Hohokam Buff Ware from Honey Bee Village: Petrographic Analysis to Reveal Aspects of Technology and Provenance

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INTRODUCTION

The refinements to a model of sand composition zones (i.e petrofacies) in the Phoenix Basin mean it is now possible to more clearly source sand temper in Hohokam buff ware pottery (Miksa et al. 2004). The current project takes full advantage of this source clarification and also initiates the first examination of buff wares from the Tucson Basin. The analyzed samples were collected during archaeological excavations at the site of Honey Bee Village (AZ BB:9:88 [ASM]) and provide an opportunity to examine exchange of these vessels to an area outside their main production and distribution zone. As the goal was to source the samples through their sand temper, petrographic analysis was performed. While this scientific method has not been commonly used to examine buff wares, it was employed here in the belief that its use has been undervalued for this ceramic ware. The results suggest petrographic analysis can provide valuable information on both the provenance and technology of Hohokam buff wares.

GEOLOGICAL SETTING

As Hohokam buff wares are believed to derive from the Phoenix Basin, and specifically in areas along the middle Gila River, the geology of this region is important to understand (Abbott et al. 2007). Several mountains in this area contribute sediments that create sand for tempering pottery (Miksa 1995). Additionally, schist can be found in this area, which was a prime component of buff wares. Small sources of schist are Gila Butte and Pima Butte, both of which also have granite outcrops. A larger source is in the Santan Mountains where schist crops out in the western and northeastern sections. Other common rock types in the Santan Mountains include granite, granodiorite, and basalt. On the south side of the middle Gila River are the Sacaton Mountains that are mostly granite in composition. Another identified area of production is along Queen Creek, which drains granite, diabase, and some schist outcrops. The distal end of Queen Creek is in the Snaketown area where sands include these grains along with inclusions from the Santan Mountains. These differences in geology have enabled petrofacies (i.e. sand composition zones) to be established for this area (Miksa and Castro-Reino 2001, Miksa et al. 2004). This allows sand temper in buff ware pottery to be sourced to specific areas along the middle Gila River.

SAMPLES AND METHDOLOGY

A total of 512 buff ware sherds was recovered from the Honey Bee Village site. Of this total, 305 (60 percent) were noted to have greater than 25 percent schist during initial binocular temper analysis by J. Heidke. These were not included in the subsequent binocular analysis by M. Ownby for this study as a lack of sand would make provenance identification difficult. Of the remaining 207 sherds, samples were selected only from contexts well dated from the Rillito phase (ca. A.D. 850-950) through the Middle Rincon 1 phase (ca. A.D. 1000-1040). This resulted in the examination of 186 sherds. Binocular analysis was conducted using a Unitron ZSM binocular microscope with a Stocker and Yale Lite Mite Series 9 circular illuminator. The magnification was 15x. Recorded information included the type of temper, generic temper characteristics (i.e. granitic, volcanic), and if it resembled sand from a particular petrofacies, its specific temper. Further recorded attributes included any features of the schist and noticeable grains or rock fragments, presence of caliche and/or clay pellets, and the color of the buff surface.

The results of the binocular analysis were used to select 30 samples for petrographic analysis (Table 1). Several criteria in addition to the binocular results were utilized. This includes the date of the sherds, as it was important to examine samples from the Rillito phase to the Middle Rincon 1 phase. In terms of the Phoenix dating system, this covers the Santa Cruz phase (ca. A.D. 850-950) to the Middle Sacaton 1 phase (ca. A.D. 1020-1070) with the last 30 years of that phase unrepresented. As some of the sherds have a ceramic type of

Table 1. Sample Inventory for Petrographic Analysis.

Sample No.	Context Phase	Ceramic Type
HBA-0105	ER-MR1	Early Sacaton or Middle Sacaton 1 Red-on-buff
HBA-0106	ER-MR1	Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff
HBA-0107	ER-MR1	Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0108	ER-MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0109	ER-MR1	Early Sacaton or Middle Sacaton 1 Red-on-buff
HBA-0110	ER-MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0111	ER-MR1	Unidentified red-painted Hohokam Red-on-buff
HBA-0112	ER-MR1	Unidentified red-painted Hohokam Red-on-buff
HBA-0113	Rillito	Santa Cruz Red-on-buff
HBA-0114	Rillito	Santa Cruz Red-on-buff
HBA-0115	MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0116	Rillito	Early Sacaton Red-on-buff
HBA-0117	ER-MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0118	ER-MR1	Early Sacaton or Middle Sacaton 1 Red-on-buff
HBA-0119	MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0120	MR1	Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff
HBA-0121	ER-MR1	Middle Sacaton 1 Red-on-buff
HBA-0122	ER-MR1	Middle Sacaton 1 Red-on-buff
HBA-0123	ER-MR1	Middle Sacaton 1 Red-on-buff
HBA-0124	ER-MR1	Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff
HBA-0125	Rillito	Santa Cruz Red-on-buff
HBA-0126	Rillito	Santa Cruz Red-on-buff
HBA-0127	Rillito	Santa Cruz or Early Sacaton Red-on-buff
HBA-0128	MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0129	ER-MR1	Early Sacaton Red-on-buff
HBA-0130	MR1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0131	ER-MR1	Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff
HBA-0132	Rillito	Santa Cruz Red-on-buff
HBA-0133	Rillito	Santa Cruz Red-on-buff
HBA-0134	Rillito	Santa Cruz or Early Sacaton Red-on-buff

Middle Sacaton 1, this was felt to be the best concordance and is utilized as the dating in most of the tables. This will hopefully facilitate the comparison of the Honey Bee buff ware results with analysis of buff wares from Phoenix.

Of the 186 sherds examined binocularly, 52 (28 percent) were from Rillito Phase contexts, 96 (52 percent) were from Early Rincon to Middle Rincon 1 phase contexts, and 38 (20 percent) were from Middle Rincon 1 phase contexts. Within the samples selected for petrographic analysis, 9 (30 percent) were from Rillito Phase contexts, 16 (53 percent) were from Early Rincon to Middle Rincon 1 phase contexts, and 5 (17 percent) were from Middle Rincon 1 phase contexts. Thus, the analyzed thin sections proportionately represent the corpus as a whole in regards to the context dates of the sherds.

Also considered for the petrographic samples was ceramic type. Most of the 186 buff ware samples were typed as unidentified red-on-buff (33 percent, n=61) or unidentified with no paint (14 percent, n=27). The remainder were mostly Santa Cruz Red-on-buff (12 percent, n=22), Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff (8 percent, n=14), or Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff (17 percent, n=32). A few sherds were typed as Gila Butte Red-on-buff or to types covering several phases (16 percent, n=30). In selecting samples for petrographic analysis, having sherds that were clearly typed was important in order to relate their provenance to their type. Therefore, only two sherds (7 percent) are unidentified red-on-buff, while six (20 percent) are Santa Cruz Red-on-buff, two (7 percent) are Santa Cruz or Early Sacaton Red-on-buff, two (7 percent) are Early Sacaton Red-on-buff, three (10 percent) are Early Sacaton or Middle Sacaton 1 Red-on-buff, three (10 percent) are Middle Sacaton 1 Red-on-buff, two (7 percent) are Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff, and seven (23 percent) are Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff. This generally reflects the percentages of these types in the corpus of 186 sherds.

While date and ceramic type were important considerations for selecting petrographic samples, the primary criterion was the temper group assignment. This is comprised of the temper type, temper generic, and temper specific. The temper types identified during the binocular analysis were "high schist and low sand" (80 percent, n=149), "low schist and high sand" (13 percent, n=24), "schist and muscovite" (3 percent, n=6), and "mixed sand, schist, and muscovite" (3 percent, n=6). A single sherd had the temper type of "high schist" only and was not analyzed as there was a lack of sand to assist in identifying the provenance. For petrographic analysis, 21 sherds (70 percent) had "high schist and low sand", 4 (13 percent) had "low schist and high sand", 2 (7 percent) had "schist and muscovite", and 3 (10 percent) had "mixed sand, schist, and muscovite". This ensured that the petrographic sample was representative of the larger set of sherds analyzed binocularly.

For the 186 sherds, the generic temper was typically listed as volcanic (n=135, 73 percent) and this cut across the temper types. Less common were sherds with indeterminate generic temper (n=50, 27 percent), while only a single sherd had granitic inclusions. In selecting samples for petrographic analysis, that single sherd was analyzed to determine how it might relate to the other generic tempers. Twenty-two (73 percent) of the 30 thin sectioned sherds had volcanic temper and 7 (23 percent) had indeterminate generic temper. In some cases a petrofacies could be assigned for the specific temper category. Within the 186 sherds, 11 percent (n=21) were characterized as having sand from the Snaketown (N) Petrofacies, while a further 18 percent (n=33) possibly had sand temper from this petrofacies. The one sample that had granitic inclusions was assigned to the Santan Mountains (A) Petrofacies. The remainder, 70 percent (n=131) had an unassigned specific temper. This reflects the difficulty in identifying a particular petrofacies for the source of sand in buff ware sherds. In selecting samples for the petrographic analysis, 13 percent (n=4) were given a specific temper assignment of Petrofacies N, 17 percent (n=5) were thought to possibly have Petrofacies N sand, and for 67 percent (n=20) no petrofacies was specified. The sherd assigned to Petrofacies A was also selected for analysis. The goal was to utilize the petrographic analysis to verify if the specific temper in the sherds had been correctly identified to a petrofacies.

During the binocular temper analysis, comments were made on the general temper (i.e., sand, mica and schist, some sand and schist, etc.), minerals and grain fragments (including the schist types), and presence of caliche and/or clay pellets. This information was also important to consider when selecting samples for petrographic analysis. However, this resulted in 110 different comments so not every single one could be selected for thin sectioning. Rather, those that were the most common were chosen after the samples had been sorted by date, ceramic type, and temper group. Some samples were selected because they contained clay pellets and/or caliche, and these features were important to examine petrographically as they could relate to the technology of buff ware production. Similarly, differences in the color of the buff surface were of interest in terms of how they related to the clay, caliche, and firing temperature, and if there were differences by location of production. The color of the painted surface was recorded for all 186 sherds by eye (not Munsell), and those selected for thin sectioning covered most of the variability seen and the most prevalent colors.

The 30 selected samples were sent to Spectrum Petrographics Inc. to be thin sectioned parallel to the vessel wall. This ensured a large area was available for analysis. The sections were not stained or cover-slipped, but were highly polished in order that microprobe analysis may one day be performed. This is different from the typical petrographic approach and the lack of staining may result in possible difficulties in establishing the percentage of plagioclase and potassium feldspar in the samples. Petrographic analysis consisted of a full examination of the entire section under 100x magnification. The minerals and rock fragments seen were recorded by their frequency (Table 2). Also noted were the clay type and the presence of clay pellets, argillaceous rock fragments (ARF, defined as more solid than clay; see Whitbread 1986), and caliche. Clay type was either mostly iron-rich, a mix of iron-rich and calcareous components (iron-rich/calcareous), or mostly calcareous. This does not imply intentional clay mixing, but rather natural clay-rich soils that have calic and cambic (soil alteration) layers. This is in keeping with a clay source in the Holocene alluvial surfaces (Ya1) found along the middle Gila River (Huckleberry 1992: 6). In thin section, reddish-brown areas of matrix are the iron-rich parts of the clay, while grayish-yellow areas are calcium rich.

Particular attention was paid to the pieces of schist and their component minerals, shape, and size. Size and shape of other rock fragments was recorded as well. Information useful for estimating firing temperature was noted such as the level of decomposition of caliche and the optical activity of the clay matrix. Above 850°C most of the caliche will be decomposed and the matrix will be optically inactive. However, the calcium content of the clay may lower the temperature at which the matrix becomes vitrified and thus optically inactive. Therefore, a general firing temperature estimate was given as low (below 800°C), medium (800-850°C), and high (above 850°C).

Table 2. Codes for grain size and grain frequency used in analysis of thin sections.

Category	Code	Definition
Size	Very fine	0.0625-0.125 mm
	Fine	0.125-0.25 mm
	Medium	0.25-0.5 mm
	Coarse	0.5 – 1 mm
	Very Coarse	1 – 2 mm
Frequency	1	Very rare (1-5 grains)
	2	Rare (c. 10%)
	3	Sparse (c. 10-25%)
	4	Frequent (c. 25-50%)
	5	Abundant (c. 50-75%)
	6	Highly Abundant (c. >75%)

To establish the provenances of the sherds, sand samples from eight petrofacies (A, B, C, D, E, G, H, and N) were examined (Figure 1; Miksa and Castro-Reino 2001, Miksa et al. 2004). Initially, binocular assessment of the sand samples was performed in preparation for the binocular analysis of the sherds. During the petrographic analysis, the thin sections of the sands were examined. This greatly facilitated the provenance assignments by revealing morphological and textural features of the grains in the sand that could be related to those seen in the sand temper. Additionally, six schist rock samples had been collected from outcrops along the middle Gila River (Miksa 1995b, 1998, 2001). These samples had been thin sectioned allowing features of the schist to be clearly related to the schist fragments in the sand. As part of an experiment, pieces of the schist rock samples were crushed (both fired and unfired schist) and added to a terracotta clay. These clay/crushed schist briquettes were fired and subsequently thin sectioned. Petrographic examination of these thin sections also assisted in characterizing fragments of crushed schist and their appearance after firing to create a briquette. The sand, schist rock, and crushed schist briquette thin sections proved invaluable to assessing the provenance of the sherds and the possible source of the schist in the temper.

RESULTS

While the binocular analysis was conducted prior to the petrographic analysis, in order to assess the results of the binocular examination it is important to discuss the provenance assignments of the 30 thin sectioned sherds. This will allow the success of the binocular analysis to be determined. The data from the petrographic analysis are presented in Tables 3 through 6.

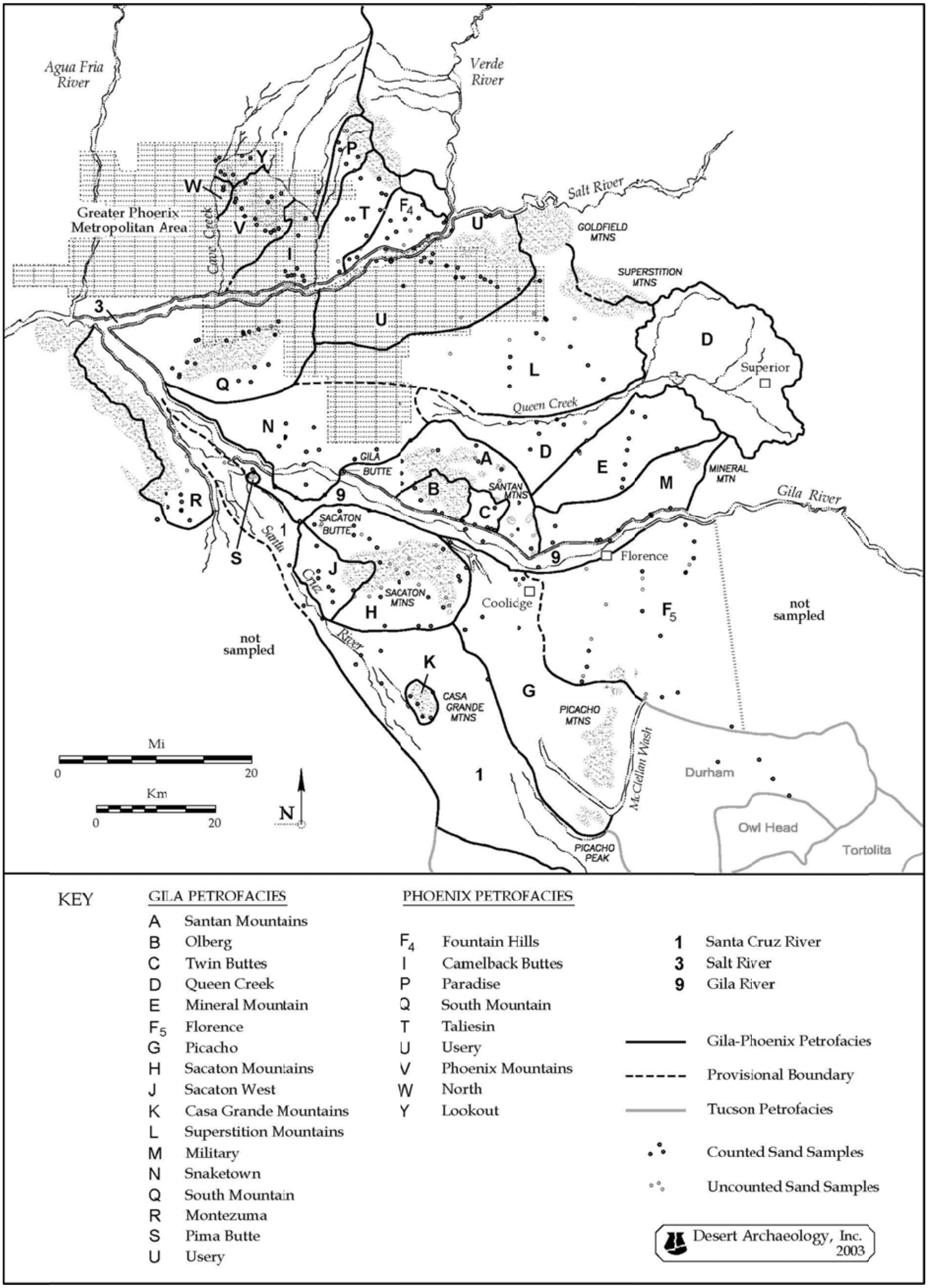

Figure 1. Map of Phoenix and middle Gila River Petrofacies.

Table 3. Binocular analysis results.

Sample No.	Phase[1]	Petrofacies	Temper Characteristics
HBA-0105	ESAC to MSAC1	A	fine sand & mica (qtz, kspar, brown mica and granular schist, few black grits, granite, granite-to-gneiss, granodiorite)
HBA-0106	ESAC to MSAC1	A	fine sand & mica (qtz, granular schist, red volcs, grog?)
HBA-0107	ESAC to MSAC1	N	fine sand & mica (qtz, kspar, plag, granular schist, black grits, red volcs, diabase)
HBA-0108	ESAC to MSAC1	A	sand, mica, schist (qtz, brown mica schist, some black grits, diabase?)
HBA-0109	ESAC to MSAC1	A	sand, mica, schist (qtz, brown mica and granular schist, some black grits, granodiorite?)
HBA-0110	ESAC to MSAC1	A	sand & schist (qtz, brown mica and granular schist, few black grits, granite, siltstone, obsidian?, brown LVI volcs=D?)
HBA-0111	ESAC to MSAC1	A	sand & schist (qtz, kspar, brown mica and granular schist, black grits, red volcs)
HBA-0112	ESAC to MSAC1	N	sand & schist (qtz, kspar, brown mica and granular schist, black grits, red volcs, diabase)
HBA-0113	Santa Cruz	N	sand & schist (qtz, kspar, brown mica and granular schist, black grits, red volcs, diabase?, plag, epidote)
HBA-0114	Santa Cruz	A?	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, grey volcs?, vitric volcs)
HBA-0115	ESAC to MSAC1	N	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, red volcs)
HBA-0116	Santa Cruz	N	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, red volcs, granodiorite)
HBA-0117	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, some black grits, grey volcs?)
HBA-0118	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, granite?)
HBA-0119	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, red volcs?, granite)
HBA-0120	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs)
HBA-0121	ESAC to MSAC1	A	some sand & schist (qtz, kspar, brown mica and granular schist, few black grits, volcs, granite-to-gneiss)
HBA-0122	ESAC to MSAC1	A	some sand & schist (qtz, kspar, brown mica and granular schist, some black grits, volcs, granite-to-gneiss)
HBA-0123	ESAC to MSAC1	A	some sand & schist (qtz, kspar, brown mica and granular schist, some black grits, volcs)
HBA-0124	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, few black grits, volcs, red volcs?)
HBA-0125	Santa Cruz	N	some sand & schist (qtz, brown mica and granular schist,some black grits, volcs, red volcs?, epidote)
HBA-0126	Santa Cruz	N	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, red volcs?, rhyolite?)
HBA-0127	Santa Cruz	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs, rhyolite, vitric volcs, granite-to-gneiss)
HBA-0128	ESAC to MSAC1	A	some sand & schist (qtz, kspar, brown mica and granular schist, some black grits, volcs?)
HBA-0129	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs?)
HBA-0130	ESAC to MSAC1	A?	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs?)
HBA-0131	ESAC to MSAC1	A	some sand & schist (qtz, brown mica and granular schist, few black grits, grog?)
HBA-0132	Santa Cruz	A?	some sand & schist (qtz, kspar, brown mica and granular schist, some black grits, volcs?)
HBA-0133	Santa Cruz	A	some sand & schist (qtz, brown mica and granular schist, some black grits, volcs?, granite-to-gneiss?)
HBA-0134	Santa Cruz	A	some sand & schist (qtz, kspar, brown mica and granular schist, some black grits, volcs?, granite)

[1]ESAC=Early Sacaton; MSAC1=Middle Sacaton 1

Table 4. Description of fired paste.

Sample No.	Phase[1]	Temper Type	Temper Generic	Temper Specific	Petrofacies	Temper (Petrographic)	Percentage of Inclusions	Sorting
HBA-0105	ESAC to MSAC1	Mixed sand, schist, and muscovite	Granitic	A	A	Sand	30	Poor
HBA-0106	ESAC to MSAC1	Mixed sand, schist, and muscovite	Volcanic	N?	A	Sand	10	Fair
HBA-0107	ESAC to MSAC1	Mixed sand, schist, and muscovite	Volcanic	N	N	Sand	50	Poor
HBA-0108	ESAC to MSAC1	Schist and muscovite	Volcanic	Indeterminate	A	Sand	30	Poor
HBA-0109	ESAC to MSAC1	Schist and muscovite	Volcanic	N	A	Sand	20	Poor
HBA-0110	ESAC to MSAC1	Low schist/high sand	Volcanic	Indeterminate	A	Sand	40	Poor
HBA-0111	ESAC to MSAC1	Low schist/high sand	Volcanic	N?	A	Sand	20	Fair
HBA-0112	ESAC to MSAC1	Low schist/high sand	Volcanic	N	N	Sand	40	Fair
HBA-0113	Santa Cruz	Low schist/high sand	Volcanic	N	N	Sand	30	Poor
HBA-0114	Santa Cruz	High schist/low sand	Volcanic	N?	A?	Sand	40	Poor
HBA-0115	ESAC to MSAC1	High schist/low sand	Volcanic	N?	N	Sand	40	Poor
HBA-0116	Santa Cruz	High schist/low sand	Volcanic	N?	N	Sand	30	Fair
HBA-0117	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Fair
HBA-0118	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Poor
HBA-0119	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Poor
HBA-0120	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	30	Poor
HBA-0121	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Fair
HBA-0122	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Poor
HBA-0123	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	10	Poor
HBA-0124	ESAC to MSAC1	High schist/low sand	Volcanic	Indeterminate	A	Sand	30	Poor
HBA-0125	Santa Cruz	High schist/low sand	Volcanic	Indeterminate	N	Sand	40	Poor
HBA-0126	Santa Cruz	High schist/low sand	Volcanic	Indeterminate	N	Sand	40	Poor
HBA-0127	Santa Cruz	High schist/low sand	Volcanic	Indeterminate	A	Sand	20	Fair
HBA-0128	ESAC to MSAC1	High schist/low sand	Indeterminate	Indeterminate	A	Sand	20	Poor
HBA-0129	ESAC to MSAC1	High schist/low sand	Indeterminate	Indeterminate	A	Sand	20	Poor
HBA-0130	ESAC to MSAC1	High schist/low sand	Indeterminate	Indeterminate	A?	Sand	20	Poor
HBA-0131	ESAC to MSAC1	High schist/low sand	Indeterminate	Indeterminate	A	Sand	20	Poor
HBA-0132	Santa Cruz	High schist/low sand	Indeterminate	Indeterminate	A?	Sand	40	Poor
HBA-0133	Santa Cruz	High schist/low sand	Indeterminate	Indeterminate	A	Sand	20	Poor
HBA-0134	Santa Cruz	High schist/low sand	Indeterminate	Indeterminate	A	Sand	20	Poor

[1] ESAC=Early Sacaton; MSAC=Middle Sacaton 1

Table 5. Types and amounts of rock fragments (see Table 2 for codes).

Sample No.	Petrofacies	LVF[1]	LVFB	LVI	LVM	LVV	LMA	LMT	LMTP	Schist Types
HBA-0105	A	2	0	2	0	1	2	3	0	Mica, quartz muscovite
HBA-0106	A	2	0	1	1	0	1	2	0	Mica, quartz muscovite, Gila Butte
HBA-0107	N	3	1	2	2	2	1	3	1	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0108	A	2	0	1	1	1	1	3	0	Mica, quartz muscovite, Gila Butte
HBA-0109	A	2	0	1	1	1	1	2	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0110	A	2	0	1	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0111	A	2	0	2	2	0	2	2	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0112	N	3	1	2	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0113	N	2	1	2	2	1	2	3	0	Mica, quartz muscovite, Gila Butte
HBA-0114	A?	1	0	1	1	0	2	3	0	Mica, quartz muscovite, also cataclastics
HBA-0115	N	2	0	2	2	2	1	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0116	N	2	0	2	2	1	1	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0117	A	2	0	2	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0118	A	2	0	0	1	1	1	3	0	Mica, quartz muscovite, Gila Butte
HBA-0119	A	2	0	1	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0120	A	2	0	2	2	1	1	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0121	A	2	0	0	0	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0122	A	2	0	0	0	0	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0123	A	2	0	1	1	0	1	3	0	Mica, quartz muscovite, Gila Butte
HBA-0124	A	2	0	2	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0125	N	3	0	2	2	2	2	3	1	Mica, quartz muscovite, Gila Butte
HBA-0126	N	3	0	2	2	1	1	3	0	Mica, quartz muscovite, Gila Butte
HBA-0127	A	2	0	1	1	0	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0128	A	2	0	1	2	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0129	A	2	0	1	2	1	2	3	0	Mica, quartz muscovite, Gila Butte
HBA-0130	A?	2	0	2	1	1	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0131	A	2	0	2	1	0	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0132	A?	2	0	1	0	0	3	3	0	Mica, quartz muscovite, Gila Butte, also many cataclastics
HBA-0133	A	2	0	1	1	0	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics
HBA-0134	A	2	0	1	1	0	2	3	0	Mica, quartz muscovite, Gila Butte, also cataclastics

[1] LVF=felsic volcanic (e.g. rhyolite), LVFB=felsic volcanic with biotite, LVI=intermediate volcanic (e.g. andesite), LVM=mafic volcanic (e.g. basalt), LVV=vitric volcanic, LVH=hypabyssal volcanics, LMA=quartz-feldspar (mica) aggregate (e.g. gneiss and cataclastics), LMT=quartz-feldspar-mica tectonite (e.g. schist), LMTP= fine-grained quartz-feldspar-mica-tectonite (e.g. phyllite).

Table 6. Types and amounts of monomineralic inclusions (see Table 2 for codes).

Sample No.	Petrofacies	QTZ[1]	KSPAR	MICR	PLAG	PLAGAL	MUSC	BIOT	CHLOR	PX	AMPH	OPAQ	EPID	GAR	TOUR
HBA-0105	A	4	3	2	3	2	2	2	2	2	2	2	0	1	0
HBA-0106	A	3	2	0	2	1	1	1	2	2	2	2	1	1	1
HBA-0107	N	4	2	1	2	2	1	1	2	2	2	3	0	0	0
HBA-0108	A	3	1	1	2	0	2	2	2	1	1	2	0	0	1
HBA-0109	A	3	1	1	2	0	3	1	2	2	2	2	1	1	1
HBA-0110	A	4	2	1	2	2	2	2	2	2	2	2	1	0	2
HBA-0111	A	4	2	1	2	2	2	2	2	1	1	2	1	0	1
HBA-0112	N	4	2	1	2	2	2	2	2	2	2	2	1	0	1
HBA-0113	N	4	2	1	2	2	2	1	2	2	2	2	1	0	1
HBA-0114	A?	4	1	0	2	2	2	1	2	1	1	2	0	0	0
HBA-0115	N	4	2	2	2	0	2	2	2	2	2	2	1	0	0
HBA-0116	N	4	2	1	2	2	2	2	2	2	2	2	1	0	1
HBA-0117	A	3	2	1	2	0	2	1	2	2	2	2	1	0	1
HBA-0118	A	3	2	0	2	2	2	1	2	1	2	2	0	0	1
HBA-0119	A	3	2	1	2	2	2	2	2	1	2	2	1	1	2
HBA-0120	A	3	2	0	2	1	2	1	2	2	2	2	1	0	1
HBA-0121	A	3	2	2	2	2	2	2	2	2	2	2	1	0	1
HBA-0122	A	3	2	1	2	2	2	2	2	2	2	2	1	0	1
HBA-0123	A	3	2	1	2	2	2	2	2	2	2	2	0	0	1
HBA-0124	A	3	2	1	2	2	2	2	2	2	2	2	0	0	1
HBA-0125	N	4	2	2	2	2	2	1	2	2	2	2	1	1	1
HBA-0126	N	4	2	2	2	2	2	2	2	2	2	2	0	0	0
HBA-0127	A	3	2	1	2	0	2	2	2	2	2	2	0	0	1
HBA-0128	A	3	2	1	2	0	2	2	2	2	2	2	1	0	1
HBA-0129	A	3	2	1	2	1	2	2	2	2	2	2	1	0	1
HBA-0130	A?	3	2	0	2	2	2	1	2	2	2	2	0	0	0
HBA-0131	A	3	2	1	2	2	2	2	2	2	2	2	0	0	1
HBA-0132	A?	3	1	0	2	2	3	1	2	1	2	2	1	0	1
HBA-0133	A	3	2	1	2	1	0	2	2	2	2	2	1	0	1
HBA-0134	A	3	2	1	2	2	2	2	2	2	2	2	0	0	1

[1] qtz=quartz, kspar=potassium feldspar, micr=microcline, plag=plagioclase, plagal=altered plagioclase, mus=muscovite, bio=biotite, chlor=chlorite, px=pyroxene, amph=amphibole, opaq=opaques, gar=garnet, epid=epidote, tour=tourmaline.

Petrographic Analysis

Samples Sourced to the Santan Mountains (A) Petrofacies

The majority of the 30 samples contained sand temper that appeared to be from the Santan Mountains (A) Petrofacies, 20 sherds in total (see Figure 1). An additional three samples had temper grains that resembled some of those in Petrofacies A, but the overall characteristics were atypical. In general, the sand temper in the 20 samples contained mostly schist that comprised at least 40 percent of the inclusions. However, most of the samples did not contain a large amount of temper with a sand to clay ratio typically in the range of 30:70. Variability was noted from sample to sample with some having more granite and others less. The presence of minor constituents, including volcanic rock fragments, also varied. This suggests that the sand present in the sherds was collected from several areas, which probably varied over time and by potter. Overall, the source of the sand temper is likely to have been from east of Gila Butte to the western edge of the Santan Mountains, adjacent to the middle Gila River.

The schist fragments ranged in size from fine to very coarse, were coarse-grained, and often subrounded. Some of the pieces were mostly quartz with grains of muscovite, chlorite, and opaques, and less common biotite. The quartz for a number of the schist fragments was strained; something previously termed "Pinal Matrix" (Miksa 2001). Other schist inclusions were dominated by muscovite, chlorite, and opaques with rarer biotite. A third schist type contained a mostly sericite (altered plagioclase) matrix with inclusions of muscovite, chlorite, opaques, and some quartz. This type resembled the schist collected from Gila Butte, especially when the schist in the briquettes was compared to that in the sherds; it is termed "Gila Butte type" (Miksa 2001). However, in examining many of the sherds, it became clear that the three schist types most likely derived from the same outcrop and represented different layers in the schist. Of note were small grains of tourmaline that were seen in most of the schist types. Tourmaline in schist was noted for a rock sample from the Santan Mountains and suggests a possible source for the schist, although a Gila Butte source cannot be excluded (confirmed by Sophia Kelly, personal communication, 2012). In fact, the appearance of the majority of the schist fragments in most of the samples suggested it was a natural part of the sand temper and not added as a crushed or disaggregated rock (Figure 2, see Appendix A for more thin section images). This means both the Santan Mountains and Gila Butte could have contributed schist grains to a sand located between the two areas, although the outcrops of the Santan Mountains are considerably more extensive.

A further indication that the schist is natural to the sand comes from the other inclusions in the temper and their morphology. The second most common rock type after schist was granite grains with quartz, plagioclase, potassium feldspar, and microcline as components. Some of the granite fragments showed strain and a gneissic texture, while pieces of more typical gneiss were also present. Both the gneiss and granite inclusions were often medium to very coarse in size, typically larger than the schist fragments and more angular as well. It seems unlikely that only a small amount of sand derived from a location close to a granite/gneiss outcrop would be added to crushed schist. Further, within the Santan Mountains, granite, gneiss, and schist can be found, and their erosion would create a sand containing angular and large granite pieces and smaller, round schist that weathers more easily. Such a sand (GB-0014) was seen in thin section from a sample taken near the southwestern part of the Santan Mountains.

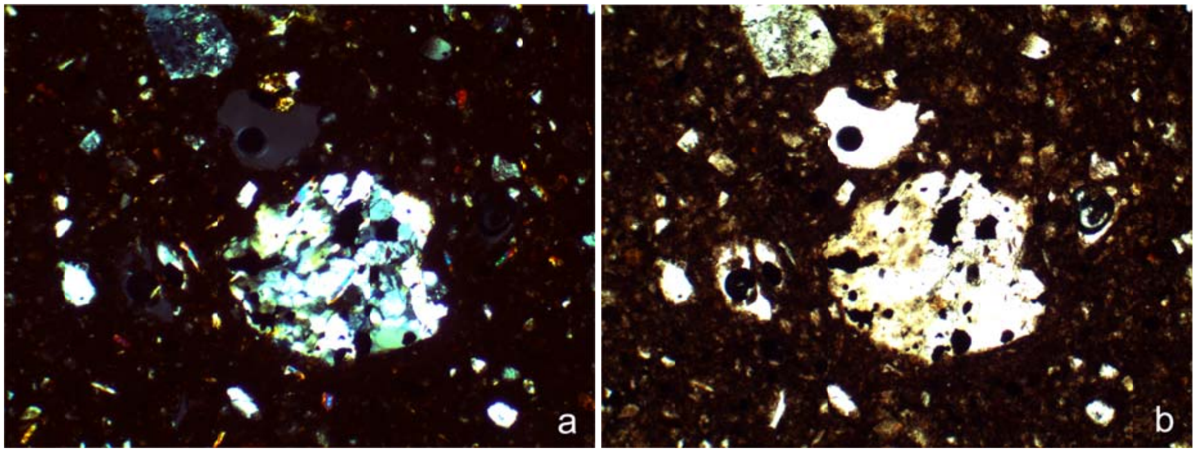

Figure 2. Photomicrographs: (a) cross polarized image of HBA-0120 showing a round schist fragment, taken at 100x magnification; (b) plane polarized image of same view.

Other inclusions in the sand were cataclastic grains and volcanic rock fragments. The cataclastic grains derive from metamorphic processes along an active fault where the grinding action has altered the texture of the original rock. This occurred in the Santan Mountains when the older Pinal Schist was intruded by Late Cretaceous to early Tertiary granite (Ferguson and Skotnicki 1996). In fact, at the west end of the range, a south-southeast fault is found in a significant valley going in the same direction. In examining samples of sand from the Santan Mountains Petrofacies, such cataclastic grains were noted, although they were also seen less frequently in sand from the Queen Creek (D) Petrofacies.

The volcanic grains are often very fine to fine in size and mostly rounded. Their composition varies from felsic to intermediate to mafic, comprising mostly grains of tuff, dacite, and andesitic basalt. The source of these grains is probably Tertiary volcanic rocks in the Santan Mountains (Ferguson and Skotnicki 1996). These are composed of red colored welded ash-flow tuff (prominent in the southwestern section) and basalt. Rare dacite and diabase dikes are also found. Other possible contributors of the minor volcanic grains in the sand are the distal end of Queen Creek and flood deposits from the Gila River. Both water courses drain areas where volcanic rocks are common.

Most of the monomineralic grains found in the sand derive from the granite and schist rock fragments. This includes quartz, plagioclase (some altered), potassium feldspar, microcline, and amphibole from granite and granodiorite. The latter was rarely seen intact in the sand but is present in the Santan Mountains. The schist contributed mostly quartz, muscovite, chlorite, opaques, and smaller amounts of biotite and tourmaline. Pyroxene grains are likely from the granodiorite and volcanic rock fragments, particularly basalt and diabase. The volcanic rock inclusions were clearly the source of some of the plagioclase. The overall appearance of the sand is one derived from an area with schist and granite along with minor volcanic rocks. This matches well the geology of the western end of the Santan Mountains.

Most of the samples, sixteen, were made with a clay that was a mix of iron-rich and calcareous components (Table 7). Some had a more heterogeneous appearance, while others were more homogenous, but almost all contained clay pellets. For four samples the clay pellets were more solidified and would be classed as argillaceous rock fragments, ARF. Six samples had a more calcareous clay and half of these included clay pellets. One sherd had a dominantly iron-rich clay that contained clay pellets and a few ARF. The firing temperature of the samples was mostly medium (800-850°C) due to the slight decomposition of the caliche and mostly optically inactive paste. Eight samples were probably fired at a lower temperature, around 750°C to 800°C. All but one of the lower fired sherds had an iron-rich and calcareous clay. The presence of caliche was helpful in establishing the firing temperature, but whether it derived from the clay, sand temper, or was a separate addition was not always easy to determine. Within the iron-rich clay samples, coarse sized caliche has the greatest chance of being an intentional addition (Figure 3, see Appendix A for more thin section images). In examining sand thin sections, caliche is not very common but this does not negate the possibility that the sand temper is the source of the caliche in the sherds. For the iron-rich/calcareous clay samples most appeared to have added caliche, except for two samples where it was difficult to determine and two where the small amount of caliche may have been natural to the clay or sand. For the calcareous clay samples, three had natural caliche, two appeared to have caliche as an addition, and in one sample it was not possible to determine the origin of the caliche. In summary, for the sherds assigned to Petrofacies A, the typical paste seems to be one composed of an iron-rich/calcareous clay with clay pellets, added caliche, and a medium firing temperature.

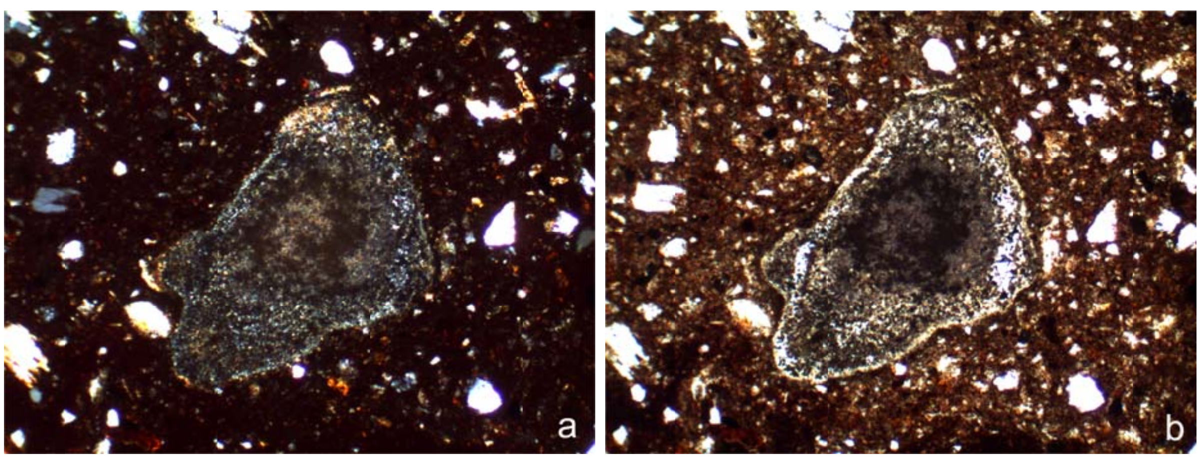

Figure 3. Photomicrographs: (a) cross polarized image of HBA-0120 showing a piece of decomposed caliche probably added to the paste, taken at 100x magnification; (b) plane polarized image of same view.

Samples Sourced to the Snaketown (N) Petrofacies

Seven of the 30 analyzed samples contained sand sourced to the Snaketown (N) Petrofacies (see Figure 1). This sand was generally similar to that seen in the samples with Santan Mountains Petrofacies sand, but included more volcanic rock fragments that were larger in size. Their composition ranged from felsic and intermediate to mafic. Most were identified as tuff, rhyolite, dacite, and basalt. Very eroded pieces of diabase were also seen. These rock

Table 7. Technological features.

			BINOCULAR ANALYSIS		PETROGRAPHIC ANALYSIS			
Sample No.	Phase[1]	Petrofacies	Surface Color	Paste Features	Clay	Clay Pellets	Caliche	Firing Temperature
HBA-0105	ESAC to MSAC1	A	pink-buff	Clay pellets	Iron-rich/calcareous	Present/ARF	Added	Medium
HBA-0106	ESAC to MSAC1	A	buff-grey	Clay pellets?	Mostly calcareous	Present	Added	Medium
HBA-0107	ESAC to MSAC1	N	pink-buff	None	Iron-rich/calcareous	Present/ARF	Added	Medium
HBA-0108	ESAC to MSAC1	A	buff-grey	None	Iron-rich/calcareous	Present	Added	Medium
HBA-0109	ESAC to MSAC1	A	pink-buff	None	Iron-rich/calcareous	Present	Added	Medium
HBA-0110	ESAC to MSAC1	A	pink-orange	None	Mostly iron-rich	Present/ARF	Added	Medium
HBA-0111	ESAC to MSAC1	A	pink-orange	None	Iron-rich/calcareous	Present/ARF	Added	Medium
HBA-0112	ESAC to MSAC1	N	pink-orange	Clay pellets, caliche	Iron-rich/calcareous	Present/ARF	Natural	Medium
HBA-0113	Santa Cruz	N	pink-buff	Clay pellets	Mostly calcareous	Present/ARF	Added	Medium
HBA-0114	Santa Cruz	A?	cream-buff	None	Mostly calcareous	Absent	Natural	Medium
HBA-0115	ESAC to MSAC1	N	pink-buff	None	Iron-rich/calcareous	Present	Added?	Low
HBA-0116	Santa Cruz	N	pink-orange	None	Mostly iron-rich	Present/ARF	Added	Medium
HBA-0117	ESAC to MSAC1	A	cream-buff	None	Iron-rich/calcareous	Present	Natural	Low
HBA-0118	ESAC to MSAC1	A	pink-buff	None	Iron-rich/calcareous	Present	Added	Medium
HBA-0119	ESAC to MSAC1	A	pink-buff	None	Iron-rich/calcareous	Present	Added	Low
HBA-0120	ESAC to MSAC1	A	pink-buff	Clay pellets	Iron-rich/calcareous	Present	Added	Medium
HBA-0121	ESAC to MSAC1	A	pink-orange	None	Iron-rich/calcareous	Present	Added	Medium
HBA-0122	ESAC to MSAC1	A	pink-buff	None	Iron-rich/calcareous	Present	Added	Low
HBA-0123	ESAC to MSAC1	A	pink-orange	None	Iron-rich/calcareous	Present	Added	Low
HBA-0124	ESAC to MSAC1	A	pink-orange	Caliche	Iron-rich/calcareous	Present	Added	Low
HBA-0125	Santa Cruz	N	pink-buff	Clay pellets	Mostly calcareous	Present/ARF	Added?	Medium
HBA-0126	Santa Cruz	N	pink	None	Iron-rich/calcareous	Present/ARF	Natural	Medium
HBA-0127	Santa Cruz	A	cream-buff	Clay pellets	Mostly calcareous	Absent	Natural	Medium
HBA-0128	ESAC to MSAC1	A	pink-orange	Caliche	Iron-rich/calcareous	Present	Added	Medium
HBA-0129	ESAC to MSAC1	A	pink-buff	None	Iron-rich/calcareous	Present	Added?	Low
HBA-0130	ESAC to MSAC1	A?	pink-buff	Caliche	Iron-rich/calcareous	Present/ARF	Added?	Medium
HBA-0131	ESAC to MSAC1	A	buff-grey	None	Mostly calcareous	Present	Added?	Low
HBA-0132	Santa Cruz	A?	cream-buff	None	Mostly calcareous	Absent	Added	Medium
HBA-0133	Santa Cruz	A	pink-buff	None	Iron-rich/calcareous	Present	Natural	Low
HBA-0134	Santa Cruz	A	cream-buff	None	Mostly calcareous	Present	Natural	Medium

1 ESAC=Early Sacaton; MSAC=Middle Sacaton 1 fragments are likely to originate from Queen Creek as the Snaketown Petrofacies encompasses the distal end of that system. However, the Petrofacies N sand has more red volcanic rock fragments (mostly basalt), less diabase and rhyolite, and more fragments of pyroxene and amphibole than sands in the Queen Creek Petrofacies. This reflects the distance of the Snaketown Petrofacies sands from the original rocks and the contribution of material from the Santan Mountains, including basalt. These mountains also contribute granite, minerals from granite, and to a lesser extent gneiss, so that the sand contains these inclusions as well. While the Queen Creek Petrofacies sand also includes granite, there are more gneiss grains and less free, rounded quartz. These distinctions between the sand from the two petrofacies allowed the sand temper to be clearly identified as derived from the Snaketown Petrofacies.

While half of the temper was composed of volcanic rock fragments and a few pieces of granite and gneiss, the other half was comprised of various types of schist and rare cataclastics in one sample. The schist included a quartz muscovite type (quartz, muscovite, chlorite, opaques, less biotite), a mica type (muscovite, chlorite, opaques , less biotite), and the Gila Butte type (sericite, muscovite, chlorite, opaques, less quartz) previously described. These grains were similar in appearance to those in the Santan Mountains samples and also appeared natural to the sand. The schist was often subrounded and ranged in size from fine to very coarse. They may have derived more from Gila Butte than from the Santan Mountains, but that is difficult to establish. This is because the schists from both sources are likely to be similar, something noted in previous studies (Miksa 1995b, 1998, 2001). The presence of tourmaline in some samples may indicate the schist is from the Santan Mountains, but more information on the varieties of schist at Gila Butte is needed to confirm this supposition. Of note, in a sand collected near Gila Butte, the schist looked more fine grained than the schist seen in the sand near the Santan Mountains.

The monomineralic grains were clearly from granite or granodiorite (quartz, plagioclase, potassium feldspar, microcline, amphibole), schist (quartz, muscovite, biotite, chlorite, opaques), and volcanic rock fragments (pyroxene, amphibole, plagioclase). In combination with the intact rock inclusions, the overall characteristics of the sand matched well with sand samples from the Snaketown Petrofacies, but in having more schist, the sand temper was likely acquired closer to schist outcrops.

The clay in these samples varied from those with a more iron-rich composition (HBA-0116) to those with a mostly calcareous appearance (HBA-0113) (see Table 7). In between were ones with a mixed calcareous and iron-rich clay (HBA -0107, HBA-0112, HBA-0115, HBA-0124, and HBA-0126). Clay pellets were present in all of the samples and more solidified iron-rich ARF were seen in all but sample HBA-0115, which also had a low firing temperature (intact caliche seen). All of the other samples had a medium firing temperature. This was determined based on the slight decomposition of the caliche, which in samples HBA-0112 and HBA-0125 was fine-sized and probably natural to the clay. In the rest of the samples, caliche fragments appeared to have been added, although this was not always clear. For samples from Petrofacies N, the paste recipe varied so it is not possible to specify a typical formula. One thing that may be characteristic is the large, noticeable ARF that were seen in all but one sample (confirmed by Sophia Kelly, personal communication, 2012).

Binocular Microscopy

Hohokam buff ware sherds are somewhat challenging to examine with binocular microscopy. Often the most visible aspects of the temper are the schist fragments. Less common are other inclusions such as sand-sized granite grains and pieces of volcanic rocks. In comparison with the petrographic results, it is clear there were difficulties in identifying sand from Petrofacies A in the sherds and most were not classified as belonging to this petrofacies or having granitic temper during the binocular analysis (Table 8). For the sherds identified as containing Petrofacies N sand, three of the four were confirmed to have sand from this petrofacies. The single sherd characterized as having Petrofacies A sand was also correct. Samples with a specific temper of Petrofacies N? could contain sand from Petrofacies A or N. The majority of samples had an indeterminate specific temper and were assigned to Petrofacies A petrographically except for two samples with Petrofacies N sand. Concerning the generic temper assignment, this was largely incorrect as most of the sand temper contained granitic and granite/gneiss grains from Petrofacies A. This is likely due to a focus on volcanic inclusions by the analyst as these are common in only two petrofacies. The temper types were largely supported by the petrographic analysis that revealed frequent, large schist grains in those samples with “high schist and low sand”, less common schist in the “mixed sand, schist, and muscovite” samples, and rare granite in the samples with “schist and muscovite” temper. However, the “low schist and high sand” samples still had prevalent and often large pieces of schist. Unfortunately, these results make it difficult to provide a provenance assignment for the sherds not examined petrographically.

Table 8. Binocular analysis results in comparison to petrographic results.

BINOCULAR ANALYSIS			PETROGRAPHIC ANALYSIS		
Temper Type	Temper Generic	Temper Specific	Petrofacies A	Petrofacies N	Total
High schist and low sand	Volcanic	N?	1	2	3
	Volcanic	Indeterminate	9	2	11
	Indeterminate	Indeterminate	7	0	7
Low schist and high sand	Volcanic	N	0	2	2
	Volcanic	N?	1	0	1
	Volcanic	Indeterminate	1	0	1
Schist and muscovite	Volcanic	N	1	0	1
	Volcanic	Indeterminate	1	0	1
Mixed sand, schist and muscovite	Granitic	A	1	0	1
	Volcanic	N	0	1	1
	Volcanic	N?	1	0	1

The lack of success of the binocular analysis is due to several issues. First is the variable amount of sand in the samples. Generally, those with common sand would be easier to assign to a generic and specific temper, while those with rarer sand would be a more difficult. The petrographic analysis allowed the percent of inclusions (relative to the clay) to be estimated. This showed that two samples had as little as 10 percent sand, while one had up to 50 percent (see Table 3). Fourteen samples had 20 percent sand temper, six samples had 30 percent sand, and seven samples had 40 percent sand. For some samples the small amount of sand appeared to make determining the generic and specific temper challenging, but for other samples this was not the case. These latter samples often had more monomineralic grains and rock fragments beside schist in the sand. Those samples with mostly schist and less frequent granite inclusions proved very difficult to classify. Overall, it seemed that above 30 percent in amount of inclusions with half being non-schist, the temper characterization can be fairly accurate. Other issues included the lack of experience with buff ware temper analysis by the analyst and the need to identify specific inclusions and guidelines that would assist in temper identification. This information was clearer after the petrographic analysis. In fact, when the thin sectioned sherds were binocularly examined a second time, after the petrographic analysis, the sand differences between Petrofacies N and A were readily identifiable for the majority of sherds (Jim Heidke, personal communication, 2012). In general, samples with Petrofacies A sand had noticeable granite and cataclastic grains, while those with Petrofacies N sand had a more heterogeneous mix of grains. It is likely that if the Honey Bee buff ware sherd collection as a whole was re-examined, these criteria would aid in characterizing their provenance. This is corroborated by the work of S. Kelly whose dissertation utilized petrographic verification of binocular analysis of buff wares. Most of the binocular identifications were confirmed petrographically, especially for the sherds containing Petrofacies N sand. Therefore, it is likely that with some newly established criteria such as the presence of cataclastic and granite grains for Petrofacies A sand and mixed sand for Petrofacies N, along with additional training, binocular analysis of buff wares would prove fairly successful. A new flowchart for sand identification in sherd thin sections has been developed by S. Kelly that considers sands used for buff ware production outside Petrofacies A and N. This could be modified for binocular analysis based on her results and those of the current study. Such a revised flowchart for buff wares would likely improve binocular analysis; however, it is highly recommended that in any study petrographic confirmation is included.

While success in relating the binocular and petrographic results for source identification was not achieved, other binocular features were recorded that could be assessed petrographically (see Table 6). These include the presence of clay pellets and/or caliche and the color of the buff surface. Clay pellets were seen during the binocular analysis in seven samples. For four samples this was confirmed and the pellets were more correctly identified as ARF. For the other three samples, two had clay pellets but no ARF, while one lacked clay pellets entirely. This latter sample contained a few large caliche inclusions that may have been confused for clay pellets. However, ARF were also seen in five samples during the petrographic analysis but not during binocular examination. In some cases, the ARF were small and/or infrequent. It should be noted that almost all of the samples, except three, had clay pellets even if they were not identified during the binocular analysis.

Caliche was recorded during the binocular examination for four samples. For all but one, the caliche appeared to have been added and was not related to the sand or clay. Fourteen additional samples had added caliche that was not seen under the binocular microscope. Only in one of the six samples with caliche natural to the clay was it seen macroscopically. However, for a number of samples only a small amount of caliche was probably added to the paste.

The color of the buff surface of the samples was of interest as this relates to technological processes. Several previous studies have shown that the buff surface is due to the use of a calcareous clay with the addition of caliche and fired above 850°C (Weisman 1987; Abbott and Love 2001; Abbott 2008). Therefore, the color of the surface will depend on the clay, amount of caliche, and firing temperature. The samples were divided into three surface color groups. Samples with a buff-grey or cream-buff surface (n=8) mostly had been made with a calcareous clay with the exception of two samples whose clay was iron-rich/calcareous. Four of the samples had natural caliche, while three and possibly four had added caliche. The firing temperature for all but two was medium (i.e., below 850°C), while those with a grey buff surface appeared to have been fired in an incompletely oxidizing atmosphere. An association between clay type, caliche, and firing temperature was not noted.

The majority of the analyzed samples (n=14) were classed as having a pink-buff surface. Two samples had a calcareous clay while the remainder had an iron-rich/calcareous clay. Caliche was believed to be natural to the clay in two samples, added in eight samples, and possibly added in four samples. Five of the samples had a low firing temperature and the rest a medium firing temperature. There was no apparent association in this group with firing temperature, caliche, and clay type.

The final group comprised eight samples with a pink-orange surface. Their clay type was mostly a blend of iron-rich and calcareous, but two had an iron-rich clay only. Only one sample had natural caliche, while all but two were fired to a medium temperature range. Once again, there seemed to be no connection between firing temperature, clay type, and caliche.

This information suggests that the surface color of the Hohokam buff ware pottery included in this study is largely due to the clay type rather than other factors. However, iron-rich/calcareous and iron-rich clays are more likely to have added caliche that is probably necessary for a more buff color to form on the surface. Surprisingly, the firing temperature appeared to play less of a role as samples fired to lower temperatures could exhibit the three different surface colors. In thin section, the lower fired samples tended to have a brown color to the clay, while those at a medium temperature had a more reddish color. This is probably due to an increase in the oxidation of iron as the temperature is raised. The two iron-rich clay samples were not fired to a low temperature and this may be due to the necessity of a higher temperature to form the buff surface. Pastes with added or natural caliche could be low fired.

With respect to the provenance of the samples, those that contained sand from Petrofacies N were not found with buff-grey or cream-buff surfaces. Five of the Petrofacies N samples had a pink-buff surface, while two had a pink-orange surface. This may suggest that the clays used by the potters who also employed Petrofacies N sand are typically more iron-rich; however, three samples had a calcareous clay in thin section. The sherds that contained Petrofacies A sands ranged from buff-grey to pink-orange in color and were made with calcareous, iron-rich/calcareous, and iron-rich clays. Overall, it seems there is a lack of association between provenance and clay type, which is also confirmed by the variety of surface colors seen in samples from Petrofacies N and A. This suggests that the color of the buff surface had no association with provenance. Accordingly, it is likely that consumers of buff ware could not determine a vessel's source by the buff color alone. Mostly likely, the decoration patterns and shapes of the pots were more indicative of producer.

DISCUSSION

The petrographic analysis of Honey Bee Village Hohokam buff wares provided useful information on provenance and technology. It revealed that the majority of samples were tempered with sand from the Santan Mountains (A) Petrofacies, and more likely in the area between Gila Butte and the western end of the Santan Mountains. A smaller amount of the buff wares contained sand temper from the Snaketown (N) Petrofacies, but probably still close enough to the schist outcrops for these rocks to contribute to the sand composition. In comparison with the dates of the analyzed samples, nine samples had been assigned to the Santa Cruz phase. Four of these had Petrofacies N sand (44 percent), while five had Petrofacies A sand (56 percent). Of the 21 samples dated to the Early Sacaton to Middle Sacaton 1 phase, 18 were assigned to Petrofacies A (86 percent), including those likely to have sand from this petrofacies, and three contained sand from Petrofacies N (14 percent). Further, the ceramic types seen in this study could be made in either Petrofacies A or N. Only a more specific examination of the decoration may suggest if certain designs are more common in one of these two production locations.

Overall, in reference to date, the results suggest a possible change in the acquisition of buff ware by the inhabitants of Honey Bee Village, or it may reflect an increase in the production and/or distribution of pottery from the Santan Mountains area (Table 9). The Honey Bee buff ware sample is dated toward the end of abundant buff ware production, so overall changes in production seen in the Phoenix area are relevant (Abbott et al. 2007). Previous work has suggested that as the sequence progressed, more sherds include sand temper. However, this analysis only focused on the 30 percent of samples with notable sand in the temper, while the remaining 70 percent had a dominantly schist temper probably from using crushed or disaggregated rock fragments. Information on these samples is necessary to more fully characterize the acquisition of buff ware pottery by the Honey Bee Village inhabitants.

Another interesting aspect to this study is any relationship between ceramic type and the other recorded features. For the buff surface color, the only notable relationship was that none of the Santa Cruz Red-on-buff had a pink orange surface. The other surface colors were found for most of the types. Related to this observation, is that most of the Santa Cruz Red-on-buff were made with a calcareous clay. This may suggest that during this period, calcareous clays that fired either cream-buff or pink-buff, and typically lacked clay pellets but had natural caliche, were being used preferentially in both Petrofacies A and N production locations. Iron-rich/calcareous and iron-rich clays were employed mostly in the Early Sacaton to Middle Sacaton 1 types, and usually contained clay pellets and added caliche. In fact, the appearance of these later sherds is more consistent, with similar clays and inclusions. The samples attributed to Santa Cruz Red-on-buff types could be divided into subgroups with similar compositions (e.g. HBA-0113 and HBA-0125; HBA-0114 and HBA-0132). Thus, the variability in the clays and sands appears greater for Santa Cruz Red-on-buff types. The firing temperatures for this type were almost always in the medium range, whereas lower temperatures were more common for the Early Sacaton to Middle Sacaton 1 types.

Table 9. Results of analysis by context phase and ceramic type.

Context Phase	Ceramic Type	Petrofacies A	Petrofacies A?	Petrofacies N
Rillito	Santa Cruz Red-on-buff	1	2	3
Rillito	Santa Cruz or Early Sacaton Red-on-buff	2	0	0
Rillito	Early Sacaton Red-on-buff	0	0	1
Early Rincon-Middle Rincon 1	Early Sacaton Red-on-buff	1	0	0
Early Rincon-Middle Rincon 1	Early Sacaton or Middle Sacaton 1 Red-on-buff	3	0	0
Early Rincon-Middle Rincon 1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff	3	0	0
Early Rincon-Middle Rincon 1	Middle Sacaton 1 Red-on-buff	3	0	0
Early Rincon-Middle Rincon 1	Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff	2	0	0
Early Rincon-Middle Rincon 1	Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff	1	0	1
Early Rincon-Middle Rincon 1	Unidentified red-painted Hohokam Red-on-buff	1	0	1
Middle Rincon 1	Early Sacaton or Middle Sacaton 1 or Middle Sacaton 2 or Late Sacaton Red-on-buff	2	1	1
Middle Rincon 1	Middle Sacaton 1 or Middle Sacaton 2 Red-on-buff	1	0	0
Total		20	3	7

These technological features are important for understanding how buff wares were produced and any changes through time. In fact, understanding the methods of buff ware production will relate to provenance as suitable clays, caliche, and schist are required for their creation. Previous studies have indicated that potters needed to use the clays collected along the middle Gila River in order to produce buff wares (Abbott 2008, Beck et al. 2012). This is because these clays are often naturally calcareous and probably contain natural salt important in the development of the buff scum surface[1]. The clays were probably somewhat variable as they were based on deposits of alluvial sediment. Thus some clays could be more iron-rich and some more calcareous. The current study suggests that if the clay was more iron-rich the potter added caliche to ensure a buff surface formed on the vessel. For this to happen, it has been suggested the firing temperature needed to reach 850°C for the caliche to decompose and contribute to the buff surface. The analyzed sherds from Honey Bee Village indicate the firing temperature could be lower and a buff surface would still form. This may be due to the natural calcium dispersed in the clay, as those samples with a mostly iron-rich clay had added caliche and were more highly fired in order to result in a buff surface. The results seem to indicate that whereas experimental work has determined a specific paste recipe and firing temperature are required for buff ware production; in practice there was room to accommodate material variability. Undoubtedly by the Santa Cruz phase, the potters had a deep knowledge of their raw materials and what alterations were necessary to achieve a buff surface. If fuel could be saved and a lower firing temperature used, this may have been preferred. Additional petrographic work examining

[1]This is the correct term for a pottery surface developed from the movement of elements to the surface of pottery during drying and the creation of a calcium alumino-silicate on the surface during firing that suppresses iron coloration. The scum on the surface of the Honey Bee Village samples was seen in five samples and its appearance confirmed it was not a slip.

these aspects of technology will undoubtedly provide more information on the technological range and chronological developments for buff ware production.

Finally, it is clear that more work on the schist would be desirable to establish both its origin in the sherds and any possible connection to specific outcrops. Unfortunately, the composition of schist can be quite variable, between outcrops but also within a single outcrop. This is due to the direction and type of temperature and pressure involved in the metamorphic process and the minerals from the parent rock that are available to be changed into other minerals. Additional post-depositional alteration and weathering often takes place that will also change the appearance of the schist rocks. This type of activity may occur in some more exposed areas or to schist fragments that have separated from the parent rock. Time is also an important factor. All of these processes can lead to a sand with schist having a variety of appearances but ultimately deriving from a main outcrop within a mountain. Additional samples of sand and schist may help to determine if there are some characteristics to schist from particular outcrops that are useful for provenance work. Another avenue of research could be examining the characteristics of the schist in samples with a provenance assignment. If those from one petrofacies are all similar and can be separated from schist in the sand of samples from a different petrofacies, that information may assist in locating the provenance of sherds dominated by schist. Similarities in clay between sherds with schist-rich sand and those with crushed schist may also be helpful, but the current study was not able to make any connection between clay type and provenance. Finding a method to identify the provenance of buff ware sherds with mostly schist temper is important because without this information the full scale of production and distribution cannot be assessed.

CONCLUSION

This study has proven the utility of petrographic analysis for identifying the provenance of Hohokam buff ware and in further understanding the technology of its production. Petrography as a tool has been undervalued for examining buff ware mostly because many pots appear to contain crushed schist and lack sand. However, petrography can still reveal important information on clays, the addition of caliche, and firing temperatures. As technology and provenance cannot and should not be separated, this may provide valuable information that will ultimately lead to a better understanding of the social and economic context of the production and distribution of Hohokam buff ware.

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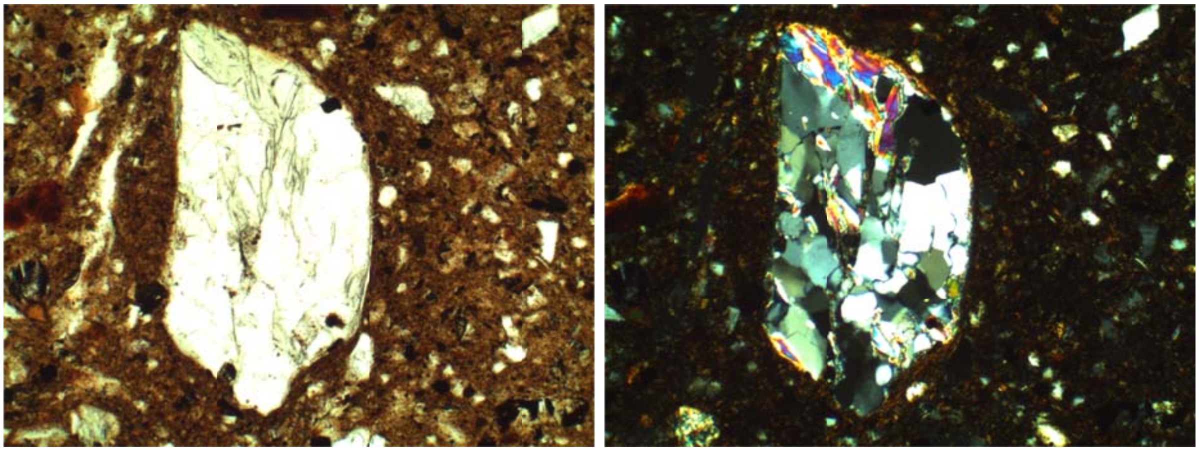
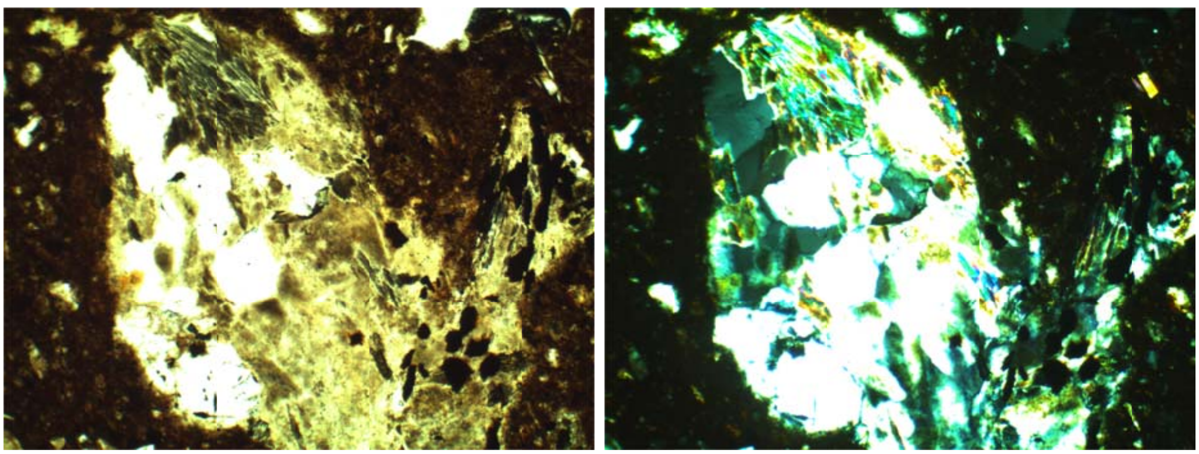
APPENDIX A

Thin Section Images

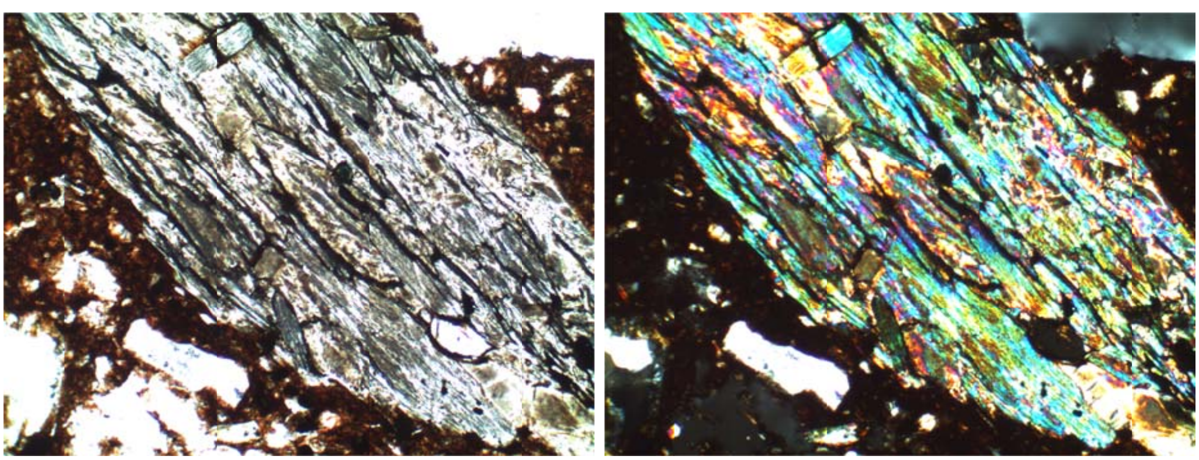


Sample HBA-0119, PPL Sample HBA-0119, XPL



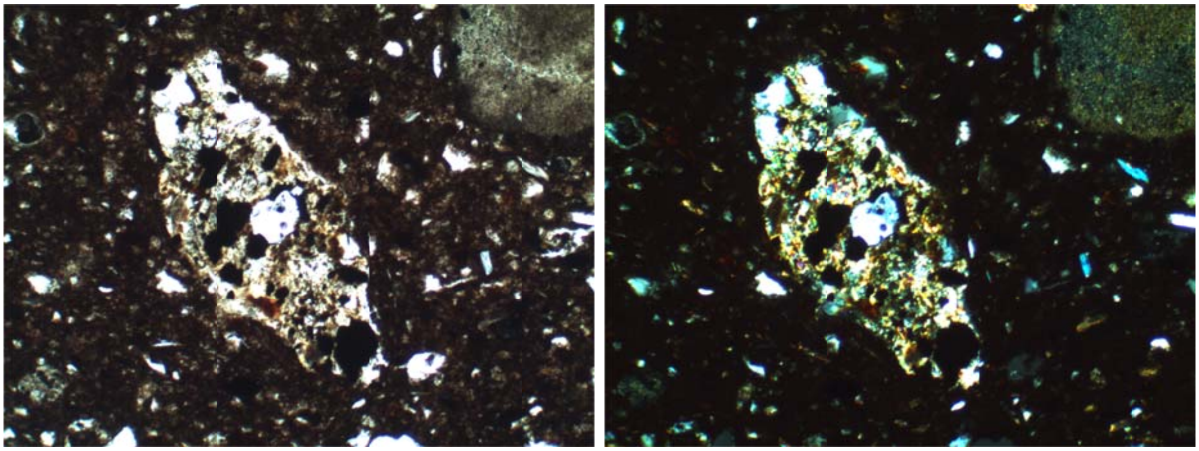
Sample HBA-0120, PPL Sample HBA-0120, XPL

Figure A.1. Plane (PPL) and cross polarized (XPL) images of round quart-muscovite schist, taken at 100x magnification.



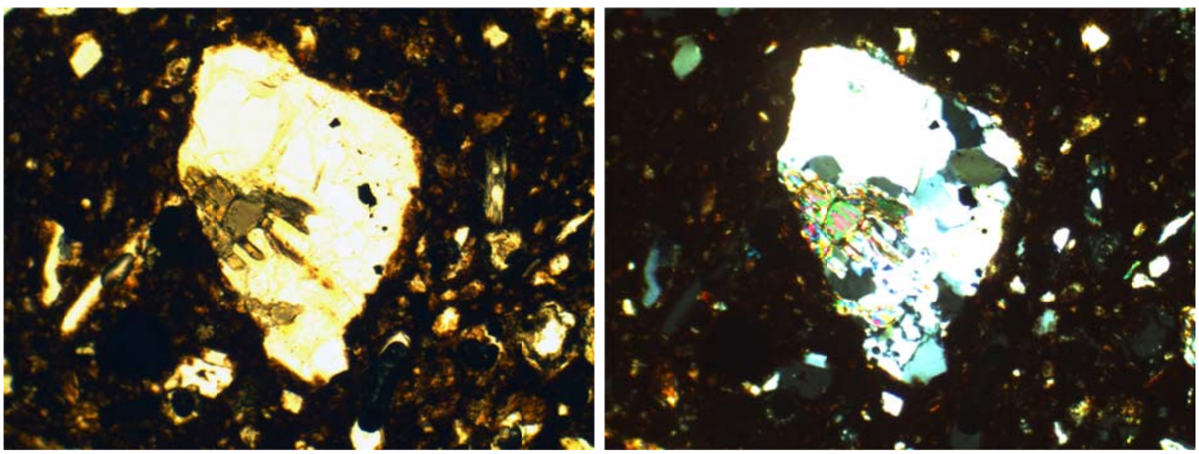
Sample HBA-0110, PPL Sample HBA-0110, XPL

Figure A.2. Plane (PPL) and cross polarized (XPL) image of mica schist, taken at 100x magnification.



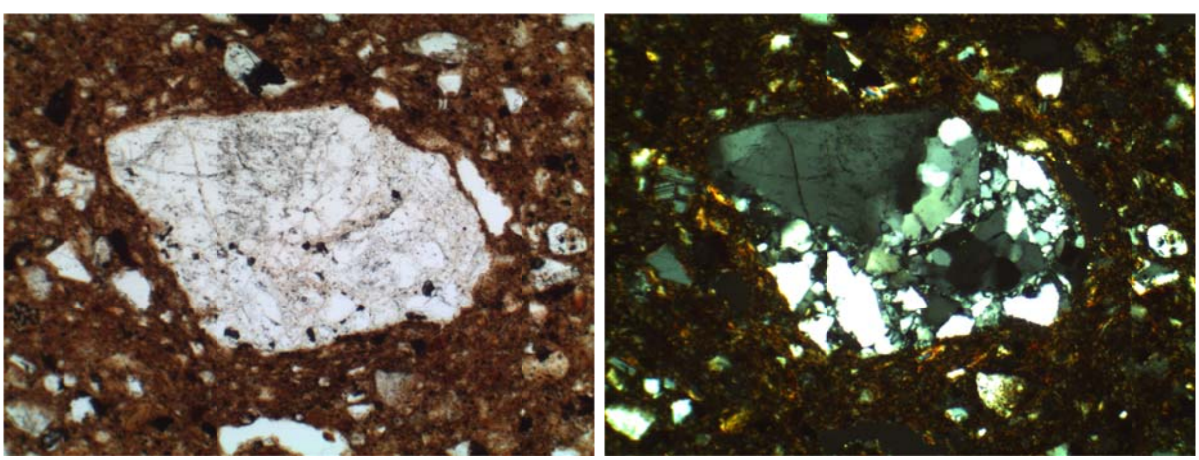
Sample HBA-0120, PPL Sample HBA-0120, XPL

Figure A.3. Plane (PPL) and cross polarized (XPL) image of "Gila Butte" schist, taken at 100x magnification.



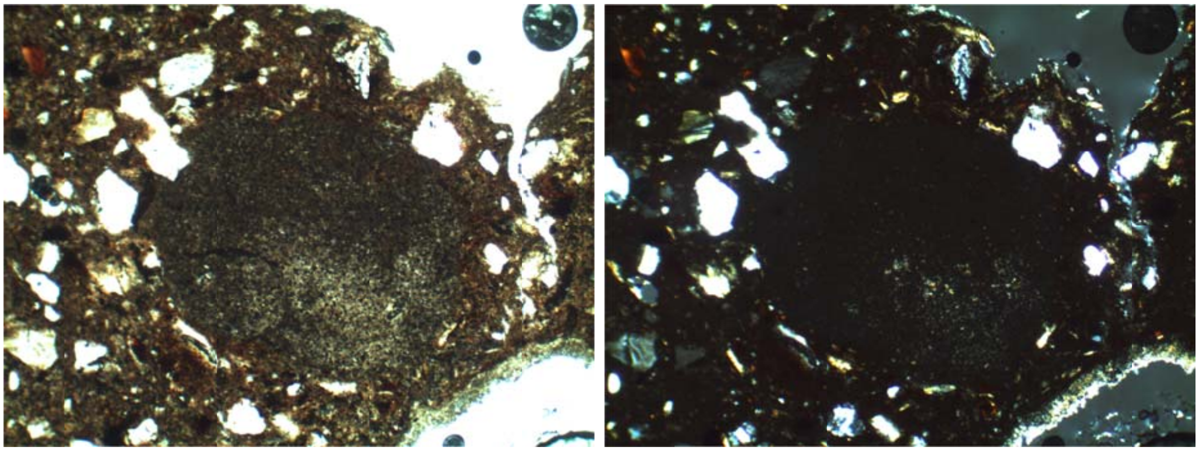
Sample HBA-0110, PPL Sample HBA-0110, XPL

Figure A.4. Plane (PPL) and cross polarized (XPL) image of tourmaline in schist, taken at 100x magnification. Dark green grains in PPL image; bright greenish pink grains in XPL image.



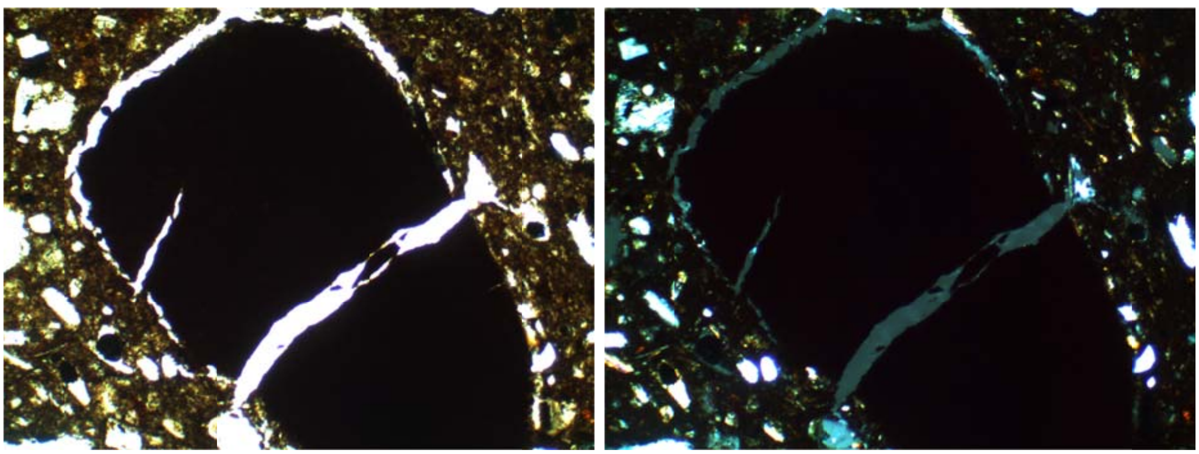
Sample HBA-0119, PPL Sample HBA-0119, XPL

Figure A.5. Plane (PPL) and cross polarized (XPL) image of cataclastic grain, taken at 100x magnification.



Sample HBA-0113, PPL Sample HBA-0113, XPL

Figure A.6. Plane (PPL) and cross polarized (XPL) image of caliche grain, taken at 100x magnification.



Sample HBA-0120, PPL Sample HBA-0120, XPL

Figure A.7. Plane (PPL) and cross polarized (XPL) image of ARF, taken at 100x magnification.