



Pottery production in a limestone-poor region of the Maya lowlands: Thin section petrography and scanning electron microscopy-energy dispersive spectrometry (SEM-EDS) analysis on pottery from Uxbenká, southern Belize

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ABSTRACT

We use thin section petrography and SEM-EDS to analyze fabrics, slips, and paints on ceramics from the Classic Period Maya center of Uxbenká located in the Toledo District of southern Belize. Pottery produced in southern Belize differs from other regions of the Maya lowlands due to the underlying bedrock composed of interbedded calcareous sandstones and siltstone rather than limestone. Our analyses indicate that Late to Terminal Classic (c. CE 600-900) pottery at Uxbenká was produced in five primary fabric groups using locally available raw materials. The composition of red slips is indistinguishable from the associated ceramic fabrics. White and orange slips on polychrome vessels are composed of very fine calcareous sandstone rather than micritic limestone used in other regions. Pottery production changed over time from the Early Classic (c. AD 250/300-600) to the Late Classic Period when crystalline calcite temper was used less frequently. This is the first study to analyze pottery from southern Belize using petrography and SEM-EDS. These data provide information on pottery production practice at Uxbenká where potters did not have access to limestone derived raw materials and will aid in evaluating social and economic interactions between southern Belize and other regions of the Maya lowlands.

1. Introduction

Most of the Maya lowlands is underlain by marine limestones and pottery produced in these areas is primarily composed of calcareous clays and added carbonate temper. Regions that lack limestone bedrock, such as the Maya Mountains and their foothills (Bateson and Hall, 1977; Dixon, 1956; Kesler et al., 1974; Ower, 1928; Schafhauser et al., 2003; Shipley, 1978), supported numerous ancient Maya communities that produced pottery using locally available raw materials. Pottery produced in these regions is compositionally distinct due to the different geology, but microscopic and/or chemical studies of the pottery are limited (e.g. Hammond et al., 1976). This paper focuses on pottery produced at Uxbenká which is located atop interbedded calcareous sandstones and siltstones with limited limestone outcrops of the Toledo Beds (Sepur Formation) in the foothills of the Maya Mountains in southern Belize. We use thin section petrography and scanning electron microscopy-energy dispersive spectrometry (SEM-EDS) to evaluate resource acquisition and pottery production during the Late to Terminal Classic Period (CE 600-900). A small sample of Early Classic pottery (CE

250/300-600) was also analyzed to determine if pottery production practice changed over time at Uxbenká.

Unslipped, monochrome red, and polychrome vessels produced locally at Uxbenká were stylistically similar to vessels produced in limestone-rich regions of the Maya lowlands. However, the availability of different raw materials required different production and decorative techniques that are unique to southern Belize. Like in other regions, potters procured raw materials from nearby and made specific decisions about which clays and tempers to use based on the functional requirements of the vessels. Local Late to Terminal Classic vessels were produced in largely the same way but with slight variations. These variations likely represent differences in the location of raw materials and/or firing regime suggesting that multiple groups of potters may have been responsible for pottery production at Uxbenká. Data collected on surface treatment provides the best evidence for differences in production practice between southern Belize and other regions. Potters used the same iron-rich clays to construct and slip monochrome Remate Red vessels. Slips were produced without refining the clay or adding iron to produce a darker red color resulting in an outwardly similar, but

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not quite as striking, appearance to monochrome vessels produced in other regions. In the absence of fine calcium carbonate to produce white slips on polychrome vessels, the white slip on local Zacatel Cream polychromes was created using locally sourced very fine calcareous sandstone. Similarly, calcareous sandstone mixed with an iron-rich clay was used to create orange slips on local Saxche-Palmar and Palmar Orange polychromes. These data facilitate regional comparisons and promote a broader understanding of human environmental relationships in resource acquisition and craft production in the Maya lowlands.

2. Background

2.1. Uxbenká

Uxbenká is medium-sized polity located in the Toledo District of southern Belize largely within the boundary of the modern Mopan speaking community of Santa Cruz (Fig. 1). The first public architecture was established towards the end of the Late Preclassic Period (c. CE 250) and Uxbenká declined around the beginning of the Terminal Classic Period after CE 800 (Aquino et al., 2013; Culleton et al., 2012; Moyes et al., 2016; Prufer et al., 2011, 2017a,b). Uxbenká reached its geographic apogee during the Late Classic Period (AD 600–800) although its monumental investment in public spaces in the built environment and landscape modification may have been earlier, peaking before AD 500 (Prufer et al., 2017a,b). Compelling data suggest that the Uxbenká locale was a culturally important region occupied since the Paleoindian period (Prufer et al., 2017a,b, 2019). For this study, we confine our discussion to periods clearly defined by ceramic and architectural histories of the Classic Period polity. The Uxbenká site core consists of 9 groups of monumental architecture situated on modified

hilltops. Using a combination of pedestrian survey and remotely-sensed lidar, the Uxbenká Archaeological Project (UAP) has identified 136 Settlement Groups (SGs) of varying sizes and architectural complexity (Prufer et al., 2011, 2015, 2017a,b; Thompson et al., 2018; Thompson, 2020). A settlement group (SG) is roughly synonymous with household as defined elsewhere in the Maya Lowlands (e.g. Ashmore and Wilk, 1988); however, at Uxbenká structures are not always formally arranged around a plaza due to constraints of the local geography which consists of long narrow ridgelines and hilltops. We identified at least three settlement groups (SG38, SG52, SG54; Fig. 2) that participated in Late Classic pottery production based on the co-occurrence of multiple lines of evidence: the presence of ceramic and stone tools used in pottery production, abundance of finished products, and the spatial location of these settlement groups (Jordan and Prufer, 2017).

2.2. Geologic setting

Southern Belize is located in the Belize Basin and, together with the Petén Basin, “form the southern edge of the Maya Block and the southernmost part of the North American Plate” (Schafhauser et al., 2003: 625). The collision of the North American Plate and the Caribbean Plate (located to the south on the opposite side of the Motagua Fault) created a large foreland basin that subsequently infilled with clastic material deriving from the Maya Mountains, Motagua Fault System, and Cretaceous marine limestones. Uxbenká is located atop the Tertiary Toledo formation (Sepur formation in Guatemala) composed of the clastic materials that accumulated in the foreland shallow marine basin. The Toledo formation is composed of interbedded mudstones, sandstones, and conglomerates. To the south, in an area known locally as the “Rock Patch”, there is a 250 m high karst composed of Cretaceous

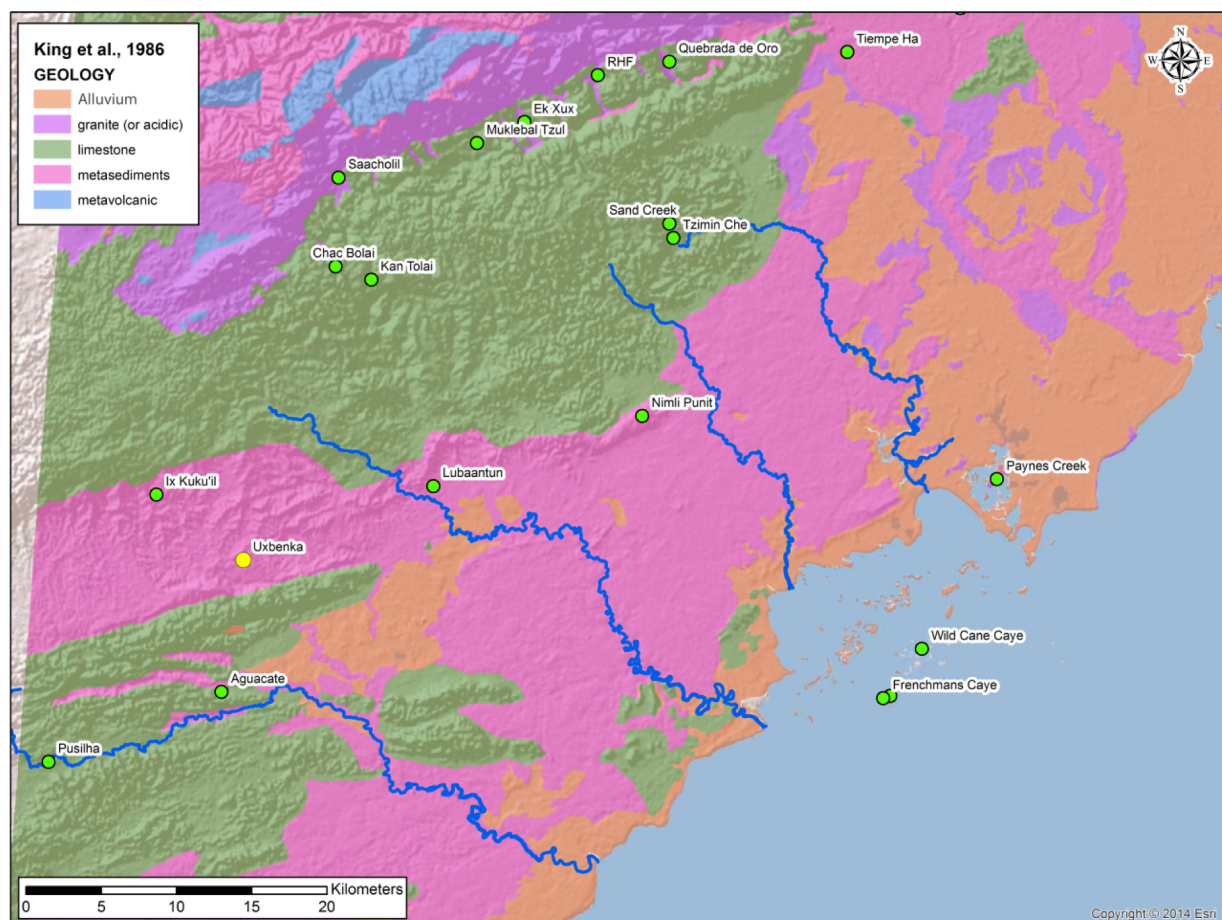


Fig. 1. Archaeological Sites and Geologic Formations of the Southern Belize Region (Map by A. E. Thompson after King et al. 1986).

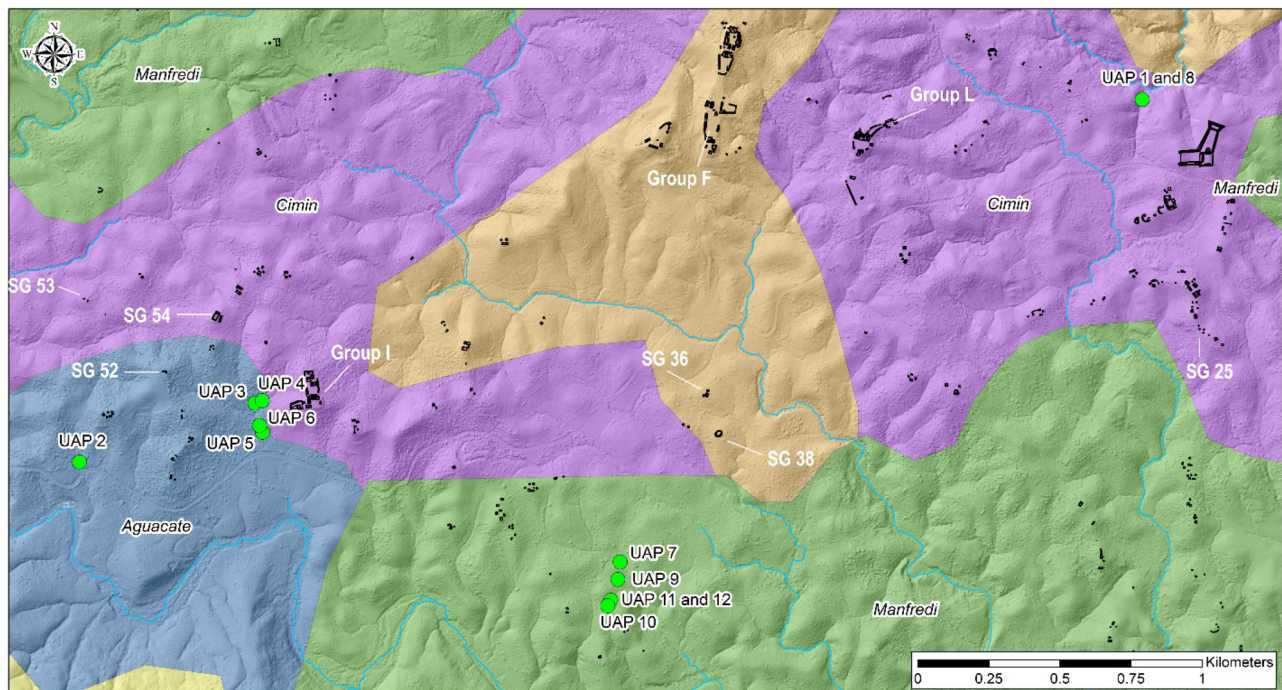


Fig. 2. The Soils around Uxbenká Showing the Location of Geologic Samples. Each color denotes a different soil subseries. The yellow represents soil on steep slopes not classified as a specific soil series (Map by A.E. Thompson *after* Wright et al. 1959). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

limestone of the La Cumbre formation. Cretaceous limestones also outcrop disconformably within the Toledo formation.

The soils of Belize are classified based on underlying parent material (King et al., 1986; Baillie et al., 1993; Wright et al., 1959). In general, soils in southern Belize are divided into lime-rich (soils that formed on limestone parent material) and lime-poor groups (soils that formed on non-limestone parent material) (Hammond, 1975: 18; Wright et al., 1959). Uxbenká is located atop comparatively lime-poor soils of the

Toledo suite although they do contain carbonate from the underlying calcareous sandstone. The soils located atop the Toledo Beds fall into two primary subsuites (Fig. 2). Cimin soils are grey to brown, relatively shallow, well-drained soils that grade into weathered mudstone and other clastic bedrock sediments (Baillie et al., 1993:21). Aguacate and Manfredi soils are sandy, well-developed, rubified, and have a higher clay content than Cimin soils (Baillie et al., 1993:21; Wright et al., 1959:78). The inhabitants of the modern Maya village of Santa Cruz,

Table 1
Context and descriptions of pottery sampled from primary contexts.

	Fabric group	Provenance	Ceramic group	Vessel form	Context	Vessel Number	Munsell Margin	Munsell Core
1	Sandstone A1	Local	Saxche-Palmar Orange	Bowl	Tomb L2	Vessel 19	2.5YR-5/8	None
2	Sandstone A1	Local	Palmar Orange	Vase	Tomb L2	Vessel 30	2.5YR-4/8	None
3	Sandstone A	Local	Zacatel Cream	Tripod Plate	Tomb L2	Vessel 15	2.5YR-4/8	2.5YR-4/3
4	Quartz A	Local	Zacatel Cream	Vase	Tomb L2	Vessel 6	2.5YR-5/8	None
5	Quartz A	Local	Zacatel Cream	Bowl	Tomb L2	Vessel 13	2.5YR-5/8	5YR-3/2
6	Calcite B	Non-Local	Saxche-Palmar Orange	Bowl	Tomb L2	Vessel 21	5YR-5/8	5YR-2.5/1
7	Volcanic Glass A	Non-Local	Saxche-Palmar Orange	Bowl	Tomb L2	Vessel 28	5YR-6/8	None
8	Quartz A	Local	Palmar Orange	Dish/Plate	Tomb L2	Vessel 12	2.5YR-5/8	5YR-4/1
9	Sandstone A2	Local	Zacatel Cream	Tripod Plate	Tomb L2	Vessel 1	2.5YR-4/8	5YR-5/2
10	Quartz A	Local	Remate Red	Vase	Tomb L2	Vessel 23	2.5YR-4/8	5YR-4/2
11	Quartz A	Local	Saxche-Palmar Orange	Bowl	Tomb L2	Vessel 17	2.5YR-4/8	5YR-3/1
12	Sandstone A	Local	Santa Cruz Red	Bowl	Tomb L2	Vessel 5	5YR-5/8	None
13	Quartz A	Local	Saxche-Palmar Orange	Bowl	Tomb L2	Vessel 8	2.5YR-5/8	None
14	Sandstone A	Local	Zacatel Cream	Tripod Plate	Tomb L2	Vessel 2	2.5YR-5/8	5YR-5/1
15	Sandstone B	Local	Remate Red?	Bowl	Tomb L2	Vessel 27	2.5YR-5/8	None
16	Quartz A	Local	Remate Red	Bowl	Tomb L2	Vessel 7	2.5YR-5/8	5YR-4/2
17	Quartz A	Local	Zacatel Cream	Vase	Tomb L2	Vessel 9	5YR-5/8	None
18	Sandstone A2	Local	Santa Cruz Red	Bowl	Tomb L2	Vessel 26	2.5YR-4/8	None
19	Mixed Sandstone and Carbonate A	Local	Balanza Black?	Bowl	Tomb L3	Vessel 2	2.5YR-4/8	5YR-3/1
20	Mixed Sandstone and Carbonate A	Local	Santa Cruz Red	Bowl	Tomb L3	Vessel 3	2.5YR-5/8	None
21	Carbonate Sand A	Non-Local	Saxche-Palmar Orange	Bowl	Group I	Vessel 2	2.5YR-5/8	7.5 YR-2.5/1
22	Dolomite A	Non-Local	Zacatel Cream	Vase	SG 25	Vessel 2	2.5YR-5/6	None
23	Calcite A	Non-Local	Zacatel Cream?	Dish/Plate	SG 53	Vessel	2.5YR-5/8	7.5 YR-2.5/1
24	Micrite A	Non-Local	Saxche-Palmar Orange	Bowl	Tomb F3	Vessel 1	5YR-7/6	None
25	Quartz A	Local	Santa Cruz Red	Bowl/Dish	Tomb F1	Vessel 4	2.5YR-5/8	None
26	Mixed Sandstone and Carbonate A	Local	Sierra Red	Bowl	Group F Plaza	Vessel 1	2.5YR-4/6	None
27	Calcite B	Non-Local	Early Classic Orange Polychrome	Bowl/Dish	Group F Plaza	Vessel 2	5YR-6/6	None

Table 2

Context and descriptions of pottery sampled from household contexts. Feature 1 is a dense ceramic deposit located outside of a structure.

Sample #	Fabric Group	Provenance	Ceramic Group	Fragment Type	Vessel Form	Mound	Context	Munsell Margin	Munsell Core
28	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 36	Fill	7.5YR-6/8	7.5YR-4/1
29	Sandstone B3	Local	Turneffe	Rim	Bowl	SG36	Fill	2.5YR-5/8	2.5YR-4/1
30	Mica A	Local	Turneffe	Rim	Jar	SG 36	Fill	2.5YR-6/8	None
31	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 36	Fill	2.5YR-6/8	None
32	Sandstone B	Local	Remate	Rim	Jar	SG 36	Fill	2.5YR-6/6	None
33	Sandstone B3	Local	Turneffe	Rim	Jar	SG 36	Fill	2.5YR-6/8	None
34	Sandstone B	Local	Remate	Rim	Jar	SG 38	Fill	2.5YR-6/6	None
35	Sandstone B1	Local	Remate	Rim	Jar	SG38	Fill	5YR-6/6	None
36	Sandstone B3	Local	Remate	Rim	Jar	SG 38	Feature 1	2.5YR-6/6	None
37	Sandstone B3	Local	Remate	Rim	Bowl	SG 38	Feature 1	2.5YR-6/6	None
38	Sandstone B1	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	None
39	Sandstone B1	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	None
40	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Feature 1	7.5YR-6/6	None
41	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Feature 1	7.5YR-6/6	None
42	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Feature 1	7.5YR-6/6	None
43	Sandstone B1	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	None
44	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	None
45	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	5YR-4/1
46	Sandstone B1	Local	Turneffe	Rim	Jar	SG 38	Feature 1	7.5YR-5/2	None
47	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Feature 1	7.5YR-6/6	None
48	Sandstone B3	Local	Unknown	Flange	Bowl/Dish	SG 38	Feature 1	2.5YR-6/6	None
49	Sandstone B2	Local	Turneffe	Rim	Jar	SG 38	Feature 1	5YR-6/6	None
50	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/8	None
51	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Fill	5YR-6/6	None
52	Sandstone B1	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/6; 2.5YR-3/1 (I)	None
53	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/6	None
54	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Fill	5YR-6/6	None
55	Sandstone B	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/6	2.5YR-5/4
56	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/6	2.5YR-5/4
57	Sandstone B3	Local	Turneffe	Rim	Jar	SG 38	Fill	2.5YR-6/6	2.5YR-5/4
58	Sandstone B1	Local	Turneffe	Rim	Bowl/Dish	SG 52	Fill	5YR-6/6	None
59	Sandstone B2	Local	Remate	Rim	Jar	SG 52	Fill	2.5YR-6/6	None
60	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	2.5YR-6/6	None
61	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	2.5YR-6/8	None
62	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	2.5YR-6/6	None
63	Sandstone B4	Local	Remate	Base	Censor?	SG 52	Fill	2.5YR-6/8	None
64	Sandstone B2	Local	Remate	Rim	Jar	SG 52	Fill	2.5YR-6/6	None
65	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/6	2.5YR-5/4
66	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/6	None
67	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/6	None
68	Sandstone B3	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/6	None
69	Sandstone B3	Local	Remate	Rim	Jar	SG 52	Artifact Concentration	2.5YR-6/6	None
70	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/8	None
71	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Artifact Concentration	2.5YR-6/6	None
72	Sandstone B2	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	2.5YR-6/6	None
73	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	5YR-6/6	5YR-4/1
74	Sandstone B3	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	5YR-6/6	5YR-4/1
75	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	5YR-6/6	None
76	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 52	Fill	2.5YR-6/6	None
77	Sandstone B	Local	Turneffe	Rim	Bowl/Dish	SG 52	Fill	5YR-6/6	None
78	Sandstone B3	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/6	2.5YR-5/4
79	Sandstone B	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	None
80	Sandstone B	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-7/4	2.5YR-4/1
81	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR6/6; 5YR-6/6 (I)	None
82	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/4	None
83	Sandstone B	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/6	None
84	Carbonate Sand B	Non-Local	Hondo	Rim	Jar	SG 54	Fill	5YR-7/8	None
85	Quartz A	Local	Zacatal	Rim	Dish	SG 54	Fill	2.5YR-6/8	None
86	Quartz A	Local	Zacatal?	Rim	Dish	SG 54	Fill	2.5YR-6/4; 2.5YR-6/6 (I)	None
87	Sandstone B3	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/6	2.5YR-5/4
88	Sandstone B	Local	Turneffe	Rim	Jar	SG 54	Fill	7.5YR-5/8	None
89	Sandstone B1	Local	Turneffe	Rim	Jar	SG 54	Fill	5YR-6/6; 7.5YR-6/2 (I)	None
90	Sandstone B	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	2.5YR-5/1
91	Sandstone B3	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	None
92	Mica A	Local	Zacatal	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/6	None
93	Mica A	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	None
94	Quartz A	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-7/4	None
95	Sandstone B3	Local	Remate	Rim	Bowl/Dish	SG 54	Fill	2.5YR-6/6	None
96	Sandstone B	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	None
97	Sandstone B3	Local	Remate	Rim	Jar	SG 54	Fill	2.5YR-6/6	None

where Uxbenká is located, make a broad distinction between two types of soils based on their productivity for particular types of crops (Cortez, 2016; Culleton, 2012). *Box lu'um* (black soil; Cimin subsuite), located in

the northern portion of the study area and at the base of the rock patch, is the more agriculturally productive soil that can support nearly every crop while *chik lu'um* (red soil; Aguacate and Manfredi subsuites),

Table 3

Samples analyzed by SEM-EDS. The brackets indicate the number of EDS readings per sample. The orange surface analyzed for Samples 13 and 21 is a burnished surface, not a slip.

	Fabric Group	Ceramic Group	White Slip	Orange Slip	Red Slip	Red Paint	Black Paint	Orange Paint	Paste
1	Sandstone A1	Saxche-Palmar		5YR-7/8 [3]		10YR-4/8 [3]	10YR-2/1 [3]		2.5YR-5/8 [3]
2	Sandstone A1	Palmar		5YR-7/6 [3]					2.5YR-4/8 [2]
3	Sandstone A	Zacatel	5YR-8/4 [3]				10YR-2/1 [3]	2.5YR-7/8 [3]	2.5YR-4/8 [3]
7	Volcanic Glass A	Saxche-Palmar		5YR-6/8 [3]		10YR-4/8 [3]	10YR-2/1 [3]		5YR-6/8 [3]
9	Sandstone A2	Zacatel	5YR-8/4 [1]			2.5YR-4/6 [3]	10YR-2/1 [1]		2.5YR-4/8 [3]
13	Quartz A	Saxche-Palmar		2.5YR-6/8 [3]		10YR-4/8 [3]	10YR-2/1 [1]		2.5YR-5/8 [3]
21	Carbonate Sand A	Saxche-Palmar		2.5YR-6/8[3]		10YR-4/8 [3]	10YR-2/1 [3]		2.5YR-5/8 [3]
34	Sandstone B	Remate Red			2.5YR-6/8 [3]				2.5YR-6/8 [3]
35	Sandstone B1	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
36	Sandstone B3	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
66	Sandstone B	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
70	Sandstone B2	Remate Red			2.5YR-6/8 [3]				2.5YR-6/8 [3]
71	Sandstone B2	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
78	Sandstone B3	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
81	Sandstone B	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]
82	Sandstone B	Remate Red			2.5YR-6/4 [3]				2.5YR-6/4 [3]
87	Sandstone B3	Remate Red			2.5YR-6/6 [3]				2.5YR-6/6 [3]

located to the south near the Rio Blanco, is used for dry rice crops (Culleton, 2012: 95; Cortez, 2016: 39; Wainwright et al., 2017). While pottery production is no longer practiced in Santa Cruz village, community members report that *chik lu'um* was used to produce ceramic vessels in the past.

3. Sample selection

Eight clay samples and four rock samples were collected to evaluate resource acquisition and raw materials processing (Fig. 2). The clay samples are represented entirely by *chik lu'um* sandy, red clays of the Aguacate and Manfredi soil subsites. Four rock samples were collected (UAP 3, UAP 8, UAP 11, UAP 12; Fig. 2) and analyzed petrographically. These samples were selected based on macroscopic observations of grain size in order to evaluate the composition of different types of rocks present in the Toledo Beds (e.g. siltstone and sandstone).

A sample of 97 sherds was analyzed using thin section petrography. The samples are from primary burial and cache contexts (n = 26; 27 percent of the sample) and construction fill, caches, and ceramic deposit contexts from households (n = 71; 73 percent of the sample). The site core petrographic sample is primarily composed of broken but complete vessels from elite contexts in Groups F, I, L and SG 25 (Table 1). Group F and Group L are elite residential groups located within the administrative core, SG 25 is an elite household group consisting of 36 structures and four formal plaza groups located to the southeast of the administrative core, and Group I is a cluster of monumental architecture including a ballcourt located over a 1 km to the southwest of the administrative core (see Fig. 2). A single vessel from a cache in SG 53, a non-elite household group, was also analyzed (Table 1; Fig. 2). The household sample was recovered from four households in the south/southwest periphery of the site: SG 36, SG 38, SG 52, and SG 54 (see Fig. 2). The household ceramic sample consists primarily of Turneffe Unslipped jars and serving vessels and Remate Red jars and serving vessels (Table 2). These are the dominant ceramic types found in household contexts at Uxbenká. Nearly all (n = 91) samples date to the Late to Terminal Classic Period. Six samples, all from primary, elite contexts (12, 18, 19, 20, 25, 26, and 27) date to the Early Classic Period.

4. Methods

4.1. Thin section petrography

Petrographic analysis was conducted using a Leica DM750P

polarizing light microscope. All thin sections are described following the descriptive system (Whitbread, 1989, 1995: 365-396, 2017; See Howie, 2012; Sanchez Fourtoul, 2018; Ting et al., 2015 for applications in the Maya lowlands). The descriptive system is a qualitative method that combines aspects of sedimentary petrography and soil micro-morphology, in addition to rock and mineral identification. This approach permits the examination of technological aspects of pottery production (e.g. raw materials processing and forming technique) in addition to provenance. The natural clay samples were also analyzed in accordance with the descriptive system to make the two datasets comparable. We use the petrographic data to (1) determine local versus non-local vessels in the sample, and (2) understand how potters at Uxbenká produced and decorated ceramic vessels.

4.2. Scanning electron microscopy-energy dispersive spectrometry (SEM-EDS)

SEM-EDS was employed to characterize the composition of the paste, slip, and paint on a subset (n = 17) of the pottery analyzed by thin section petrography. The sample consists of 10 local Remate Red jars and serving vessels and 7 polychrome vessels representing local (n = 5) and non-local (n = 2) fabrics. The analysis was conducted at University of New Mexico Institute of Meteoritics. A freshly fractured sample was mounted on an aluminum pin stub and coated with gold palladium using an Emitech K950x Turbo Evaporator. All samples were analyzed using a Tescan Vega3 XMU with a model 550i SSD EDS with Iridium Ultra analysis software from IXRF Systems under high vacuum. We used a 20.0 kV accelerating voltage with a process time set to 4 for all samples. The data were converted to oxides and normalized to 100 wt%. In most cases, three analyses were recorded and averaged; however, due to poor preservation fewer analyses were recorded on some samples (Table 3 shows the samples analyzed by SEM-EDS. The number in brackets is the number of analyses per targeted portion of the sherd).

5. Results

5.1. Geologic samples results

The sandstone is a grain supported calcareous sandstone with inclusions of sedimentary, metamorphic, and volcanic origin (UAP 12; Fig. 3a). The inclusions are composed of monocrystalline quartz (zoned and undulose), polycrystalline quartz, chert, chalcedony, bioclastic limestone, micrite, plagioclase feldspar (often zoned), muscovite,

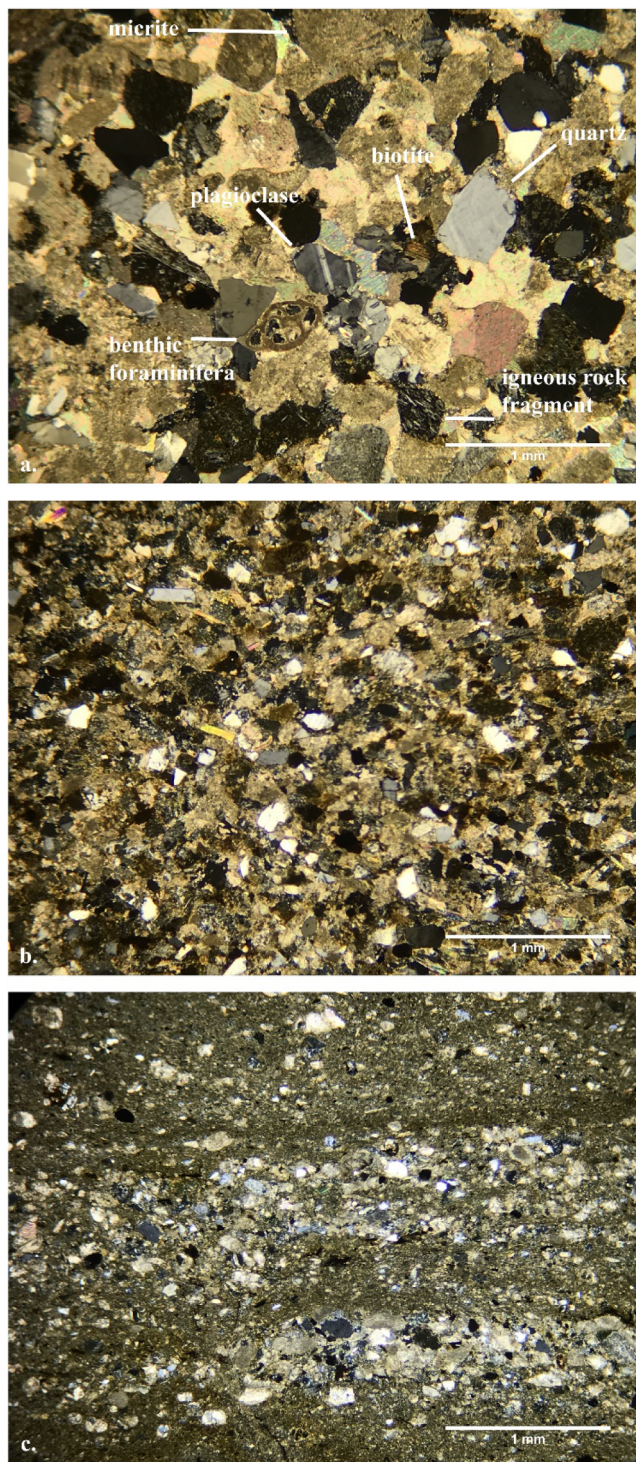


Fig. 3. Local Rock Samples Micrographs: a. Calcareous Sandstone (UAP12, XPL); b. Fine-grained calcareous sandstone (UAP11, XPL); c. Laminated calcareous sandstone, siltstone, and mudstone (UAP8, XPL).

biotite (often chloritized), igneous rock fragments and zircon. The igneous rock fragments (primarily basalt and glass) likely derive from the Santa Cruz Ophiolite Complex in Guatemala (Schaffhauser et al., 2003:6). In this study, they are referred to generally as igneous rock fragments because most inclusions are very small and difficult to

identify. The chert, chalcedony, and bioclastic limestone inclusions likely derive from Campur formation limestone. The very fine-grained calcareous sandstone sample (UAP 11; Fig. 3b) and graded bed sample consisting of sandstone, siltstone, and mudstone lamellae (UAP 8; Fig. 3c) are composed of the same inclusions but include a greater abundance of micrite and biogenic carbonate grains. All clay samples are sandy clays, but they exhibit considerable variability. Inclusions in all samples are rounded to subangular but they differ in both size and composition. The samples contain varying frequencies of the minerals and rocks discussed above as well as sandstone inclusions (Table 4). They also contain red, iron-rich concentration features contributing to the overall red color of most clay samples (Fig. 4); however, the quantity and size of these features differs between samples. While some clay samples contain an abundance of a particular rock or mineral relative to other samples, there is no discernable pattern concerning their location on the landscape around Uxbenká. For example, the UAP 9 contains more mica (muscovite and biotite) than any other samples (Fig. 4c). It is located between the UAP 7 and UAP 10 clay samples that are mica-poor (Fig. 4d).

5.2. Thin section petrography

Petrographic analyses revealed 13 distinct fabric groups representing both non-local and local pottery. Non-local pottery is composed of raw materials inconsistent with the local geology and is primarily limited to serving vessels in elite, tomb contexts. This paper briefly addresses non-local pottery, including possible provenance. See Supplemental Materials for the full petrographic descriptions and additional micrographs for each of the fabric groups.

5.2.1. Non-local fabric groups

Seven non-local fabric groups ($n = 8$), each represented by a single sample with the exception of Calcite B which is represented by two samples, were identified in the petrographic sample (Table 5). The paucity of detailed petrographic studies in many regions of the Maya lowlands precludes definitive provenance assessment for most of the non-local samples with the exception of the Belize River Valley (Samples 6, 23, 27; Fig. 5d). The provenance for these samples is based on comparison to petrographic analyses conducted by Jordan (2019; Jordan et al., 2020) on Belize Valley pottery. Table 5 summarizes the non-local fabric groups and includes possible provenance, but these associations should be considered tentative at this time. The Micrite A fabric group has been tentatively assigned to the Petén region of Guatemala based on stylistic attributes (Fig. 5b) and geologic characteristics that are appropriate for the region. The presence of abundant dolomite (Fig. 5c), consistent with the geology of the Coban Formation that outcrops near the Caribbean Coast, suggests interaction with coastal polities perhaps in conjunction with the distribution of salt (McKillop, 2009; McKillop and Aoyama, 2018). Most ($n = 6$) of the non-local pottery comes from elite, primary contexts and these data provide information on elite interactions with other regions, possibly through gift exchange, and indicate that Uxbenká had political and/or economic ties to the north with the Belize River Valley, to the Caribbean Coast, and possibly west into Guatemala. One of the vessels from the Belize River Valley (Sample 27) dates to the Early Classic period indicative of interaction with this region in the early phase of occupation at Uxbenká. The cached possible Zacatel Cream polychrome vessel from SG 53 (Sample 23) and Hondo Red sherd from SG 54 (Sample 84) demonstrate that at least some households could acquire non-local pottery although households primarily provisioned themselves with locally produced vessels.

Table 4
Petrographic analysis of natural clay samples.

	UAP 1	UAP 2	UAP 4	UAP 5	UAP 6	UAP 7	UAP 9	UAP 10
Textural Characteristics								
Color (PPL)	Golden Reddish Brown	Golden Reddish Brown	Golden Reddish Brown	Brown	Brown	Golden Reddish Brown	Golden Reddish Brown	Golden Reddish Brown
Color (XPL)	Dark Golden Red	Dark Golden Red	Dark Golden Red	Golden Brown	Golden Brown	Dark Golden Red	Dark Golden Red	Dark Golden Red
Coarse (> 0.125 mm):Fine	20:80	40:60	40:60	30:70	40:60	20:80	30:70	20:80
Inclusion Packing	Single to Open Spaced	Single to Open Spaced	Closed to Open Spaced	Single to Open Spaced	Closed Spaced to Double Spaced	Single to Open Spaced	Closed Spaced to Double Spaced	Single to Open Spaced
Inclusion Sorting	Moderately Sorted	Moderately Sorted	Moderately Well Sorted	Moderately sorted	Poorly Sorted	Moderately Well Sorted	Well Sorted	Moderately Well Sorted
Characteristics of Inclusions								
Roundness	Rounded to Subangular	Rounded to Subangular	Rounded to Subangular	Rounded to Subrounded	Rounded to Subrounded	Rounded to Subangular	Rounded to Subrounded	Rounded to Subangular
Size (mm) Largest of all/ range of 98%	0.75 mm (IRF)/0.04 mm to 0.45 mm	1.5 mm (mudstone)/0.04 mm to 1 mm	.9mm (quartz)/0.04 mm to .5mm	0.75 mm (mudstone)/0.04 mm to .5mm	2 mm (quartzite)/0.04 mm to 1.2 mm	.5mm (quartz)/0.04 mm to .4mm	.5mm (quartz)/0.04 mm to .3mm	.5mm (quartz)/0.04 mm to .4mm
Mode size (mm)	.2mm (fine sand)	.8mm (coarse sand)	.3mm (medium sand)	0.25 mm (medium sand)	.3mm (medium sand) and .8mm (coarse sand)	.3mm (medium sand)	.2mm (fine sand)	.3mm (medium sand)
Inclusions								
Quartz	Dominant	Common	Dominant	Predominant	Common	Dominant	Common	Dominant
Quartzite	Very Few	Very Few	Very Few	Very Few	.8mm	Very Few	Few	Very Few
Polycrystalline Quartz	Few	Few	Few	Few	Common	Few	Few	Few
Chert	Very Few	Very Rare	Very Rare	Very Few	Few	Few	Very Few	Few
Chalcedony	Rare	Very Rare	Rare	Very Few	Very Few	Absent	Very Few	Absent
Plagioclase	Few	Few	Few	Very Few	Few	Few	Few	Few
Muscovite	Common	Common	Few	Very Few	Few	Few	Dominant	Few
Biotite	Few	Few	Absent	Absent	Few	Few	Common	Few
Sandstone	Few	Few	Few	Very Few	Common	Very Few	Few	Very Few
Mudstone	Few	Dominant	Few	Very Few	Common	Very Few	Few	Very Few
Igneous Rock Fragments (IRF)	Common	Few	Few	Absent	Common	Very Few	Few	Very Few
Zircon	Absent	Very Rare	Very Rare	Absent	Very Rare	Absent	Very Rare	Absent
	Predominant (Pred.)		> 70%	Few		5–15%		
	Dominant (Dom.)		50–70%	Very Few (V. Few)		2–5%		
	Frequent (Freq.)		30–50%	Rare		0.5–2%		
	Common		15–30%	Very Rare (V. Rare)		< 0.5%		

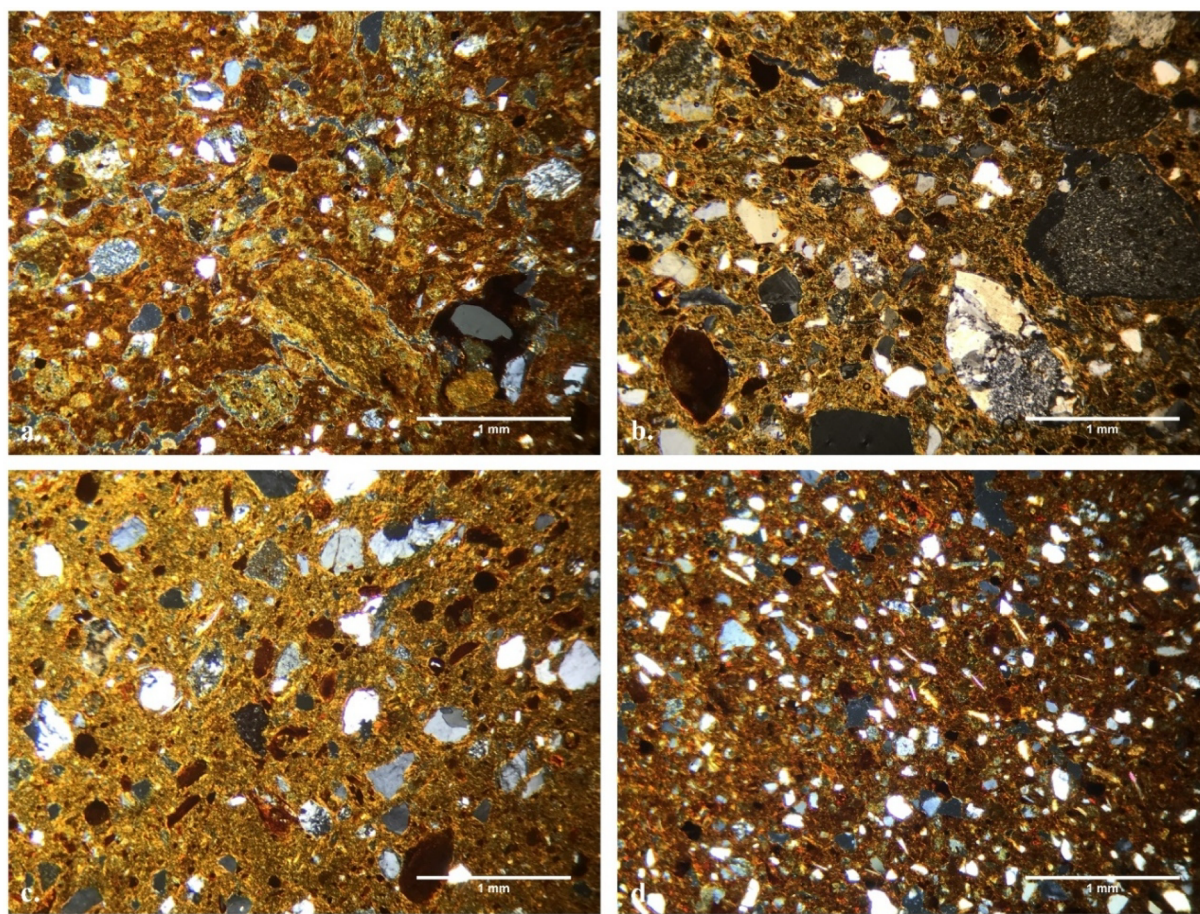


Fig. 4. Local Clay Sample Micrographs: a. Sample UAP3, XPL; b. UAP6, XPL; c. UAP7; d. UAP9, XPL.

5.2.2. Local fabric groups

Five primary locally produced fabric groups were identified in this sample. The *Sandstone A* ($n = 7$) fabric group is a moderately sorted, sandy clay containing monocrystalline quartz, calcareous sandstone, plagioclase feldspar, calcareous mudstone, quartzite, chert, chalcedony, polycrystalline quartz, igneous (mostly extrusive) rock fragments, muscovite, and zircon (Fig. 6a; Table 6; Fig. 7). The fabric is tempered with calcareous sandstone. It is unevenly distributed; however, it is not angular. The rounded habit would be expected if collecting soft, calcareous bedrock (*nib*). The size, sorting, and composition of the other mineral and rock inclusions are consistent with locally derived clays. Sandstone A, Subgroup 1 contains smaller temper and naturally occurring inclusions. Sandstone A, Subgroup 2 contains crystalline calcite temper in addition to the calcareous sandstone. The Sandstone A fabric group was identified in samples dating to the Early Classic and Late Classic vessels in Tomb L2 only (Fig. 8).

The *Sandstone B* Fabric Group ($n = 27$) [and its subgroups ($n = 37$)] is a moderately to poorly sorted, sandy clay containing sandstone and the same inclusions described above consistent with local provenance. These sandstone inclusions are different than those identified in the Sandstone A fabric group but identical to inclusions found in the natural clay samples. This fabric is tempered with angular, rhombic carbonate (Fig. 6b). However, the presence of this temper,

likely crystalline calcite but possibly dolomite, is based on the shape of the void because the carbonate is no longer present. Sample 15 (a bowl recovered from Tomb L2 in the site core), however, still contains calcite providing additional evidence for carbonate temper. It is likely that carbonate was removed due to post depositional leaching and that it remained in the tomb sample because the constructed sandstone walls protected the vessel. The presence of angular, unevenly distributed temper gives this fabric a bimodal appearance. Furthermore, crystalline calcite inclusions are not present in clay samples. The mineralogical variability in the subgroups is the same as the main group but they differ slightly in the color of the groundmass and abundance of naturally occurring inclusions. It is likely that these subgroups represent differences in firing or slight differences in local provenance producing the color variation noted in petrographic analysis. The Sandstone B fabric group was identified primarily in Late to Terminal Classic Remate Red and Turneffe Unslipped vessels.

The *Quartz A* Fabric Group ($n = 12$) is nearly identical to the Sandstone B Fabric Group except for an almost complete lack of rock content and limestone temper (Fig. 6c). The unimodal size distribution indicates that no temper was added. The mineralogy, sorting, and size of the sand inclusions is consistent with geology descriptions of the Toledo formation and comparable to natural clay samples indicative of a local provenance. However, the clay samples also include rock

Table 5
Summary of non-local fabric groups.

Fabric group	Sample # and Context	Ceramic group	Temper	Inclusions (in order of abundance)	Defining characteristics	Possible provenance
Carbonate Sand A	21 (Group I Tomb)	Saxche-Palmar Orange	None	Carbonate sand, calcite terminal grades, micrite, monocrystalline quartz, sparry calcite	Predominant (> 80%) carbonate sand (mode size: 0.05 mm); optically inactive matrix (high fired); unimodal size distribution	Unknown
Carbonate Sand B	84 (SG 54 Fill)	Hondo Red	None	Carbonate sand, monocrystalline quartz, chert, chalcadony, muscovite	Predominant (> 80%) carbonate sand (mode size: .1mm); red groundmass (PPL and XPL); unimodal size distribution	Unknown
Calcite A	23 (SG 53 Cache)	Zacatel Cream?	Limestone	Calcite terminal grade, monocrystalline quartz, dolomite, micrite, sparry calcite, polycrystalline quartz, chert	Abundant terminal grade calcite (mode size: .3mm); tempered with sparry calcite	Belize River Valley
Calcite B	6 (Str. L2 Tomb) and 27 (Group F Plaza Cache)	6. Saxche-Palmar Orange; 27: Early Classic Orange Polychrome	Limestone	Calcite terminal grades, carbonate sand, monocrystalline quartz, dolomite, polycrystalline quartz, micrite, sparry calcite	Carbonate rich clay (dusty appearance); abundant terminal grade calcite (mode size: .1mm); tempered with various types of limestone (sparry calcite and micrite)	Belize River Valley
Micrite A	24 (Str. F3 Tomb)	Saxche-Palmar Orange	None	Micrite, monocrystalline quartz, polycrystalline quartz, chert, muscovite, igneous rock fragments	Fine micritic clay; angular quartz inclusions; volcanic rock inclusions; unimodal size distribution	Peten?
Dolomite A	22 (SG 25 Crypt)	Zacatel Cream	None	Dolomite, muscovite, monocrystalline quartz, chert, micrite, chalcadony	Predominance of dolomite (> 80%); well-sorted; unimodal size distribution	Southern Belize Coast, near Punta Gorda (Coban Formation)
Volcanic Glass A	7 (Str. L2 Tomb)	Saxche-Palmar Orange	None	Tuff, volcanic glass, monocrystalline quartz, biotite, muscovite, plagioclase feldspar, micrite	Predominance of volcanic inclusions (< 90%)	Unknown

(mudstone, sandstone, igneous rock fragments) inclusions. This suggests that potters either removed the rock content as part of raw materials processing or purposefully selected clays devoid of large rock content. The Quartz A fabric group was identified in Early and Late Classic samples in thin-walled monochrome red and polychrome serving vessels (Fig. 7).

The *Mica A* Fabric Group (n = 3) is similar to the Sandstone B Fabric Group except that the clay is very micaceous (primarily muscovite) and the rock and mineral inclusions are much smaller. The *Mica A* group is also tempered with rhombic crystalline calcite or dolomite (Fig. 6d). The *Mixed Carbonate and Sandstone A* fabric group (n = 3) was only identified in samples dating to the Early Classic Period. This group is nearly identical to Sandstone B but with abundant crystalline calcite temper. The abundance of this type of temper is consistent with macroscopic characterizations of pottery from the Early Classic Period.

5.2.3. Monochrome red slips

The slip color on Remate Red vessels analyzed in this study is identical to the paste color (see Table 4). In general, slips are thin, flakey, and occasionally glossy. The slip on Remate Red vessels is barely visible microscopically in plane polarized light (PPL) and cross polarized light (XPL). The slips do not appear to be enriched in iron compared to the ceramic body although they do appear slightly darker in XPL and the composition of the slip looks nearly identical to the paste in PPL (Fig. 9d). Although the slips are thin and appear to be compositionally similar at the microscopic level, they form a clear layer (best seen in PPL; Fig. 9c) above the paste indicating that the slips were a purposeful addition and not the result of burnishing the surface of the vessel.

5.2.4. White and orange slips on polychrome vessels

Both white and orange slips on locally produced vessels are composed of very fine calcareous mudstone/siltstone (Fig. 9a, b). The slips contain very small, fine silt sized inclusions of quartz, feldspar, and muscovite similar to the fine layers of calcareous sandstone (Fig. 3c). The slip layer varies in thickness (0.02–0.3 mm) but they all contain non-carbonate inclusions. The difference between white and orange slips is color; the orange slips likely include added iron oxide or an iron-rich clay. The slip was then painted with black, red, and sometime orange paint (red paint is visible on Fig. 9b). The slips on non-local polychrome vessels differ in terms of both composition and production technique. White slips on non-local Zacatel Cream polychromes are composed of pure calcium carbonate (Sample 22, Dolomite A fabric group). The non-local Saxche-Palmar polychromes exhibit two different methods to produce an orange surface: a calcium carbonate slip and a burnished surface. Sample 24 (Micrite A fabric group) is slipped with calcium carbonate; the orange color is likely the result of added iron oxide or iron-rich clay. Sample 7 (Volcanic Glass A fabric group) and Sample 21 (Carbonate Sand A fabric group) are not slipped. Rather, the orange paste is burnished, and paint is applied to the burnished surface. All of the non-local vessels have a lustrous sheen suggesting that some sort of clear coating was added to the surface after painting (Rice, 2009: 121). None of the locally produced polychromes have a glossy surface although it is unclear if this is the result of pottery production practice or post-depositional processes.

5.3. SEM-EDS

SEM-EDS produces semi-quantitative data which provides insight into composition of paste, slips, and paints. These data are exploratory and form the basis for future analysis on understanding the composition of decorative elements on pottery produced in limestone-poor regions of the Maya lowlands. Additional quantitative methods are required to evaluate differences in recipes at the local level and between Uxbenka and other regions.

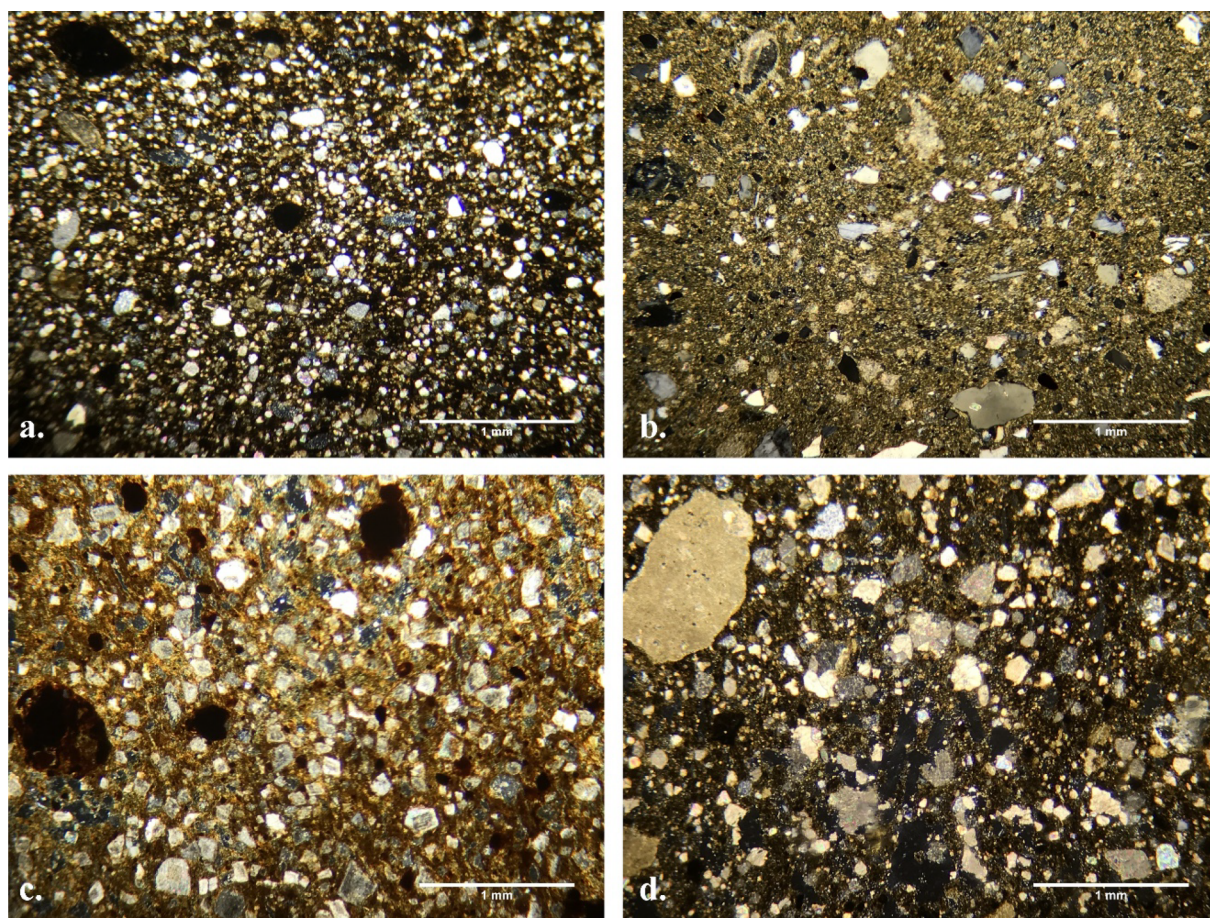


Fig. 5. Non-Local Pottery Fabric Groups Micrographs: a. Carbonate Sand A, XPL (Sample 21); b. Micrite A, XPL (Sample 24); c. Dolomite A, XPL (Sample 22); d. Calcite B, XPL (Sample 6).

5.3.1. Monochrome red slips

The results of SEM-EDS analysis of 10 Remate Red serving vessels and jars confirm that the composition of the paste and the slip is nearly identical (Table 7). The average Fe_2O_3 content for red slips is slightly higher than the paste; however, in many cases the paste contains more abundant iron. These data indicate that potters were likely using the same iron rich clays to produce both vessels and slips at Uxbenká and did not enrich the slip by adding additional iron oxides to enhance the red color on slipped utilitarian vessels at Uxbenká. The similarities between paste and slip with regard to other elements (e.g. SiO_2 , Al_2O_3) suggests that the clays were not refined other than removing rock and mineral content prior to their addition to the vessel as slip on utilitarian vessels. There are some Remate Red vessels in the Uxbenká assemblage that clearly have a darker red slip layer above the associated paste, but they were not analyzed using SEM-EDS for this study. This darker red color suggests that at least some Late to Terminal Classic red slips were composed of clays enriched with iron oxide.

5.3.2. White and orange slips on polychrome vessels

The white slips on locally produced polychromes contain calcium carbonate (CaCO_3) and the orange slips contain both calcium carbonate

and iron oxide (Fe_2O_3). The abundance of aluminum and silica in the locally produced slips suggest that the calcareous sandstone was added to clay to adhere the slip to the body of the vessels. These concentrations could also be due to the presence of quartz, feldspar, and muscovite inclusions in the sandstone. The orange color was likely produced by adding iron-rich clay to the calcareous sandstone.

5.3.3. Red, black, and orange paint

Red and orange paints contain high concentrations of iron oxide (Fe_2O_3) added to clay (SiO_2 , Al_2O_3) for both locally produced and non-local ceramic vessels (Table 8). The slightly different shades of red were likely achieved by adding different amounts of iron oxide to the clay while the orange color was achieved by adding less iron oxide. Black paint contains high concentrations of manganese oxide (MnO) and (Fe_2O_3) added to clay (SiO_2 , Al_2O_3). Sample 9 (Zacatel Cream) is an outlier in the local sample. Both the red paint and black paint contain much higher concentrations of manganese oxide than the other locally produced polychromes suggesting that there was more than one recipe for black paint. Both iron oxide (Fe_2O_3) and manganese oxide (MnO) occur naturally as nodules in the soils around Uxbenká and may have been the source for paint on local polychrome vessels.

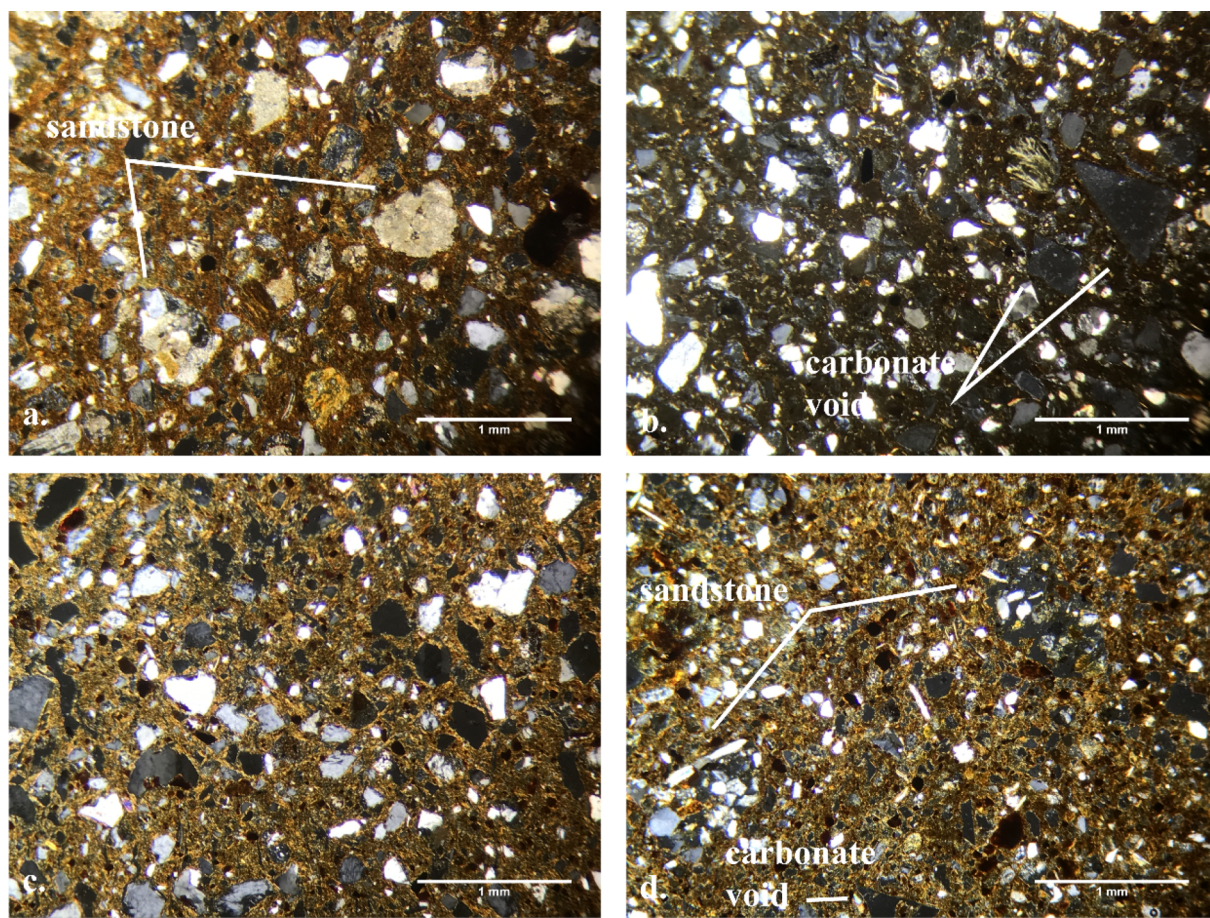


Fig. 6. Locally Produced Ceramic Groups Micrographs: a. Sandstone B, XPL (Sample 14); b. Sandstone B, XPL (Sample 75); c. Quartz A, XPL (Sample 10); d. Mica A, XPL (Sample 94).

6. Discussion

The data presented in this paper illustrate how potters living in a limestone-poor region used locally available resources to produce and decorate pottery. The pottery produced at Uxbenká consists of vessel forms and decorative elements consistent with Late Classic ceramic assemblages across the Maya Lowlands. Potters at Uxbenká would have been aware of what ceramic vessels from other regions looked like, either through interactions with other potters or viewing non-local vessels and sought to create similar vessels using locally available raw materials. The similarities in the outward appearance of ceramic vessels underscore the exchange of information, in addition to the exchange of vessels, across the Maya lowlands. The petrographic data on ceramic fabrics presented serve to distinguish pottery produced in southern Belize from limestone-rich regions and provide some information on diachronic change and the organization of production at Uxbenká. The data collected on slips and paints serves a similar purpose but also highlights the ingenuity of ancient Maya potters and diversity of regional approaches to ceramic manufacture.

Most of the pottery produced at Uxbenká is remarkably similar. However, there are differences in both paste recipe and context. Potters

procured clay and temper from the red, clay-rich sandy soils located in the southern portion of the settlement area (Aguacate and Manfredi soils). Previous research indicates that SG 38, SG, 52, and SG 54 participated in pottery production and SG 36 likely participated in pottery production based on the presence of ceramic and stone tools, abundance of finished products, and spatial location near one another (Jordan and Prufer, 2017). The petrographic data presented here suggest that these households were located on or near the clay resources used in pottery production. Freter (1996) noted a similar spatial relationship between pottery production households and high-quality clays at Copan.

The sandy clay, with a wide variety of rock and mineral inclusions, was used by potters in five primary paste recipes. These recipes differ in how the clays were processed, both in terms of removing large inclusions to refine the natural clay and by adding (or not adding) temper. The Sandstone A Fabric Group is the only fabric tempered with calcareous sandstone. Early Classic and Late Classic vessels produced in this manner were recovered from a single elite tomb located in Group L. The choice by potters to use a paste recipe with calcareous sandstone inclusions is likely not a functional one. Rather, it appears to have been used for the production of special purpose items and this practice

Table 6
Summary of Locally Produced Fabric Groups.

Fabric group	Temper	Inclusions (in order of abundance)	Mode size of inclusions	Defining characteristics
Sandstone A	Calcareous sandstone	Monocrystalline quartz, muscovite, calcareous sandstone, plagioclase feldspar, calcareous mudstone, biotite, quartzite, chert, chalcedony, polycrystalline quartz, igneous rock fragments, zircon	.3mm (medium sand)	Highly birefringent calcareous sandstone temper; various naturally occurring rock and mineral inclusions
A1	Calcareous sandstone		0.25 mm (medium sand)	Same as Sandstone A but with smaller sized temper and naturally occurring inclusions.
A2	Calcareous sandstone and rhombic carbonate		.3mm (medium sand)	Same as Sandstone A but with rhombic, carbonate inclusions as temper
Sandstone B	Rhombic Carbonate (likely calcite but possibly dolomite)	Monocrystalline quartz, muscovite, rhombic carbonate, sandstone, chert, mudstone, quartzite, plagioclase feldspar, biotite, igneous rock fragments, zircon	0.35 mm (medium sand)	Naturally occurring sandstone (not birefringent); angular carbonate temper; various naturally occurring rock and mineral inclusions; more abundant chert than in Sandstone A; golden brown micromass (XPL)
B1				Same as Sandstone B but with a very dark golden brown (XPL) micromass
B2				Same as Sandstone B but with a golden reddish brown (XPL) micromass
B3				Same as Sandstone B but with sparse naturally occurring inclusions
Quartz A	None	Monocrystalline quartz, polycrystalline quartz, quartzite, chert, chalcedony, plagioclase feldspar, muscovite, biotite, igneous rock fragments, sandstone, zircon	.2mm (fine sand)	No carbonate (either as temper or naturally occurring); unimodal size distribution; generally smaller inclusions; absence of large rock and mineral inclusions
Mica A	Rhombic Carbonate (likely calcite but possibly dolomite)	Monocrystalline quartz, muscovite, biotite, rhombic carbonate, sandstone, plagioclase feldspar, quartzite, polycrystalline quartz, igneous rock fragments, zircon	.1mm (very fine sand)	Micaceous clay; very fine sand inclusions
Mixed Carbonate and Sandstone A	Rhombic crystalline calcite	Monocrystalline quartz, muscovite, calcite, sandstone, chert, mudstone, quartzite, plagioclase feldspar, biotite, igneous rock fragments, zircon	0.35 mm (medium sand)	Abundant rhombic crystalline calcite inclusions; very similar to Sandstone B except for the use of more carbonate temper

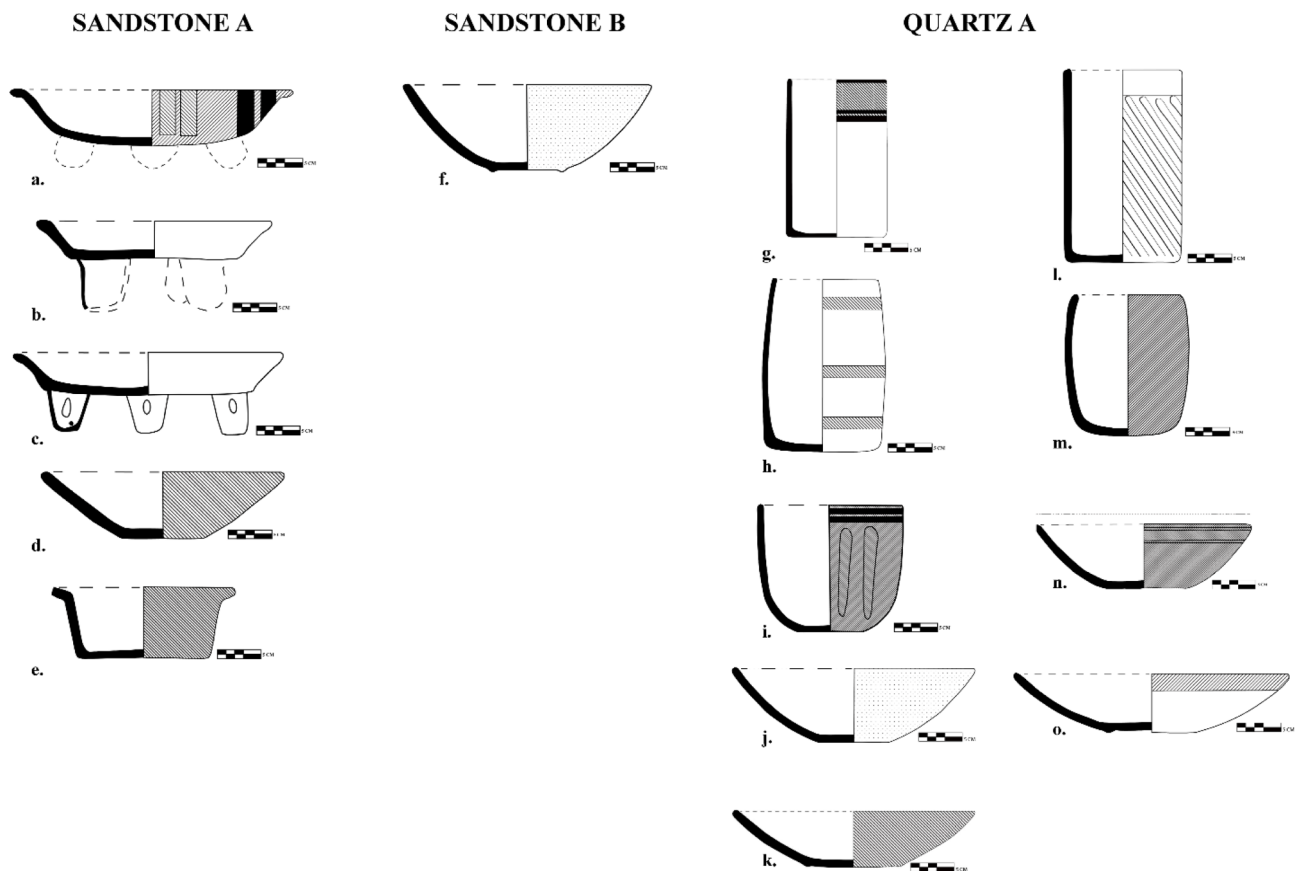


Fig. 7. Vessel Profiles by Fabric Group: a. Sample 3; b. Sample 9; c. Sample 14; d. Sample 12; e. Sample 18; f. Sample 15; g. Sample 4; h. Sample 17; i. Sample 13; j. Sample 16; k. Sample 25; l. Sample 10; m. Sample 11; n. Sample 5; o. Sample 8.

extends back to the earliest period of occupation at Uxbenká. A larger sample set is necessary to determine if the vessels composed of this paste recipe are exclusively found in funerary contexts.

Nearly all pottery ($n = 64$; 90 percent of the household sample) recovered from domestic contexts was characterized as the Sandstone B Fabric Group. Potters used this paste recipe to produce Turneffe Unslipped and Remate Red jars in a wide variety of forms including restricted orifice and unrestricted orifice jars, incurving wall bowls, and flared wall bowls and dishes. The variation in the Sandstone B fabrics (i.e. subgroups) could indicate the presence of multiple groups of potters and/or change over time during the Late to Terminal Classic Period. The Quartz A fabric group was used in the production of Zacatel Cream, Saxche-Palmar, and Palmar Orange polychrome vessels recovered from both site core and household contexts. Potters produced multiple vessel forms, including vases and flared wall dishes. The difference in these two fabric groups is related to raw materials processing. The clay used to produce thin-walled polychrome vessels was either processed to remove large rock and mineral inclusions or preferentially selected because it contained smaller inclusions. In addition, no carbonate was added to the Quartz A fabric. The absence of carbonate in the Quartz A fabric may be because calcium carbonate rehydrates when heated, causing expansion of the vessel walls and creating stress. This rehydration can cause low strength, spalling,

cracking, and crumbling (Rice, 2015:377), which are more likely to affect a thin-walled vessel. The sample for the Mica A fabric group only contains 3 samples so the relationship between this fabric and others produced at Uxbenká is unclear; however, this fabric group appears to represent the use of a slightly different clay. The Mixed Carbonate and Sandstone A fabric group is only present in Early Classic samples and is characterized by the addition of abundant crystalline calcite temper. Although the sample in this study is small, macroscopic observations indicate that most Early Classic pottery at Uxbenká, both slipped and unslipped serving ware and jars, contained carbonate temper. This pottery production practice was abandoned sometime before the Late Classic Period although Remate Red and Turneffe Unslipped vessels contain a few crystalline calcite inclusions. These fabric groups are unique to the southern Belize region and distinguish pottery produced at Uxbenká from other parts of the Maya lowlands where fabrics are composed primarily of calcareous clays with various types of calcium carbonate temper.

The composition of red, white, and orange slips on ceramic vessels also distinguishes vessels produced locally at Uxbenká. Petrographic and SEM-EDS data indicate that potters likely used the same, iron-rich clay to produce ceramic vessels and red slips on monochrome Remate Red jars and serving vessels. The use of similar clays to produce ceramic vessels and their associated slip is consistent with pottery production

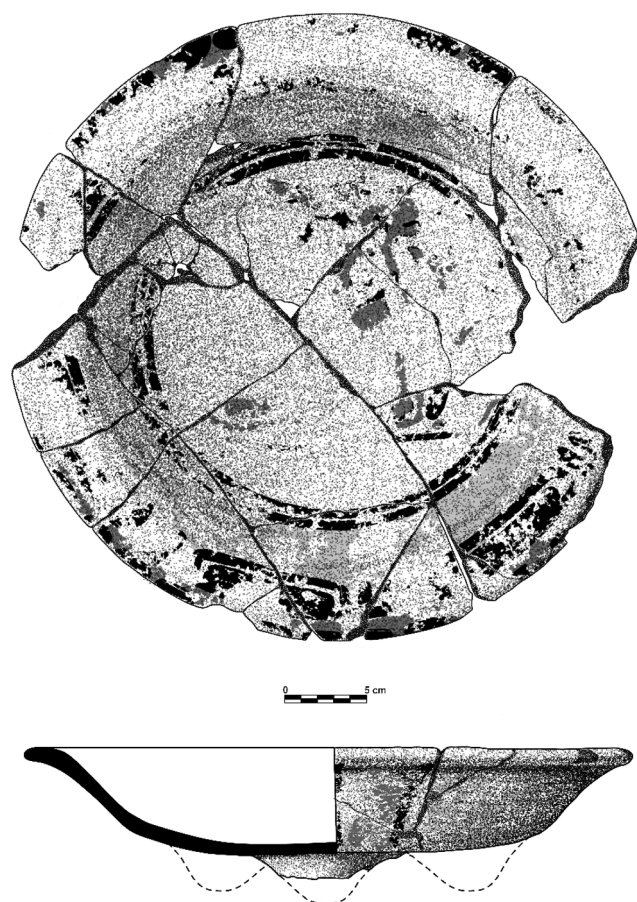


Fig. 8. Tomb L2 (Vessel 15) Zacatel Cream Polychrome (Sandstone A1 Fabric Group, Sample 3). Drawing by Shawn G. Morton.

elsewhere in the Maya lowlands (e.g. [Howie, 2012](#); [Ting et al., 2015](#)). The sample of Remate Red analyzed for this study is composed only of utilitarian vessels recovered from household contexts. SEM-EDS analysis of Late to Terminal Classic fine wares [Ahk'utu' molded-carved vases ([Ting et al., 2015](#); [Ting, 2018](#)) and Zakpah serving vessels ([Ting, 2018](#))] indicate that slips contain higher concentrations of iron oxides, likely do to the addition of iron to the clay to enhance the color of the slip. A larger sample from Uxbenká is required to determine if red slipped vessels from other contexts is consistent with data collected on pottery from outside of southern Belize.

The orange appearance on Saxche-Palmar and Palmar Orange polychromes can be achieved in two ways: by heavily burnishing a vessel with a paste that fires to a bright orange color or by adding a slip (see [Brady et al., 1998: 27-28](#)). Orange slips are the product of calcium carbonate (generally fine micritic limestone) and added iron oxide to produce the orange color or were simply burnished when the color of the clay fires to a bright orange color. In both cases, the vessel was then painted with black, red, and orange designs and finished with a thin, transparent glossy coating composed of fine, colloidal particle size clay

(< 0.001 mm). The gloss may have been produced from the fine clay material or through the addition of plant extracts ([Rice, 2009: 121](#)).

Potters at Uxbenká did not have access to micrite, or clay that fires orange, so their solution to producing Zacatel Cream, Saxche-Palmar, and Palmar Orange polychromes was to use very fine-grained calcareous sandstone. The slip contains quartz, feldspar, and muscovite inclusions consistent with the composition of the Toledo Beds that underlie most of the southern Belize region. Ethnographic data collected by [Arnold \(1985: 52-53\)](#) indicates that potters will travel much farther to acquire the raw materials used to slip and paint ceramic vessels. Rather than travel to limestone-rich regions to collect micrite, or acquire this resource via trade, Uxbenká potters used locally available carbonate sandstone to develop a different, possibly distinctively southern Belize, decorative technique. Vessels slipped with carbonate sandstone are not visually identical to those slipped with calcium carbonate but do provide a white or orange surface to paint with black, white, and red geometric designs. None of the locally produced Uxbenká polychromes exhibit evidence of a glossy coating applied to the surface. It is unclear if this represents a technological choice or is the result of post-depositional processes that eroded the surface finish. The latter explanation is the most likely given the poor preservation of the Uxbenká ceramic assemblage in general. The data collected on paint confirm that red and orange designs were produced using hematite and black designs were produced using a mixture of hematite and manganese. These data are consistent with other regions where paint is a mixture of iron and manganese minerals added to clay ([Howie, 2012](#); [Reents-Budet, 1994](#); [Rice, 2009](#)).

7. Conclusion

This study is the first to focus on thin section petrography and SEM-EDS analysis on pottery produced in the limestone-poor region of southern Belize. The pottery produced at Uxbenká is distinctive based on the locally available raw materials derived from interbedded calcareous sandstone rather than the limestone bedrock that dominates much of the Maya lowlands. Early Classic and Late to Terminal Classic pottery was produced using clays available in the immediate vicinity of Uxbenká, consistent with other lowland Maya polities and worldwide ethnographic evidence ([Arnold, 1985](#)). Ceramic fabrics contain calcareous sandstone and an abundance of non-carbonate inclusions derived from the Toledo Beds. Slips also differ compositionally from other regions of the Maya lowlands. Red slips on utilitarian vessels are nearly identical to the paste and are not enriched in iron oxide. White and orange slips on polychrome vessels are composed of very fine calcareous sandstone because limestone was unavailable. Potters in southern Belize produced vessels that were outwardly similar to vessels produced in other parts of the Maya lowlands using locally available, non-carbonate clays and tempers. The data presented in this paper provide important comparative information for scholars who may encounter pottery from southern Belize in their assemblages as imported vessels. The ability to identify vessels produced in southern Belize will aid in understanding social and economic relationships between this understudied region of the Maya lowlands and other regions. Additional work is required to determine how pottery production practice at Uxbenká is similar to, or different from, other polities in the region like Nim Li Punit, Lubaantun, and Ix Kuku'il that were also located atop the Toledo Beds, as well as the relationship between inland and coastal sites in southern Belize.

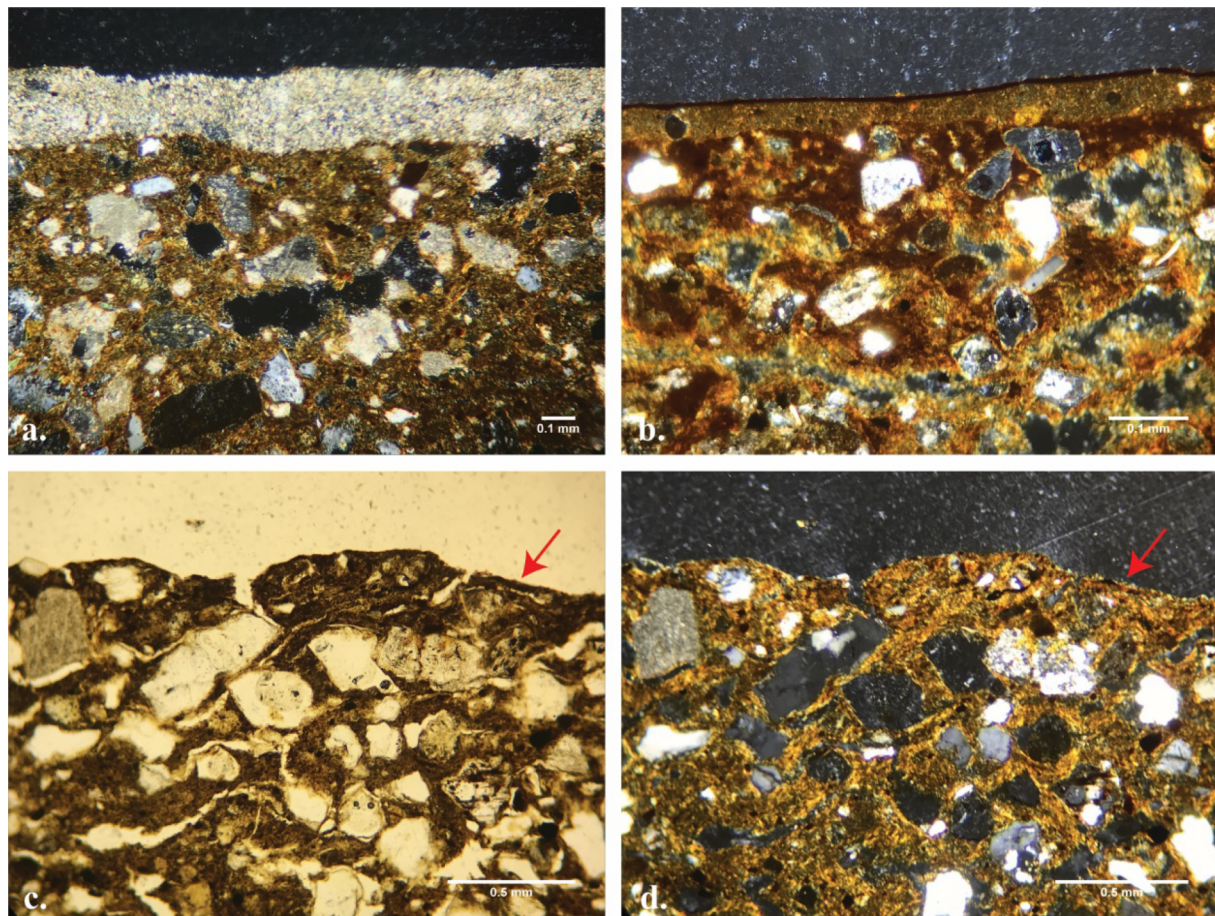


Fig. 9. Micrographs of Local Slips: a. White slip with quartz, feldspar, and mica inclusions (Sample 3, XPL); b. orange slip with quartz, feldspar, and mica inclusions (Sample 1, XPL); c. arrow pointing to red slip (Sample 71, PPL); d. arrow pointing to red slip (Sample 71, XPL). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 7
SEM-EDS of remate red vessels.

Sample	Ceramic Group	Fabric Group		Fe ₂ O ₃	MnO	TiO	CaO	K ₂ O	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O ₃	CO ₂
UXB 34	Remate	Sandstone	Slip	8.89	0.08	1.39	0.99	1.74	39.73	20.58	1.27	0.42	24.91
	Red	B	Paste	13.42	0.10	0.99	1.02	1.47	36.95	18.96	1.07	1.05	24.97
UXB 35	Remate	Sandstone	Slip	6.67	0.93	0.41	0.71	0.83	35.17	23.63	1.28	0.22	30.14
	Red	B1	Paste	4.76	0.06	0.97	0.77	0.78	38.87	21.99	0.85	1.25	29.71
UXB 36	Remate	Sandstone	Slip	6.77	0.11	1.12	2.26	2.20	42.35	18.90	1.41	0.50	24.37
	Red	B3	Paste	6.95	0.12	0.83	6.24	1.82	37.15	18.90	1.46	1.47	25.08
UXB 66	Remate	Sandstone	Slip	12.51	0.29	1.08	1.33	0.58	31.47	25.09	0.76	0.43	26.45
	Red	B	Paste	9.89	0.11	0.87	0.96	0.65	37.86	20.15	0.55	0.90	28.07
UXB 70	Remate	Sandstone	Slip	10.27	0.29	0.65	1.01	0.59	39.14	19.96	0.80	0.19	27.11
	Red	B2	Paste	9.25	0.10	0.66	0.86	0.43	32.04	19.79	0.77	0.17	35.94
UXB 71	Remate	Sandstone	Slip	10.41	1.00	1.24	1.08	1.02	36.16	19.32	0.97	0.39	28.41
	Red	B2	Paste	14.13	0.08	1.08	1.07	0.75	32.83	19.09	0.90	0.30	29.76
UXB 78	Remate	Sandstone	Slip	5.99	0.13	0.88	1.96	1.10	42.84	19.70	1.71	0.56	25.14
	Red	B3	Paste	11.25	0.36	1.79	2.52	1.73	40.66	17.30	1.39	0.44	22.56
UXB 81	Remate	Sandstone	Slip	11.28	0.03	1.14	0.79	1.44	34.71	26.28	1.61	0.60	22.13
	Red	B	Paste	12.36	0.19	1.80	0.64	1.10	41.56	21.96	0.95	0.35	19.09
UXB 82	Remate	Sandstone	Slip	10.62	0.07	0.97	1.58	1.16	37.88	19.08	1.15	0.36	27.13
	Red	B	Paste	11.06	0.36	0.64	1.22	0.89	39.57	17.91	0.92	0.36	27.07
UXB 87	Remate	Sandstone	Slip	6.88	0.07	1.02	1.94	1.50	40.19	20.66	1.70	0.47	25.57
	Red	B3	Paste	10.08	0.09	1.41	1.96	3.29	40.84	18.12	1.04	1.73	21.43
					Fe ₂ O ₃	Fe ₂ O ₃	Fe ₂ O ₃						
					Min	Max	Average						
				Slip	5.99	12.51	9.08						
				Paste	4.76	14.13	10.17						

Table 8
SEM-EDS of polychrome vessels.

Sample	Ceramic Group	Fabric Group	Provenance	Target	Fe ₂ O ₃	MnO	TiO	CaO	K ₂ O	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O ₃	CO ₂
1	Saxche-Palmar	Sandstone A1	Local	Red Paint	18.73	1.82	1.15	2.21	0.27	31.79	16.31	0.92	0.25	26.54
9	Zacatel Cream	Sandstone A2	Local	Red Paint	9.50	14.37	1.07	3.25	0.66	25.26	14.03	1.00	1.49	29.59
13	Saxche-Palmar	Quartz A	Local	Red Paint	12.98	0.68	1.05	2.10	0.95	36.85	17.01	1.35	0.20	26.84
7	Saxche-Palmar	Volcanic Glass A	Non-Local	Red Paint	28.23	0.17	1.20	2.05	0.25	26.74	16.61	0.55	0.13	24.08
21	Saxche-Palmar	Carbonate Sand A	Non-Local	Red Paint	8.94	0.12	0.73	4.14	1.15	34.51	19.47	1.80	0.16	28.99
1	Saxche-Palmar	Sandstone A1	Local	Black Paint	17.26	6.15	0.85	2.27	0.57	30.00	13.64	1.52	0.36	27.39
3	Zacatel Cream	Sandstone A	Local	Black Paint	11.51	4.16	0.75	2.97	0.36	29.95	16.86	1.19	0.28	31.97
9	Zacatel Cream	Sandstone A2	Local	Black Paint	5.40	28.63	0.79	4.62	0.86	16.05	10.06	1.09	2.73	29.77
13	Saxche-Palmar	Quartz A	Local	Black Paint	13.70	1.52	1.13	1.84	0.85	38.03	13.44	1.49	0.50	27.50
7	Saxche-Palmar	Volcanic Glass A	Non-Local	Black Paint	30.23	6.54	1.26	2.33	0.18	22.24	14.92	0.67	0.19	21.43
21	Saxche-Palmar	Carbonate Sand A	Non-Local	Black Paint	12.11	1.37	0.64	3.54	0.77	31.66	18.81	1.57	0.17	29.35
3	Zacatel Cream	Sandstone A	Local	Orange Paint	5.27	0.21	0.66	7.79	0.31	33.44	16.53	1.09	0.15	34.66
1	Saxche-Palmar	Sandstone A1	Local	Orange Slip	11.98	0.09	1.03	2.17	0.53	37.76	16.95	1.47	0.28	27.74
2	Palmar Orange	Sandstone A1	Local	Orange Slip	9.03	0.13	0.89	1.99	0.68	42.22	16.47	1.69	0.22	26.67
13	Saxche-Palmar	Quartz A	Local	Orange Slip	8.07	0.25	0.68	2.24	1.12	41.21	14.24	1.79	0.34	30.07
7	Saxche-Palmar	Volcanic Glass A	Non-Local	Burnished Surface	10.46	2.26	1.04	2.76	0.57	35.08	20.42	0.89	0.24	26.30
21	Saxche-Palmar	Carbonate Sand A	Non-Local	Burnished Surface	6.62	0.11	0.71	3.16	0.74	35.20	20.04	1.62	0.28	31.52
3	Zacatel Cream	Sandstone A	Local	White Slip	5.32	0.69	0.53	9.14	0.42	31.53	14.90	1.17	0.29	36.02
9	Zacatel Cream	Sandstone A2	Local	White Slip	3.16	0.17	0.31	1.65	1.36	43.65	16.16	2.98	0.27	30.30
1	Saxche-Palmar	Sandstone A1	Local	Paste	10.51	1.24	0.44	1.86	0.38	38.29	14.86	1.20	1.10	30.12
2	Palmar Orange	Sandstone A1	Local	Paste	7.49	0.08	0.69	1.61	0.39	44.04	15.74	1.61	0.22	28.14
3	Zacatel Cream	Sandstone A	Local	Paste	4.86	0.08	0.40	1.73	0.38	46.95	11.51	1.05	0.56	32.48
9	Zacatel Cream	Sandstone A2	Local	Paste	15.53	9.72	0.77	3.92	1.04	26.63	13.82	0.99	1.20	26.48
13	Saxche-Palmar	Quartz A	Local	Paste	3.67	0.05	0.15	0.92	0.57	39.32	13.18	0.59	1.23	40.33
7	Saxche-Palmar	Volcanic Glass A	Non-Local	Paste	3.98	1.17	0.49	1.40	0.80	36.26	19.24	0.55	0.67	35.44
21	Saxche-Palmar	Carbonate Sand A	Non-Local	Paste	4.54	0.08	0.74	11.00	0.11	24.75	18.24	0.38	0.39	39.76

CRediT authorship contribution statement

Jillian M. Jordan: Conceptualization, Methodology, Investigation, Resources, Data curation, Writing - original draft, Visualization, Project administration, Funding acquisition. **Keith M. Prufer:** Investigation, Writing - review & editing, Resources, Funding acquisition.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2020.102371>.

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