Ahk'utu' Vases Petrographic Description

The petrographic data reveals that the 62 Ahk'utu' samples were placed into 3 major fabric groups, namely the Crystalline Calcite Group, Mixed Carbonate Group, and Volcanic ash-tempered Group. The mineralogical and textural characteristics of each fabric group is described as below:

1. Crystalline Calcite Group

This group consists of two subgroups, both of which are characterised by the use of crystalline calcite as the principal type of tempering material. Variation in mineralogical constituents and texture is evident between the samples of Subgroups A and B. The predominance of crystalline calcite in the samples of these subgroups is not particularly useful in determining the provenances, in particular the samples of Subgroup A, because the underlying bedrock of the majority of Belize is limestone. Yet, the presence of chert and chalcedony in the samples of Subgroups B points to the areas adjacent to Altun Ha or Yucatan as potential provenances.

1.1. Crystalline Calcite Subgroup A (n=42)

Samples: AHMC 2, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 16, 22; PHMC 1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 21, 22, 23; BPMC 2, 3, 8; MGMC 1, 2, 5; CPMC 1, 2; SDRMC 1, WTCMC 1

I. Microstructure

(a) Voids: Few to very few (5-10%), size=0.16mm to 2.16mm, mode size=0.4mm. Dominant meso-vughs, few to very few macro-vughs, very rare mega-vughs. Few meso-vesicles, rare macro-vesicles.

(b) c/f related distribution: A close-spaced, porphyric distribution of inclusions for some samples (PHMC 6, 7, 8, 11, 14, 23; BPMC 8; MGMC 1, 2, 5; WFCMC 1), in which points of contact between crystalline calcite inclusions are very frequent. In other samples (AHMC 4, 5, 6, 8, 9, 10, 14, 15, 16, 22; PHMC 10; BPMC 2, 3; CPMC 1), inclusions are packed in a single- to double-spacing, in which points of contact between crystalline calcite inclusions are less frequent. There are also samples (PHMC 1, 2, 3, 9, 12, 13, 15, 16, 17, 18, 21, 22; AHMC 2, 7, 13; CPMC 2; SDRMC 1), in which points of contact are only common for crystalline calcite in the coarse fraction.

(c) Preferred orientation: Inclusions do not generally display any preferred orientation, but some inclusions with size >0.48mm are crudely aligned parallel to the margin of the thin sections. Some meso- and mega-vughs are also crudely aligned parallel to the margin of the thin sections.

II. Groundmass

(a) Homogeneity: Although all samples in this subgroup are characterised by the presence of crystalline calcite, there is a wide range of size distribution of inclusions and their sorting. The matrix of some samples (PHMC 6, 7, 8, 11, 14, 23; BPMC 8; WFCMC 1; MGMC 1, 2, 5) is dominated by well-sorted crystalline calcites of fine sand size (mode size=ca. 0.16mm) and few calcite of medium and coarse sand size (>0.56mm). There are also samples (AHMC 4, 5, 6, 8, 9, 10, 14, 15, 16, 22; PHMC 10; BPMC 2, 3; CPMC 1) with matrix that is characterised by the presence of dominant crystalline calcite inclusions of very fine sand size (mode size=ca. <0.08mm) and few to very few calcite of medium sand size. Other samples (PHMC 1, 2, 3, 9, 12, 13, 15, 16, 17, 18, 21, 22; AHMC 2, 7, 13; CPMC 2; SDRMC 1) is dominated by the presence of coarser and more angular crystalline calcite of medium sand size (mode size=ca. 0.4mm). The majority of the samples in this subgroup display a characteristic orange paste, with the exception of AHMC 2 and PHMC 13. AHMC 2 appears to be more reddish brown than the rest in the subgroup; whereas PHMC 13 appears to be more brownish-gray; both of which might be the result of firing in a relatively reducing atmosphere or post-depositional effect. Variation in the colour of the matrix can be observed in most samples, due to the presence of dark firing core.

(b) Micromass: The matrix of the sample is slightly optically active to optically inactive, especially for the dark firing core. The colour of the matrix appears to be brown to reddish brown in PPL (x50) and dark brown and dark yellowish brown in XP (x50).

(c) Inclusions: Samples generally display a weak bimodal size distribution of inclusions, consisting of a coarse and fine fraction. The coarse fraction is made of crystalline calcite and quartz, ranging from 0.08mm to 3.2mm. With the exception of these samples, PHMC 6, 7, 8, 11, 14, 23; BPMC 8; MGMC 1, 2, 5; WFCMC 1, which are characterised by inclusions in the coarse fraction with the mode size of ca. 0.24mm, all other samples in subgroup have a mode size of ca. 0.4mm to 0.48mm. Although inclusions with size >0.8mm are present in most samples, but their occurrence varies from common to very few. Inclusions in the coarse fraction are mostly sub-angular to sub-rounded, packing in close- to double spacing. The fine fraction (<0.08mm) consists of crystalline calcite and quartz inclusions.

c:f:v ratio: between 40: 55: 5 and 50: 45: 5 for samples PHMC 6, 7, 8, 11, 14, 23; BPMC 8; WFCMC 1; MGMC 1, 2, 5

between 10: 85: 5 and 30: 65: 5 for samples AHMC 4, 5, 6, 8, 9, 10, 14, 15, 16, 22; PHMC 10; BPMC 2, 3; CPMC 1

between 30: 65: 5 and 40: 55: 5 for samples PHMC 1, 2, 3, 9, 12, 13, 15, 16, 17, 18, 21, 22; AHMC 2, 7, 13; CPMC 2; SDRMC 1

Coarse fraction (0.08mm – 3.2mm)

Predominant to Dominant: Crystalline calcite, equate to elongated, sub-angular to sub-rounded. Size=0.08mm to 3.2mm. Mode size varies from 0.24mm for PHMC 6, 7, 8, 11, 14, 23; BPMC 8; WFCMC 1; MGMC 1, 2, 5, to 0.4mm for AHMC 4, 5, 6, 8, 9, 10, 14, 15, 16, 22; PHMC 10; BPMC 2, 3; CPMC 1, and 0.48mm for PHMC 1, 2, 3, 9, 12, 13, 15, 16, 17, 18, 21, 22; AHMC 2, 7, 13; CPMC 2; SDRMC 1. Mosaic of microcrystalline calcites, which range from 0.72mm to 1.76mm are also present, but their occurrence is very few to rare.

Common to Rare: Textural concentration features, sub-rounded to well-rounded. Size=0.08mm to 4.8mm, mode size=0.24. See below for description

Few to Very Few: Quartz, predominantly monocrystalline, very few to rare polycrystalline, equate to elongated, angular to sub-rounded, commonly undulose extinction. Size=0.08mm to 3.6mm, mode size=0.4mm.

Very Few to Rare: Dolomite, rhombic to equate, angular to sub-angular. Size=0.08mm to 0.48. Mode=0.24mm.

Very Rare: Chert, equate, angular. Size=0.32mm to 0.72mm.
Chalcedony, equate, angular. Size=0.52mm to 0.68mm.
Muscovite, elongated, angular. Size=1.04mm

Fine fraction (<0.08mm)
Predominant: Crystalline calcite
Common to Very Few: Quartz
Few to Rare: Dolomite

III. Textural Concentration Features (Tcf)

Iron-rich nodules are present in all samples and their occurrence varies from common to very few. Size=0.08mm to 0.32mm, mode size=0.24mm. These iron-rich nodules have clear to sharp boundaries, appearing to be dark reddish brown in PPL and XP. Clay pellets are present in some samples and their occurrence ranges from few to rare. BPMC 8 and MGMC 5, in particular, have more common occurrence of clay pellets than other samples in the subgroup. Size=0.56mm to 4.4mm. These clay pellets have clear to sharp to merging boundaries, displaying a discordant relationship to the rest of the matrix. They often have high optical density, appearing to be dark reddish brown or dark brown in PPL and XP. Fine-grained quartz inclusions are common in some of the clay pellets with size >1.2mm.

IV. Comments

The samples in this subgroup display a wide range of size distribution and sorting of crystalline calcite inclusions, contributing to the varying relative proportion of the coarse and fine fractions. As one may have realised, the samples can be further divided into three smaller subsets: one group with dominance of fine-grained crystalline calcite inclusions with size ca. 0.24mm; second group with the presence of crystalline calcite with size ca. 0.4mm setting in a matrix of much finer crystalline calcite (<0.08mm); and a third group with the dominance of more angular crystalline calcite inclusions with size ca. 0.48mm. Whereas it is highly probable that these three groups are representative of the natural variation existing within the clay sources, it is also possible that these variations might be attributable to the ways different potters or potting communities treated the ceramic paste. The samples were likely to be fired in an atmosphere that ranges from relatively complete oxidation to incomplete oxidation, as reflected in the presence of dark firing core of varying thickness. Evidence of gouging and incising – techniques that were used to decorate the vases – are noted in some samples (PHMC 13, 17, 23, BPMC 5, MGMC 2, WFCMC 1). With reference to the clay samples collected by Howie (2005) and Sunahara (2009), there are several possible provenances for the samples of this subgroup, including the Belize River valley region and New River Lagoon.

1.2. Crystalline Calcite Subgroup B (n=5)

Samples: AHMC 11, 12, 20, 21; BPMC 4

I. Microstructure

(a) Voids: Rare to very few (2-5%), size=0.24mm to 1.36mm, mode size=0.4mm. Frequent meso-vughs, macro-vughs with size >0.8mm are also present but few to very few, very few meso-vesicles.

(b) c/f related distribution: A close-spaced to single-spaced, porphyric distribution of inclusions. Points of contact between calcite inclusions, especially those with size >0.56mm, are frequent.

(c) Preferred orientation: Inclusions, especially the calcites that are elongated and with size >0.56mm, and macro-vughs are aligned parallel to the margin of the thin sections.

II. Groundmass

(a) Homogeneity: Samples in this subgroup exhibit homogeneity in size distribution of inclusions and their sorting. Although no dark firing core can be observed in the samples, AHMC 11 appears to be slightly more reddish brown than other samples in this subgroup or samples from Altun Ha in general.

(b) Micromass: The matrix of the sample is slightly optically active to inactive. The colour of the matrix appears to be brown to dark brown in PPL (x50) and dark brown to dark reddish brown in XP (x50).

(c) Inclusions: A strong bimodal size distribution of inclusions, consisting of a coarse and fine fraction. The coarse fraction ranges from 0.16mm to 2mm, and is dominated by very angular crystalline calcite inclusions with coarse sand size (ca. 0.56mm). These calcite inclusions are particularly well-sorted, packing in close- to single-spacing. Inclusions of quartz and chalcedony are also present but their occurrence varies from few to rare. Textural concentration features are common in all samples. The fine fraction (<0.16mm) consists of dominant crystalline calcite inclusions.

c:f:v ratio: 30: 65: 5

Coarse fraction (0.16mm – 1.6mm)

Dominant to Frequent: Crystalline calcite, elongated to equate, very angular to sub-angular. The angularity of the calcite inclusions increases with their grain size. Size=0.16mm to 1.6mm, mode size=0.56mm. Calcite inclusions with size >0.96mm are also present, but their occurrence is few to very few, and they are mostly packed in double-spacing. Mosaic of microcrystalline calcite inclusions can also be identified but their occurrence is rare.

Few to Very Few: Monocrystalline quartz, equate to elongated, sub-rounded to angular, commonly undulose extinction. Size=0.24mm to 0.72mm, mode size=0.4mm.

Very Few to Rare: Dolomite, rhombic to equate, angular to sub-angular. Size=0.08mm to 0.48. Mode=0.24mm. Chalcedony, equate, angular to sub-angular. Size=0.24mm to 0.4mm.

Very Rare: Chert, equate, angular. Size=0.4mm

Fine fraction (<0.16mm)

Frequent to Common: Crystalline calcite
Few to Rare: Dolomite
Very Few to Rare: Quartz
Rare to Very Rare: Chert, Chalcedony

III. Textural Concentration Features (Tcf)

Iron-rich nodules are present in all samples and their occurrence ranges from common to very few. Size=0.08mm to 0.24mm. These rounded to sub-rounded nodules have high optical density, appearing to be dark reddish brown in PPL and XP. Clay pellets can be found in most samples but their occurrence is rare, with the exception of AHMC 11 and

BPMC4, in that their occurrence is few. It is also in these two samples that the clay pellets reach the size of >2mm in AHMC11 and 1.44mm in BPMC 4, as opposed to the clay pellets in other samples, which have a mode size of ca.0.4mm. In most cases, clay pellets have clear to sharp to merging boundaries, displaying a discordant relationship with the rest of the matrix. They have high optical density, appearing to be reddish brown in PPL and dark reddish brown or dark brown in XP. Fine-grained quartz inclusions are common in these clay pellets.

IV. Comments

The samples in this subgroup display a strong bimodal size distribution of inclusions, with the coarse fraction being dominated by very angular crystalline calcite inclusions of coarse sand size and microcrystalline mosaic calcites in non-calcareous clay. Judging from the sorting, angularity and bimodal size distribution, it is postulated that the crystalline calcite inclusions were crushed and added intentionally as temper. The variation in the size and sorting of crystalline calcite inclusions, coupled with the presence of chert and chalcedony, in these samples serve to differentiate them from the samples of Subgroup A. The samples were fired in a relatively oxidising atmosphere, as evident in their homogeneous paste colour and the absence of dark firing core. Despite its relatively small sample size, this subgroup has significant implication on the ceramic tradition during the transition from the Classic to Postclassic period. The same ceramic paste was used to make both the Ahk'utu' vase and the Buk-phase chalices, suggesting continuity with regard to the technology of ceramic production. The mineralogical composition of these samples is consistent with the geology of Altun Ha and its surrounding area in the coastal plain east of the New River, which are underlain by limestones of Cayo and Doubloon Bank formations (King et al. 1992: 28). The limestones of Cayo and Doubloon Bank formations are described to have contained flints, and by crushing these limestones might have contributed to the presence of chert and chalcedony in the clay. Alternatively, the mineralogical composition of the samples is also consistent with the geology of the areas adjacent to the northeast coast of northern Belize and in Yucatan, Mexico.

2. Mixed Carbonate Group (n=3)

Samples: MGMC 3, PHMC 4, BPMC 5

I. Microstructure

(a) Voids: Few to very few (5-10%), size=0.16mm to 3.84mm, mode size=0.48mm. Dominant meso-vughs, few to very few macro-vughs, very rare macro-vughs. Meso-vesicles are also present but their occurrence is very few to rare.

(b) c/f related distribution: A close-spaced to double-spaced, porphyric distribution of

inclusions. Points of contact between crystalline calcite, micritic calcite inclusions are common.
(c) Preferred orientation: Inclusions, especially the crystalline calcites and micritic calcites with size >0.64mm, and some mega-vughs are aligned crudely parallel to the margin of the thin sections.

II. Groundmass
(a) Homogeneity: Samples in this group exhibit homogeneity in size distribution of inclusions and their sorting. With the exception of PHMC 4, all samples from this group display a characteristic grey paste, with the presence of dark firing core with varying thickness. The paste of PHMC 4, on the other hand, is orange without the presence of dark firing core.
(b) Micromass: The matrix of the samples is optically inactive. For the vast majority of the samples with grey paste, the colour of the matrix of all samples appears to be dark brown in PPL and dark greyish brown in XP; whereas for PHMC 4, the colour of the matrix appears to be brown in PPL and dark yellowish brown in XP.
(c) Inclusions: A bimodal size distribution of inclusions, consisting of a coarse and fine fraction. The principal constituents of the coarse fraction are micritic calcite, crystalline calcite inclusions, and limestone fragments, ranging from 0.16mm to 1.44mm. Although its upper limit is 1.44, the coarse fraction is dominated by inclusions of medium sand size. These angular to sub-angular inclusions are poorly sorted, and are packed in close- to double spacing. The fine fraction (<0.16mm) consists of crystalline calcite and quartz inclusions.

c:f:v ratio: between 15: 80: 5 and 20: 75: 5

Coarse fraction (0.16mm – 1.44mm)
Frequent to Common: Crystalline calcite, equate to elongated, angular to sub-angular. Size=0.16mm to 0.88, mode size=0.4mm.

Frequent to Few: Micritic calcite, equate to elongated, sub-rounded to sub-angular. Size=0.16mm to 1.44mm, mode=0.4mm. Micritic calcite inclusions with size >0.64mm are also present but their occurrence is few to very few.

Few to Very Few: Monocrystalline quartz, equate to elongated, sub-rounded to sub-angular, commonly undulose extinction. Size=0.16mm to 0.56mm, mode size=0.32mm.

Fine fraction (<0.16mm)
Dominant: Crystalline calcite
Few to Very Few: Quartz

III. Textural Concentration Features (Tcf)
Iron-rich nodules are present in all samples and their occurrence ranges from very few to few. Size=0.08mm to 0.32mm. These rounded iron-rich nodules have high optical density, appearing to be dark reddish brown in PPL and XP.

IV. Comments
The samples in this group is characterised by the presence of a mixture of carbonate materials in calcareous clay. Inclusions of micritic calcite, crystalline calcite, and limestone fragments of medium sand size appear to have occurred in the clay naturally. With the exception of one sample which was fired in a relatively complete oxidising atmosphere, all samples were likely to be fired in a reducing atmosphere, followed by a brief period of oxidation, as evident in the varying thickness of dark firing core. The ceramic fabric of this group displays characteristics that are distinctive to the Yalbec clays – which formed directly on the surface of the ground or in association with the subsurface horizons comprising limestones at various stages of weathering – occurring in the immediate area surrounding Lamanai. Thus, it is suggested that the production of these vessels was related to Lamanai. This fabric group has significant technological implication, in which the same ceramic paste was used to make different types of vessels during the Classic to Postclassic transition periods; thus inferring continuity in terms of raw material use in ceramic production during the transitional period.

3. Volcanic Ash-tempered Group
The fabric group is distinguishable for the presence of volcanic ash as the predominant type of inclusion. Variation in the mineralogical constituent and textural characteristic serves to divide the samples into three subgroups. In addition to volcanic ash, the presence of biotite, plagioclase feldspar and quarts inclusions suggests that the samples of Subgroups A and B are likely to have been originated in the Maya Mountains areas. Yet, the fineness of volcanic ash and the absence of biotite and plagioclase feldspar inclusions have made it difficult to determine the provenance of Subgroup C. Nonetheless, it is interesting to note that this fabric group is exclusively related to the production of Ahk'utu' vases in the 9^{th} and 10^{th} centuries.

3.1. Volcanic Ash-tempered Subgroup A (n=4)
Samples: AHMC 1, 3; BPMC 6; ZCMC 1

I. Microstructure
(a) Voids: Rare to Very Few (1-5%). In general, voids are difficult to be identified in the volcanic ash tempered groups because of volcanic ashes, which share similar optical properties with glass, are translucent in both PPL and XP. Frequent meso-vughs, and

common to few vesicles can be found.
(b) c/f related distribution: A close-spaced to double-spaced, porphyric distribution of inclusions. Points of contact between volcanic ash inclusions are frequent.
(c) Preferred orientation: Inclusions and voids are not aligned in an particular orientation.

II. Groundmass
(a) Homogeneity: Samples in this subgroup have homogeneous paste colour, without the presence of dark firing core. There is slight variation in the size distribution of inclusions, in which inclusions of CLMC 1 appear to be coarser than those of other samples in the subgroup, even though the composition of the inclusions is homogeneous throughout the subgroup.
(b) Micromass: The matrix of the sample is optically inactive. The colour of the matrix is brown in PPL (x50) and dark reddish brown in XP (x50).
(c) Inclusions: A strong bimodal size distribution of inclusions, consisting of a coarse and fine fraction. The coarse fraction consists of volcanic ash, quartz, plagioclase feldspar, and biotite inclusions, ranging from 0.0625mm to 2.4mm. Inclusions in the coarse fraction are poorly to moderately well-sorted, which are characterised as elongated to equate, angular to sub-rounded. They are packed in close- to single- spacing, especially the volcanic ash which are packed in close-spacing. The fine fraction (>0.0625mm) consists of volcanic ash and quartz.

c:f:v ratio: between 59: 40: 1 and 45: 50: 5

Coarse fraction (0.0625mm – 2.4mm)
Predominant: Volcanic ash, elongated to equate, angular to sub-rounded. Size=0.16mm to 1.12mm, mode size=0.24mm. They are packed in closed-spacing. Volcanic ash inclusions with size >0.56mm are present but their occurrence is few. These volcanic ash inclusions are packed in single- to open-spacing.

Frequent: Biotite, elongated to equate, angular to sub-angular. Size=0.08mm to 1.12mm, mode size=0.32mm.

Common: Quartz, predominantly monocrystalline, few to very few polycrystalline, commonly undulose extinction, equate to elongated, angular to sub-rounded. Size=0.8mm to 0.48, mode size=0.16mm.

Few to Very Few: Plagioclase feldspar, equate to elongated, angular to sub-angular. Size=0.24mm to 0.64mm, mode size=0.56mm.

Fine fraction (<0.0625mm)
Predominant: Volcanic ash
Frequent: Biotite
Common to Few: Quartz

III. Textural Concentration Features (Tcf)
Iron-rich nodules, very few to rare, sub-rounded to well-rounded, clear to sharp boundaries. Size=0.08mm to 0.24mm. These nodules appear to be dark reddish brown in both PPL and XP.

IV. Comments
The samples in this subgroup displays a strong bimodal size distribution of inclusions, with predominant volcanic ash, frequent biotite, common quartz, and few to very few plagioclase feldspar inclusions in non-calcareous clay. Volcanic ash inclusions appear to be added deliberately to the clay. A thin layer of slip can be found in one sample (AHMC 3). These samples were likely to be fired in a relatively complete oxidising atmosphere, as evident in the homogenous paste colour without the presence of dark firing core. The volcanic ash tempers added to the vases were unaltered, retaining all the characteristic shapes and isotropic properties of fresh ash. This rules out the Paleozoic welded tuff of the Maya Mountains, and the Orange Walk lens, as possible sources of temper, leaving airborne ash deposits and the importation of volcanic ash from the Highlands as the potential sources of ash temper. However, without more detailed chemical characterisation of ash particles by SEM-EDS or EPMA, it is difficult to offer further provenance suggestions. Nonetheless, the presence of quartz, plagioclase feldspar, and biotite inclusions of these samples is consistent with the geology of the Bladen Volcanic Member of the Santa Rosa Group, consisting of rocks rich in quartz and feldspar phenocrysts, and mica-bearing granites (Bateson and Hall 1977: 14). Thus, it is likely that the production of the ash-tempered samples of Subgroup A was associated with or involved the utilisation of ash source, as well as clay resource, derived from the Maya Mountains area.

3.2. Volcanic Ash-tempered Subgroup B (n=4)
Samples: AHMC 26, AHMC 32, MTMC 1, MTMC 2

I. Microstructure
(a) Voids: Rare to very few (2-5%). Size=0.32mm to 3.04mm. Dominant meso-vughs, very rare mega-vughs, common to few meso-vesicles.
(b) c/f related distribution: A closed-spaced to single-spaced, porphyric distribution of inclsuions. Points of contact between volcanic ash inclusions are frequent.
(c) Preferred orientation: Inclusions, especially those with size >0.64mm, and vughs

voids are aligned crudely parallel to the margin of the thin sections.

II. Groundmass

(a) Homogeneity: Samples in this subgroup exhibit homogeneity in size distribution of inclusions and their sorting, even though MTMC 2 appears to have slightly more frequent occurrence of quartz and biotite inclusions. Again, these samples have homogeneous paste colour, without the presence of dark firing core.

(b) Micromass: The matrix of the sample is slightly optically active to inactive. The colour of the matrix appears to be brown in PPL (x50) and dark brown in XP (x50).

(c) Inclusions: A very weak bimodal size distribution of inclusions, consisting of a coarse and fine fraction. The coarse fraction consists of volcanic ash, biotite, quartz andtextural concentration features, ranging from 0.0625mm to 1.28mm. Inclusions are elongated to equate, rounded to angular, well sorted, and packed in close- to single spacing. The fine fraction (>0.0625mm) consists of volcanic ash, biotite, and quartz.

c:f:v ratio: between 10: 85: 5 and 20: 75: 5

Coarse fraction (0.0625mm – 1.28mm)

Predominant: Volcanic ash, elongated to equate, angular to sub-rounded. Size=0.0.08mm to 1.28mm, mode size=0.16mm. They are packed in close-spacing. Volcanic ash inclusions with size >0.56mm are present but their occurrence are very few to rare. These volcanic ash inclusions are packed in single- to open-spacing.

Frequent to Common: Biotite, elongated to equate, angular to sub-angular. Size=0.16mm to 0.4mm, mode size=0.24mm.

Common: Monocrystalline quartz, equate to elongated, rounded to sub-angular, commonly undulose extinction. Size=0.16mm to 0.48mm, mode size=0.16mm.

Fine fraction (>0.0625mm)

Predominant: Volcanic ash

Common: Quartz, biotite

III. Textural Concentration Features (Tcf)

Iron-rich nodules can be found in all samples. Very few to rare, sub-rounded to rounded, clear to sharp boundaries. Size=0.08mm to 0.24mm. These nodules appear to the dark reddish brown in PPL and XP. Clay pellet can be found in two samples (AHMC 26, AHMC32). Very rare, well- rounded to sub-rounded, clear to sharp to merging boundaries. Discordant in relation to the rest of the matrix. Size=0.48mm to 0.80mm. These clay pellets have high optical density and appears to be dark brown in PPL and dark reddish-brown in XP.

IV. Comments

The samples in this subgroup is characterised by a weak bimodal size distribution of volcanic ash, biotite, and quartz inclusions in non-calcareous clay. The inclusions in the coarse fraction of this subgroup are significantly finer than those of the Volcanic Ash Subgroup A. Also, the quartz inclusions of this subgroup appear to be rounder in shape than those in Subgroup A, suggesting that the clay used to make the vases in this subgroup might be of river alluvium origin. Again, volcanic ash inclusions are added intentionally by ancient potters. The samples were likely to be fired in a relatively complete oxidising atmosphere, as evident in the homogeneous paste colour and the absence of dark firing core. Like Subgroup A, the volcanic ash tempers added to the vases were unaltered, retaining all the characteristic shapes and isotropic properties of fresh ash. This rules out the Paleozoic welded tuff of the Maya Mountains, and the Orange Walk lens, as possible sources of temper, leaving airborne ash deposits and the importation of volcanic ash from the Highlands as the potential sources of ash temper. However, without more detailed chemical characterisation of ash particles by SEM-EDS or EPMA, it is difficult to offer further provenance suggestions. Nonetheless, the presence of quartz, plagioclase feldspar, and biotite inclusions of these samples is consistent with the geology of the Bladen Volcanic Member of the Santa Rosa Group, suggesting that production of these vessels was originated from the Maya Mountains area. However, the finer grain size of the volcanic ash temper and biotite inclusions in these samples indicate a different paste recipe from Subgroup A.

3.3. Volcanic Ash-tempered Subgroup C (n=4)

Samples: AHMC 33; BPMC 7, 9; MGMC 4

I. Microstructure

(a) Voids: Very few to rare (2-5%), size=0.24mm to 1.6mm. Dominant meso-vughs, very rare macro-vughs, few to very few vesicles.

(b) c/f related distribution: A closed-spaced, porphyric distribution of inclusions. Points of contact between volcanic ash inclusions are frequent.

(c) Preferred orientation: Inclusions and voids are aligned crudely parallel to the margin of the thin sections.

II. Groundmass

(a) Homogeneity: Samples in this subgroup exhibit homogeneity in size distribution of inclusions, their sorting, and paste colour. No dark firing core can be observed.

(b) Micromass: The matrix of the sample is optically inactive. The colour of the matrix appears to be brown in PPL and dark brown in XP.

(c) Inclusions: An unimodal distribution of inclusions, consisting of a fine fraction (<0.16mm). Inclusions in the fine fraction are volcanic ash and quartz, which are mostly equate, sub-rounded to sub-angular, well sorted, and packed in closed spacing.

Fine fraction (<0.16mm)
Predominant: Volcanic ash
Common to Few: Quartz

III. Textural Concentration Features (Tcf)
Iron-rich nodules are present in all samples. Very few to rare, rounded to well-rounded. Size <0.16mm. These nodules appears to be dark reddish-brown in PPL and XP.

IV. Comments
The samples in this subgroup display a characteristic unimodal size distribution of volcanic ash, quartz inclusions and iron-rich nodules in non-calcareous clay. This subgroup is significantly differentiated from the other volcanic ash subgroups for its fine-grained inclusions and the absence of a coarse fraction. Like the other subgroups, volcanic ash was added as tempering materials in this subgroup, but unlike the other subgroups, the clay used in this subgroup was considerably refined, as evident in the absence of inclusions with size <0.16mm. The samples were likely to be fired in a relatively complete oxidising atmosphere, as reflected in the homogeneous paste colour without the presence of dark firing core. The fineness of the paste, coupled with the absence of biotite and other inclusions, has made the determination of the provenance of the samples of this subgroup difficult. Yet, the absence of impurities in the volcanic ash has discarded the possibility of using ash sources that are local to Belize, including the Maya Mountains and the Orange Walk lens. It is likely that a foreign ash source was used in the production of these vases, suggesting the presence of exchange mechanism with either raw materials or finished vessels.