelco, Tezonchichilco, Zone Incised) and the Early Postclassic period (Macana, Ink Stamp, Sloppy, and Wavy Line) (Table 1). The red painted pottery comprises the largest sample of the study, 88 specimens. Fe, as the element with the highest concentrations within the red paints, also has a low variance among the pottery types. A comparison of means among pottery types with red paint indicates a range from $\log_{10}$ concentration of Fe from 4.6 to 5.0. Wavy Line pottery has the lowest amounts of Fe in the red, which is significant due to the qualitative difference of the paint as compared to other decorated type. Wavy Line pottery was decorated with the use of a multi-prong paint brush that applied 10 to 15 thin lines at once in a panel of waves and rainbow motifs. The paint recipe for this type of pottery produced a thin paint, a consistency much like modern ink, that spreads evenly and in narrow lines. The lower concentrations of Fe in this paint may be due to the dilution of the pigment into paint with a more watery or thinner consistency than the other pottery types in this study. The paint on Wavy Line pottery does not have spec-

ular hematite and the vessel surfaces are matte finished with little evidence for burnish or polish. The paint tends to be a reddish-orange colour. Ink Stamp pottery also has a matte finish, no specular hematite, and has a similarly low concentration of Fe to Wavy Line.

There is one exception to the Wavy Line pattern, which is notable for a variant of the type that is an emulation of the typical Wavy Line pottery. This emulated variant does not have the multi-prong brush, tends to be burnished, and has a paint more similar to the Coyotlatelco pottery. This variant is expressed in Table 1 as Wavy Line-Texcoco, indicating that this compositional source zone for these samples was assigned to the central area of Texcoco in the eastern portion of the Basin of Mexico. These specimens have a somewhat higher means of Fe than the other Wavy Line pottery; this likely reflects the differing technological production methods of this variant from the other Wavy Line pottery.

Conversely, the three pottery types with the highest concentrations of Fe (ranging from $\log_{10}$ concentrations of 5.0 to 5.1) occur on Coyotlatelco, Macana, and Zone Incised pottery. These pottery types are qualitatively similar in the use of red paint: the paint is thickly applied, tends to contain specular hematite, the surface is well polished to a glossy shine. The paint tends to be a dark red to purplish-red colour. Shepard (1956) noted that the mechanical action of polishing rubs the pigment granules into the clay surface rendering some pigments more permanent than without burnish. The combination of the thicker paint consistency, resulting in less dilution of the pigment, and the mechanical action of burnishing on these pottery types resulted in the higher concentration of Fe in the resulting paint recipe as compared to the Wavy Line pottery.

Mn can be another significant contributor to red paint and higher concentrations can lend a brownish tint to the colour. In comparing the means of Mn across pottery types in this study (overall means ranging from $\log_{10}$ concentrations of 2.9 to 3.0), there is a vary low variance (0.04) indicating that this element is not differentiating paint recipes for the red paint. A selection of other elements is reported here, but most do not significantly contribute to pigmentation or colourant. Shepard (1956) notes that *the clay that occurs as an impurity acts as a binder. Mechanical effects resulting from polishing, particularly compacting and rubbing the pigment into pores increases their resistance to abrasion.* The lighter elements that occur in trace amounts (such as As, Sr, Zr) likely signify local impurities in the minerals used for pigments and paints.

Cream coloured slips are most common in the Early Postclassic pottery in this sample and occur on three pottery types: Joroba, Proa, and Jara Pulido (Table 2). A total of 45 specimens

of cream slip pottery were assessed for slip characterisation. In Figure 1, Joroba and Proa make up the cream category and Jara Pulido is the orange. Visual inspection of the slips reveals a great variation in colour shades from beige and pinkish slips towards lighter cream towards a white colour. Shepard (1956) identifies a set of paints that are mixed with clay, which act as binding agents. For the cream slips here, calcium carbonate is a likely component to the recipe, which is present in varying proportions in materials such as marlstone (lime-rich mud) to more pure limestone. The cream slips in this study are distinct in slightly higher amounts of Ca and Mg (Figure 1), as well as somewhat higher means of elements such as scandium (Sc), Cr, Zn, Rb, Sr and Zr.

There is a chronological difference between these cream slip pottery types (Cobean, 1978), with Joroba being produced in the earlier part of the Early Postclassic and Proa more common in the later Tollan phase of Tula. Both types at Tula are characterised by a thick cream-white slip covering bowl interiors and exteriors. The surfaces are well-smoothed to polished. Both have a painted red rim. The earlier Joroba is identified mainly by a broad brush decoration of spirals and parallel lines. Proa does not typically have painted designs. Jara Pulido is the latest of the Early Postclassic types, in which a thin coat of red or orange paint is placed over a cream base slip. The thin layer of orange does not significantly change the overall paint recipe, especially the heavier elements. Some variation in the lighter, high-energy trace elements is detectable between the orange paint and other cream slip types.

Visual comparison of Tula and Basin produced variants of these types reveals that Basin produced bowls vary in quality and thickness of slip. Although a thick whitish-cream slip does occur in the Basin, the majority are thinner slipped than Tula versions, and the Basin bowls often tend towards a pinkish tint. Comparison of Fe levels (an indicator of reddish iron oxide) supports this observation (Figure 3), as Basin produced bowls higher in this element.

Calcium may be an indicator for calcium carbonate, a major constituent in white clay slips (Figure 3). The means of Ca for Joroba between Chalco and Tula source groups are similar to one another, suggesting broad regional similarity. However, Proa Ca amounts indicate a very big change in Tula recipes for slips. Tula Proa production appears to have increased relative amounts of Ca to slip mixture. Corresponding production of Proa in the Basin indicates no significant change in Ca amounts. This may reflect continuity in Basin production of slips, while Tula potters, likely specialised workshop production, shifted some major components within the slip mix.

The Tula produced Proa are high in quality

Table 1. Comparison of means (log$_{10}$ of ppm concentration) by element for red paint on Epiclassic and Early Postclassic pottery. Pottery groups organised by type and instrumental neutron activation analysis compositional source zone assignment.

Pottery	Basin source zone	Pigment				Other elements								Rare or trace elements				
		Fe	Mn	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Zn	As	Rb	Sr	Zr
Epiclassic																		
Tezonchichilco	Southeast: Chalco	4.84	2.99	3.73	3.78	4.75	5.25	3.43	3.82	2.80	4.03	4.29	3.59	1.49	-	1.11	2.34	2.11
Zone Incised	Southeast: Chalco	5.15	2.89	3.83	3.89	4.85	5.32	3.36	3.70	3.17	4.03	4.33	3.62	1.65	-	-	2.34	2.02
Coyotlatelco	Southeast: Chalco	4.99	-	3.69	3.99	4.90	5.45	3.51	3.45	-	3.96	4.35	3.67	1.22	-	-	2.03	1.79
	Southeast: Xico	4.96	-	3.94	3.92	4.89	5.35	3.38	3.15	-	4.11	4.09	3.66	1.25	-	1.25	1.82	1.69
	Southeast: CPZ	5.04	2.91	3.64	3.77	4.84	5.36	3.27	3.49	-	3.93	4.23	3.65	1.72	-	-	2.60	2.46
	Northeast: Teotihuacan	4.99	3.10	3.58	3.84	4.90	5.41	3.33	3.53	-	4.10	4.01	3.57	1.63	1.33	-	2.31	2.14
	Overall	5.00	2.98	3.69	3.86	4.88	5.39	3.40	3.45	-	4.04	4.14	3.63	1.52	1.33	1.25	2.25	2.09
Early Postclassic																		
Wavy Line	East: Texcoco	4.86	-	3.34	3.70	4.65	5.19		4.15	-	3.99	4.48	3.57	2.48	-	-	2.99	2.41
	Northeast: Teotihuacan	4.78	2.86	3.53	3.68	4.84	5.35	3.40	2.90	-	4.20	4.11	3.57	2.05	1.77	2.15	2.84	2.50
	Northwest: Tula	4.79	3.02	3.71	3.75	4.86	5.37	3.13	3.63	-	4.12	4.25	3.66	2.07	1.91	2.08	3.03	2.69
	Northwest: Zumpango	4.66	2.77	3.68	3.82	4.80	5.33	3.07	3.17	-	4.28	4.19	3.58	2.01	2.32	2.24	2.94	2.74
	Overall	4.76	2.90	3.62	3.76	4.82	5.33	3.29	3.41	-	4.15	4.22	3.61	2.09	1.94	2.13	2.93	2.59
Ink Stamp	Northwest: Group X	4.71	2.98	3.52	3.89	4.94	5.30	3.24	3.06	-	4.19	4.29	3.73	2.17	2.40	2.21	2.92	2.60
Sloppy RN	East: Texcoco	5.04	3.22	3.37	3.81	4.65	5.11	3.38	3.48	-	3.89	4.14	3.47	2.28	2.87	2.11	2.58	2.56
	Northeast: Teotihuacan	4.87	2.86	3.70	4.05	4.92	5.41	3.43	2.98	-	4.33	4.32	3.63	2.25	2.65	2.08	2.89	2.59
	Western Basin	4.63	2.77	3.68	3.65	4.82	5.28	-	3.02	-	3.82	4.20	3.67	2.21	-	-	3.07	2.82
	Overall	4.87	2.90	3.58	3.92	4.78	5.27	3.35	3.24	-	4.11	4.24	3.58	2.27	2.71	2.16	2.82	2.61
Macana	Southern Basin	4.89	3.06	3.64	3.68	4.84	5.30	3.65	2.97	-	4.17	4.17	3.62	2.13	1.78	-	2.93	2.61
	East: Texcoco	5.01	2.85	3.39	3.61	4.61	5.17	3.22	3.66	-	4.12	4.30	3.52	1.98	-	-	2.81	2.50
	Southeast: CPZ	4.87	2.87	3.55	4.07	4.70	5.28	3.39	3.65	-	4.02	4.37	3.50	2.09	2.02	2.20	2.90	2.52
	Northeast: Teotihuacan	4.98	2.85	3.56	3.94	4.89	5.37	3.28	2.92	3.10	4.19	4.20	3.64	1.68	3.07	1.66	2.27	2.16
	Northwest: Tula	5.12	2.88	3.54	3.79	4.78	5.27	3.31	3.38	2.73	4.01	4.28	3.58	2.14	2.40	-	2.92	2.68
	Western Basin	5.02	2.72	3.50	3.82	4.80	5.28	3.16	3.50	-	3.93	4.21	3.68	2.06	2.62	2.07	2.83	2.74
	Overall	5.02	2.89	3.54	3.84	4.79	5.29	3.29	3.36	2.92	4.07	4.25	3.60	1.99	2.41	1.90	2.74	2.52
Red/Cream slip	Northwest: Tula	4.90	2.81	3.71	3.93	4.82	5.37	-	3.76	3.11	4.16	4.34	3.43	1.91	2.69	2.34	2.70	2.17
Polychrome	Southeast: Chalco	5.14	3.05	3.59	3.82	4.87	5.29	3.67	2.95	-	3.85	4.24	3.65	1.21	-	-	2.05	1.67

Fe, iron; Mn, manganese; Na, sodium; Mg, magnesium; Al, aluminium; Si, silicon; P, phosphorus; S, sulphur; Cl, chlorine; K, potassium; Ca, calcium; Ti, titanium; Zn, zinc; As, arsenic; Rb, rubidium; Sr, strontium; Zr, zirconium; CPZ, Cerro Portezuelo.

Table 2. Comparison of means (log$_{10}$ of ppm concentration) by element for cream slips on Early Postclassic pottery. Pottery groups organised by type and instrumental neutron activation analysis compositional source zone assignment.

Pottery	Basin source zone	Pigment			Other elements									Rare or trace elements			
		Fe	Mn	Ca	Na	Mg	Al	Si	P	S	Cl	K	Ti	Zn	Rb	Sr	Zr
Joroba	Southeast: Chalco	4.4	2.7	4.3	3.8	3.9	4.8	5.3	-	4.2	-	4.1	3.4	2.1	2.2	2.8	2.7
	Northwest: Tula	4.3	3.0	4.5	3.6	4.2	5.2	5.4	3.3	3.8	3.3	4.2	3.3	1.7	1.3	2.7	2.3
	Southern Basin	4.4	-	4.9	3.9	4.0	4.8	5.2	2.9	4.0	3.1	3.9	3.5	2.0	-	3.1	2.7
Proa	Southeast: Chalco	4.4	2.8	4.2	3.5	4.1	5.0	5.4	3.6	3.2	3.1	4.1	3.5	2.1	2.2	2.8	2.7
	Northeast: Teotihuacan	4.4	2.8	4.3	3.4	4.2	4.8	5.4	3.5	3.1	3.1	4.3	3.5	1.5	-	2.2	1.9
	Northwest: Tula	4.3	2.9	4.8	3.6	4.2	4.8	5.4	3.4	3.6	3.1	4.3	3.3	2.1	2.2	3.2	2.7
	East: Texcoco	4.5	2.8	4.7	4.1	4.4	4.9	5.4	3.2	2.9	-	4.2	3.5	1.9	-	2.9	-
Jara Pulido	Southeast: Chalco	4.5	2.9	4.4	3.5	3.8	4.8	5.2	3.2	3.2	2.9	4.1	3.6	1.9	2.0	2.5	2.5
	Southern Basin	4.6	2.9	4.4	3.7	4.1	4.9	5.4	-	-	-	4.1	3.7	1.7	1.3	2.4	2.3
	Western Basin	4.4	-	4.6	4.5	4.0	4.9	5.2	-	4.6	-	4.0	3.6	2.4	-	2.8	2.7
	Northwest: Tula	4.6	2.8	4.6	3.6	4.1	4.9	5.7	3.2	3.5	3.5	4.3	3.6	2.4	2.3	3.0	2.6

Fe, iron; Mn, manganese; Ca, calcium; Na, sodium; Mg, magnesium; Al, aluminium; Si, silicon; P, phosphorus; S, sulphur; Cl, chlorine; K, potassium; Ti, titanium; Zn, zinc; Rb, rubidium; Sr, strontium; Zr, zirconium.
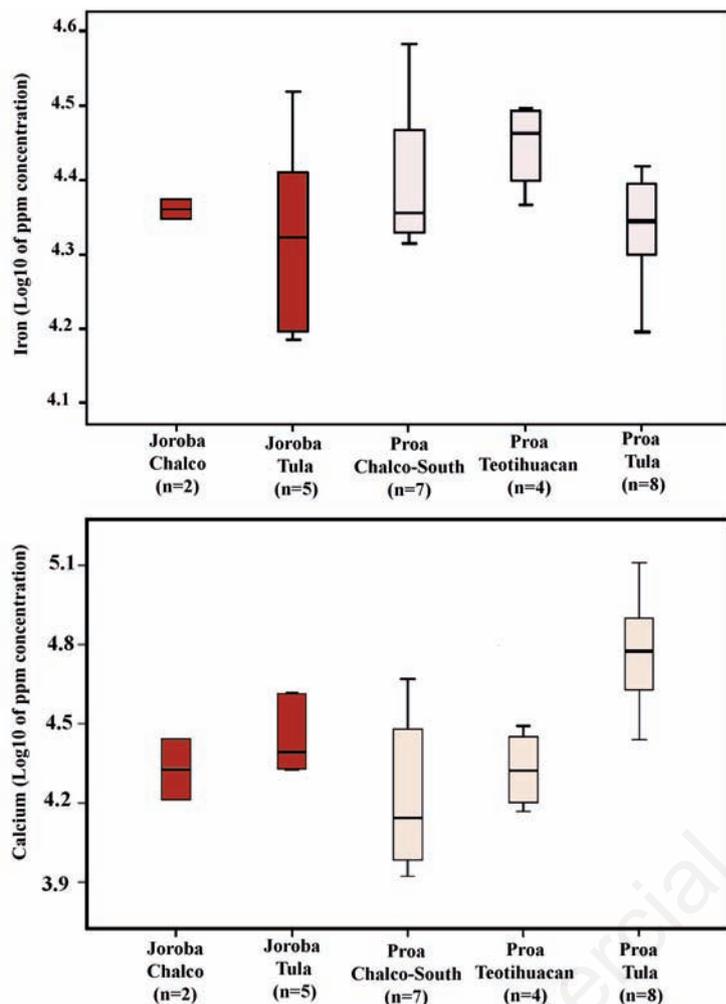
Figure 3. Box and whisker graphs comparing Joroba and Proa element concentrations. Groups are organised by pottery type and instrumental neutron activation analysis compositional source zone. Graphs show iron and calcium concentrations (log₁₀ ppm).

of thickness of slip, consistency of colour, and well finished surface treatments. This suggests a demand for good quality serving ware around the Tula centre. Basin versions of these two types are far more variable in these qualities, indicating a range of training and emphasis on standard quality, especially in the southern Basin. This may also reflect a conservation of resources used to produce a thinner cream slip.

Black paint is also high in Fe. Shepard (1956) details two differing methods of achieving a black mineral paint in pre-wheel potting traditions: i) black Fe oxide paint is achieved using magnetite or hematite in controlled firing conditions, errors of which can produce a reddish colour rather than black; ii) Mn and iron-manganese paints, which tend to retain their black colour. The samples here are significantly high in Mn compared to the other paints (Figure 1). Fe is also well represented. These trends indicate that for most of the sam-

ples, the black paint is likely an Fe-Mn paint. The specimens tested here are Aztec I Black-on-orange pottery (n=4) from the latter part of the Early Postclassic period and two specimens of other pottery types. This small sample size was used as a pilot test for characterizing black mineral paints in Central Mexico.

Conclusions

This work highlights some of the trends evident in the chemical analysis of pottery paints and slips from Central Mexico. PIXE provides a non-destructive and effective method for identifying trends in paint and slip recipes when combined with INAA source groups and technological attributes. PIXE characterisation identifies not only the elements contributing to the colourant pigments, but also particles present in clay matrix binding materials, and

trace indicators of localised impurities in the clays and minerals contributing to the paint.

This exploratory research complements previous PIXE studies on red paints from Epiclassic and Early Postclassic pottery from Teotihuacan (Ontalba Salamanca *et al.*, 2000). Other PIXE pigment studies confirm the use of red hematite in low-fire, oxidizing atmosphere are common in Southwest Salado paints, and differing methods of acquiring a black paint occur in Arizona (Simon, 1996; Simon *et al.*, 1997; Gosser *et al.*, 1998). Although not part of this study, XRD is often used to confirm the identification of mineral components in paints and clays (Ruvalcaba-Sil, 1999). However, time and funding limitations prevented completion of XRD at this time, but are considered for future assessment.

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