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Provenance of Clays in Pre-Columbian Ceramics in Jamaica: A Preliminary Assessment

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The elemental chemistry of 90 pottery samples from ten Pre-Columbian sites distributed across Jamaica was analyzed using X-ray fluorescence (XRF) spectrometry. The results were subjected to univariate, bivariate and multivariate analyses in order to understand the relationships of the concentrations of the fourteen elements analysed between sites. Bivariate plots for Rb versus K, Rb versus Sr, and Si versus Rb show two major trends: one with relatively depleted Rb concentrations and one with relatively elevated Rb concentrations. The results are interpreted as representing pottery made from clays deposited in specific river basins and have a strong signal relating to the underlying geology. The potsherds analyzed fall into three groups: north coast (low strontium), *south coast (high strontium), and Kingston (relatively high rubidium). This suggests that in general the manufacture of pottery in Pre-Columbian Jamaica was localized. In contrast, two water jar fragments do not plot together with other sherds from the same site where they were found, suggesting that these were specific vessels transported around the island.*

La chimie élémentaire de 90 échantillons de poterie provenant de dix sites précolombiens répartis à travers la Jamaïque a été analysée à l'aide de la spectrométrie de fluorescence X (XRF). Les résultats ont fait l'objet d'analyses univariées, bivariées et multivariées afin de comprendre les relations des concentrations des quatorze éléments analysés entre les sites. Les diagrammes bivariés pour Rb contre K, Rb contre Sr et Si contre Rb montrent deux tendances principales : une avec des concentrations de Rb relativement appauvries et une avec des concentrations de Rb relativement élevées. Les résultats sont interprétés comme représentant des poteries fabriquées à partir d'argiles déposées dans des bassins fluviaux spécifiques et ont un signal fort lié à la géologie sous-jacente. Les tessons analysés se répartissent en trois groupes: côte nord (faible teneur en strontium), côte sud (forte teneur en strontium) et Kingston (relativement forte teneur en rubidium). Cela suggère qu'en général la fabrication de la poterie dans la Jamaïque précolombienne était localisée. En revanche, deux fragments de jarre à eau ne correspondent pas à d'autres tessons du même site où ils ont été trouvés, ce qui suggère qu'il s'agissait de vaisseaux spécifiques transportés autour de l'île.

La química elemental de 90 muestras de cerámica de diez sitios precolombinos distribuidos en Jamaica se analizó mediante radiografía espectrometría de fluorescencia (XRF). Los resultados fueron expuesta a análisis univariados, bivariados y multivariados para comprender las relaciones de las concentraciones de los catorce elementos analizados entre sitios. Los gráficos bivariados de Rb contra a K, Rb contra a Sr y Si contra a Rb muestran dos tendencias principales: una con concentraciones de Rb relativamente reducidas y otra con concentraciones de Rb relativamente elevadas. Los resultados se interpretan como representación de cerámica hecha de arcillas depositadas en cuencas de ríos específicas y tienen una fuerte señal relacionada con la geología subyacente. Los tiestos analizados se dividen en tres grupos: costa norte (estroncio bajo), costa sur (estroncio alto) y Kingston (rubidio relativamente alto). Esto sugiere que, en general, la fabricación de cerámica en la Jamaica precolombina estaba localizada. En contraste, dos fragmentos de cántaros de agua no concuerdan con otros tiestos del mismo sitio donde fueron encontrados, lo que sugiere que se trataba de vasijas específicas transportadas alrededor de la isla.

Introduction

The Pre-Columbian settlement of Jamaica is generally thought to have commenced at about AD 650 (Vanderwal 1968). Archeologically, Jamaica has been formally characterized by three known prehistoric styles, namely, Little River Style/Ostionan Ostionoid, locally known as Redware (Carlson and Keegan 2004; Keegan 2002), White Marl, St. Catherine (Meillacan Ostionoid) (Rouse 1992) and Sweetwater, Westmoreland (Montego Bay Style, Meillacan, 1180±60 BP) (Keegan et al. 2003). Lee (2006) conducted much research on the Ostionan whereas Howard (1950) focused primarily on the White Marl Style and Conolley (2011), the Montego Bay Style. A possible fourth style may exist, the Port Morant Style, recognized by the late Tyndale-Biscoe (1960), but has not been formally accepted into the literature (Atkinson 2019).

There is a tendency to use the term Taíno to describe the Indigenous settlements in Jamaica. This paper uses the term "Pre-Columbian" in its discourse as the sites have not been characterized to the extent of determining if the sites from which samples were collected were purely related to Taíno, Ostionan, Meillacan, etc. This is evident, for example in Carlson and Keegan (2004) and Keegan (2002) in Westmoreland, two settlements east of Deans Valley River, where one site suggests Ostionan (Paradise in the east) whereas another site suggests Meillacan, specifically Montego Bay Style (Sweetwater in the west). Some collections were surface collections and not full excavations and as such the derived conclusions may not show the true picture, e.g., Lee's material was from the surface, hence it cannot be located stratigraphically (Allsworth-Jones 2008).

Pottery is by far the most common artifactual material available to us (Rouse

1992; 1990; 1965), it seemed that it would be a useful target for analysis, attempting to address such questions as the extent to which there was local as distinct from island-wide manufacture and distribution of products, which in turn could mirror the likely social organization of the inhabitants (Rouse 1992; 1965).

A pilot study (Allsworth-Jones et al. 2001) determined the elemental composition (27 major, minor, and trace elements) of 12 pottery samples from six sites in the Kingston area (Jacks Hill, Harbour View, Bellevue, Chancery Hall, Rodney's House, and Norbrook) using neutron activation analysis (NAA). The objective was to determine whether the same clay source was used at each site, and whether different vessel types were constructed from different clay sources. The material analyzed therefore included rims and body sherds with different inclusions, and two griddles (flat plates which it is thought were used for baking cassava bread). The results indicated a general homogeneity in the quantity of each element present in each sample site. This was particularly evident in the case of the four major elements, aluminium, iron, titanium, and calcium. In addition, the proportions of each element analyzed were consistent with their known occurrence in soils of the Kingston area (Lalor 1995). Consequently, this pottery was considered to be made from a single clay source, possibly in the Hunts Bay area, as previously suggested by Medhurst (1976).

The results of the Kingston study suggested that a larger study looking at Pre-Columbian sites across Jamaica would be of interest. Was pottery made locally from local clay sources? Did all wares have similar elemental constructions at the same location? An opportunity to carry out such a study came when Dr. James Lee donated his collection of Pre-Columbian artifacts to the University of the West Indies (UWI) in 2000 (Allsworth-Jones and Rodrigues 2005). The current paper presents the results of an analysis of ninety pottery samples from ten sites across Jamaica together with four clay samples. Further assessment of other clay samples is then provided based on a dataset from the Mines and Geology Division (MGD) of an island-wide assay of clay deposits to mirror the Bailey 1970 publication, plus additional locations where clays have been discovered since the Bailey study.

Some limitations of this study include only a limited number of elements are represented because of different sampling operations. Also, the elemental analyses of the MGD dataset are different from those in the Pottery dataset. The results are nonetheless of interest and are therefore presented here.

Archaeological Background

Lee mapped 265 Pre-Columbian sites across the island of Jamaica, including 201 middens or open-air sites and 64 caves (Lee 1970, 1971a, 1971b, 1973, 1976, 1979, 1983, 1990). Artifacts or other remains from 191 (164 middens and 27 caves) of these sites are included in the collection. Lee collected this material over a 35-year period between 1951 and 1986, and the collection represents a valuable resource for anyone interested in Jamaican prehistory (Allsworth-Jones 2008).

Pottery samples were analyzed from nine of Lee's sites, together with a site excavated by a joint team from UWI and Murray State University (Allsworth-Jones and Wesler 2003). The sites were selected to provide a fair geographical spread, including both caves and open-air sites, and it was also the intention that it should be representative of the different cultural variants recognized in the island. All the sites have codes according to the scheme suggested by Lee, whereby a capital letter stands for the parish and the number is the order in which he recorded the site in that parish. A capital "C" following the parish code indicates a cave. Thus, C-1 is the first site which Lee recorded in the parish of Clarendon, and CC-15 stands for a cave in the same parish.

In terms of their geographical distribution, it is instructive to see how the sites relate to the main drainage basins in the island (**Figure 1**, **Table 1**) as defined in the National Atlas of Jamaica (1971).

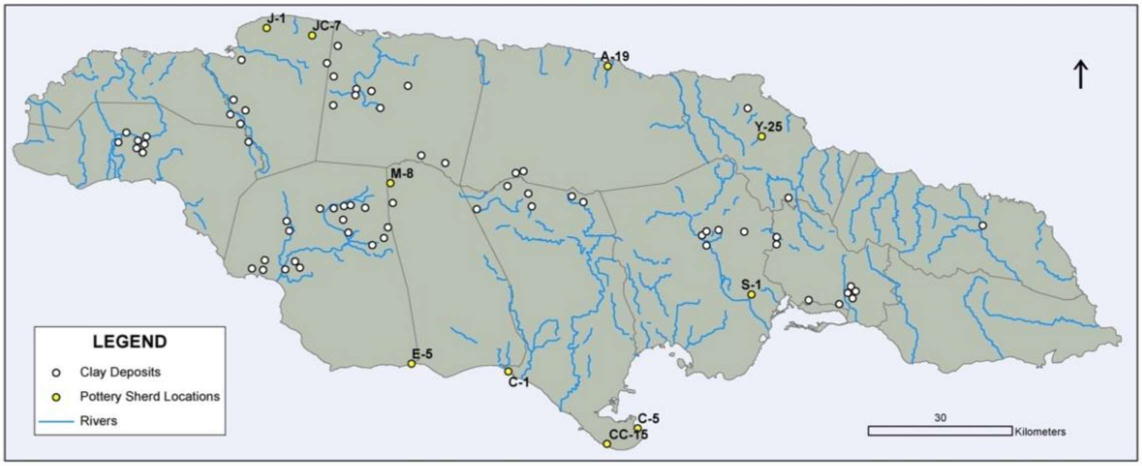

Figure 1. Map of Jamaica showing clay and sherd sites and their proximity to related drainage basins. (Source: Modified after Bailey 1970 and Atkinson 2019).

Table 1. Table showing site codes, site type, drainage basin, parish, and corresponding age.

Site ID/Code	Site Type	Locality & Parish	Drainage Basin/Ricer System
A-19	Open-Air	Windsor, St. Ann	St. Ann's Great River
C-1	Open-Air	Round Hill, Clarendon	Rio Minho
C-5	Open-Air	Holmes Bay, Clarendon	Rio Minho
CC-15	Cave	Taylor's Hut #1, Clarendon	Rio Minho
E-5	Open-Air	Alligator Pond River, St. Elizabeth	Alligator Pond River
J-1	Open-Air	Hartfield, St. James	Martha Brae
JC-7	Cave	Spot Valley Cave, St. James	Martha Brae
M-8	Open-Air	Auchtembeddie, Manchester	Black River (Hectors River)
S-1	Open-Air	White Marl, St. Catherine	Rio Cobre
Y-25	Open-Air	Green Castle, St. Mary	Wagwater

S-1 is within the Rio Cobre drainage basin, and until 1722 the river swept right by it (Duerden 1897). C-1, C-5 and CC-15 all fall within the basin of the Rio Minho. E-5 is close to the Alligator Pond River. M-8 is in the vicinity of the Hectors River, which forms part of the Black River Drainage Basin. J-1 and JC-7 are situated in a drainage basin again without a predominant watercourse, between Montego Bay and Salt Marsh Bay, where a number of small rivers flow north to the sea. A-19 is situated in another drainage basin where several rivers flow north to the sea, chief among them the White River, but the site itself is in the vicinity of the Great River. Y-25 is in the Wag Water River basin.

The sites sampled represent all the main cultural variants known in Jamaica. The oldest site (E-5) represents the "Redware culture". Four sites (S-1, C-1, CC-15, and Y-25) are definitely characterized by White Marl style ceramics. Two sites (J-1 and A-19) are representative of the Montego Bay Style, which Howard (1950) considered to be a (possibly later) variant of the predominant White Marl Style. Evidence found at sites C-5 and JC-7 suggests Ostionan and Meillacan, whereas M-8 has been traditionally associated with Meillacan. Eight of the ten sites are open-air middens, whereas two (CC-15 and JC-7) are caves. Representative pots are shown in **Figure 2**.

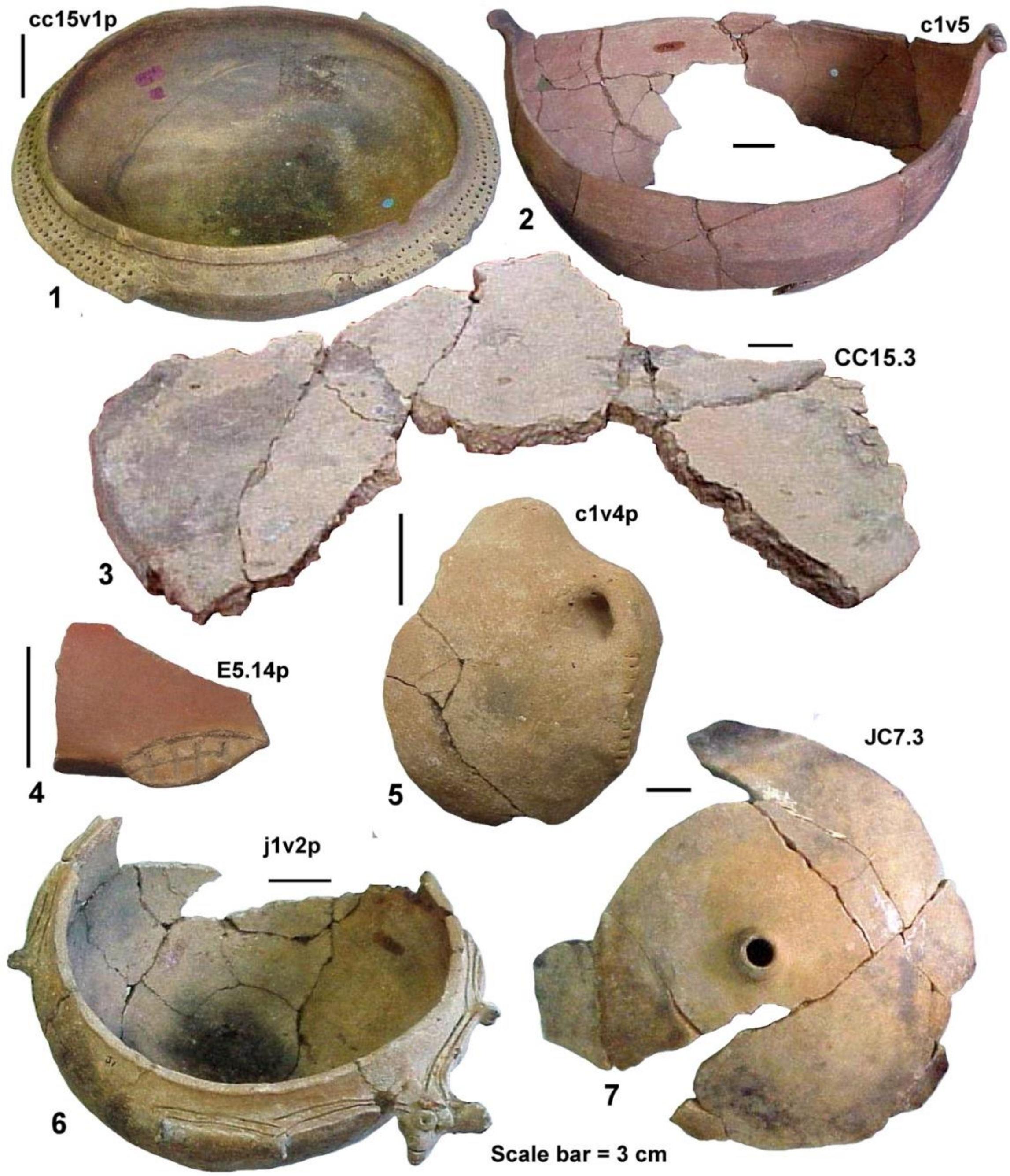

Figure 2. Representative pots – 1, Taylor's Hut #1. 2, Round Hill. 3, Taylor's Hut. 4, Alligator Pond River. 5, Round Hill. 6, Hartfield. 7, Spot Valley Cave. (Source: Allsworth-Jones 2008).

A-19 (Windsor). This is an open-air site on the north coast, on a hilltop immediately east of St. Ann's Bay. This site was excavated by M. de Wolf in 1933 and later by Capt. Charles Cotter (Cotter 1952; de Wolf 1953). Cotter was particularly interested in a British colonial fort which was apparently built at the same location. De Wolf recognized the prehistoric finds as belonging to Howard's Montego Bay style, and this description is borne out by the abundant finds in the Lee collection at UWI. The site is a midden and burial site of the Meillacan series (Howard 1950; Lee 1973-3; 1977-2; 1978-1; 1980-2; 1982-1; 1985-1&2; Cotter 1952; DeWolf 1953; Carlson 2002; Atkinson 2006; Allsworth-Jones 2008; Conolley 2011.

C-1 (Round Hill). This site is a large open-air site on the coast north-west of Farquhar's Beach, subject to active wave erosion (Donovan et al. 1995:7-12). It was visited frequently by Lee and his colleagues but was first described by Tyndale-Biscoe in the 1950s (Atkinson 2019). The UWI collection contains 2,045 potsherds, including 60 fragments of griddles and 148 fragments of water jars, as well as eight complete reconstructed vessels and a few non-ceramic items. The style of the pottery is again comparable to that from White Marl. The site has been designated as both Ostionan and Meillacan with a midden and burial function (Howard 1950; Tyndale-Biscoe 1954; Lee 1967-4; 1970-4; 1977-4; 1980-2; 1982-1; 1983-3; 1984-2; Vanderwal 1968; Carlson 2002; Atkinson 2006; Allsworth-Jones 2008).

C-5 (Holmes Bay). This site is described by Lee as a "village right at the sea's edge" on the northern coast of Portland Ridge, the potsherds were said to be "in no way remarkable except for the coarseness of the clay used in their manufacture" (Howard 1950:49-50; Lee 1971a).

CC-15 (Taylor's Hut). This site is a cave on the southern coast of Portland Ridge, discovered by Lee in 1971 and described by him as "an essentially undisturbed burial cave of major importance" (Lee 1971b, 1973). There were at least three human skulls, as well as other bones, and 11 complete pottery vessels, including a "squat bottle" which can be regarded as a water jar, three griddles, and other pottery fragments. The characteristics of the pottery are comparable to those from White Marl.

E-5 (Alligator Pond River). This is an open-air site immediately west of Alligator Pond River and near to the seashore. Lee visited this site frequently and reported that the material "appeared to have been scattered by storm waves" (Atkinson 2019). The UWI collection contains 2,956 potsherds, including 52 fragments of griddles and 90 fragments of water jars, as well as a few other items. A sizeable proportion of the sherds are decorated with red slip, and the site belongs to what Lee called the "Redware culture" (Lee 1976, 1979). To the east of Alligator Pond River, in a similar position to E-5, is another Redware site (M-4). This site was excavated by Vanderwal in 1966, when he obtained a radiocarbon date for it (Vanderwal 1968:130). The uncalibrated age determination of 1300 ± 120 BP (Y-1897) corresponds to a calibrated date of 645-879 cal AD (1σ p=1). It is likely that E-5 was occupied at about the same time and is therefore significantly earlier than White Marl.

J-1 (Hartfield). The site was given this name by Lee in 1983, whereas previously it had been mistakenly equated with Mammee Hill, described by Duerden in 1897 (Duerden 1897:16-17; Lee 1983). As Lee said, "Both sites are the same distance from the seashore, both occupy ridge tops in marly terrain, and both contain Montego Bay style pottery" (Meillacan). This style was first defined by Howard (1950:57-58, 145-146) as a variant of the dominant White Marl style. Excavated by Vanderwal in 1966, the site is on the north coast, east of Montego Bay and south of Ironshore. Abundant material was collected by Lee but was unrelated to Vanderwal's excavations. The site function was a midden and burial site; a complete griddle as well as flint chips and stone mauls and mortars were found at the site (Cundall 1934; Sherlock 1939; Howard 1950; 1956; 1965; Lee Site List 1965-10; 1966-8; 1967-12; 1970-2; 1980-2; 1982-1; Vanderwal 1968; Carlson 2002; Atkinson 2006; Allsworth-Jones et al. 2007; Allsworth-Jones 2008; Conolley 2011). It is to be noted that excavation of this site revealed three separate layers in addition to the overburden – an old occupation and two consecutive ash layers separated by a layer of sterile marl (Vanderwal 1968).

JC-7 (Spot Valley Cave). This site is apparently an undisturbed burial cave with pictographs located, and mapped by Lee, in 1970 (Lee 1970, 1990). The site is on the north coast, between Montego Bay and Falmouth, and south of Lilliput. At least eight individuals were buried in this cave. The UWI collection contains 693 potsherds, and one complete vessel, as well as a small chert component. The remains include at least one large water jar, but the majority of the pieces are plain body sherds, mainly dark in colour with prominent white temper (Lee 1974; Atkinson 2003; Carlson 2002; Allsworth-Jones 2008; JCO 2012). The site has been designated as being part of both the Ostionan and Meillacan series.

M-8 (Auchtembeddie). This is a small open-air site between Troy and Balaclava, not far from Oxford Cave. Located and mapped by Lee in 1967 (Lee 1967-11; Carlson 2002; Allsworth-Jones 2008).

S-1 (White Marl). This site is one of the largest middens in Jamaica, immediately east of Spanish Town, known since 1860, and the eponymous site for the "White Marl" cultural variant, which is the most widely represented in the island. The site was excavated between 1958 and 1969 by R. R. Howard, R. L. Vanderwal, and J. St. Clair. Eleven radiocarbon dates were obtained during Howard's excavations in 1963 and 1964 (Silverberg et al. 1972: 39-42). Two of the dates are considered to be probably contaminated. The remainder extend from 1073 ± 95 (Y-1118) to 460 ± 120 (Y-1750) BP, corresponding to a calibrated range from c. AD 950 to c. AD 1460 (Stuiver and Reimer 1993; CALIB version 4.4 Y-1750 1393-1525 cal A.D. [1σ p=0.902] Y-1118 859-1038 cal A.D. [1σ p=0.897]).

Y-25 (Green Castle). This site was mapped and given a code number by Lee, but much more about it has been revealed thanks to the UWI-MSU (Murray State University) excavations in 1999-2001 (Allsworth-Jones and Wesler 2003). It is also on the north coast on a hilltop west of Annotto Bay. Six trenches have been excavated to a maximum depth of 1.5 meters. Nine radiocarbon dates have been obtained, of which one is regarded as contaminated. The remainder (Allsworth-Jones and Wesler 2003: 187-188) extend from 920 ± 60 (Beta-158964 1034-1163 cal AD [1σ p=0.974]) to 330 ± 60 (Beta-134379 1488-1603 cal AD [1σ p=0.812]) BP, corresponding to a calibrated range from c. 1098 to c. 1545 cal AD (although in relation to the latter date it must be noted that there is no sign of Spanish presence). Broadly speaking the archaeological material is comparable to that from White Marl (Allsworth-Jones 2008).

Materials and methodology

Ten pottery samples were selected for analysis from each site (except for C-5 and M-8 where five were used since the UWI collection is not large). Most samples came from simple undecorated sherds, which did not include griddles. The external appearance of each sample was noted, and it was given a laboratory ID. All the material is from the surface, as collected by Lee, except for the Y-25 samples, which were excavated in 2000. Two samples [A-19 (36 LC1) and S-1 (74 LC45)] were deliberately selected to represent water jars. These vessels are distinctive (the handles in particular frequently survive) and their external appearance differs little throughout the island. Medhurst (1976) drew special attention to these "buff-yellow potsherds" which, as he said, are relatively thick, with no evidence of them having been used as cooking vessels, and their designation as water jars has been commonly accepted.

In addition, four clay samples were analyzed in an attempt to compare Pre-Columbian pottery with some raw material reflecting the different clay sources available on the island (Bailey 1970; Hill 1978). The first sample was obtained from Clays of Jamaica Ltd. (31 Molynes Road, Kingston 10) and is typical of what they currently use for manufacture. It comes from "Six Miles" on the Spanish Town Road and should correspond to the Hunts Bay area mentioned by Medhurst (1976). The three other samples were obtained by Anthony Porter (formerly of Alcan Jamaica). One is from Porus, and the other two are from the Black River area (Frenchman and Hodges), both sites mentioned by Bailey (1970). It was expected that these samples could provide a standard of comparison complementary to the *Geochemical Atlas of Jamaica*, and elements were selected based on those analyzed in the atlas.

In 2017, the Mines and Geology Division embarked on a clay project as part of their Economic Minerals Unit with funding from UNDP, to produce a modern assay of the clay deposits around the island. This survey and analysis of clay deposits mirrored the sites sampled by Bailey (1970). Data from thirty-nine clay samples were analyzed and data incorporated into this study. The analysis of these samples allowed for a more comprehensive look at possible relationships between clay deposits and the potsherds and by extension would begin the process of determining the provenance of the clays from which the potsherd have been manufactured.

Sample Preparation

Compositional analysis was performed using X-Ray Fluorescence (XRF) because of its ability to perform multi-element quantitative analysis without destruction of the samples. The pottery samples were filed using an aluminium file to create a smooth surface for irradiation and cut to fit the 50 mm in diameter sample holder of the analyzer. Clay samples, collected from Porus, Hodges, Frenchman and Six Miles, were oven dried at 80°C and finely ground to less than 50 microns. They were fired in a laboratory muffle furnace at a temperature of 1,200°C for 24 hours. Four grams of each sample were pressed into a 25 mm pellet under 10 tones pressure using a hydraulic press.

Measurements

The pottery and clay samples were measured using the EDX-771 X-ray Fluorescence Spectrometer. **Table 2** summarizes the measurement conditions used for the analysis of the elements of interest. The Standard Reference Material NIST Jamaica Bauxite 698, was used to calibrate the spectrometer and quantify for unknown elements (Al, Br, Ca, Cu, Fe, K, Mn, Mo, Rb, Si, Sr, Y, Zn, Zr). Quality control for the 90 clay samples was carried out using an in-house standard reference material SOJ (Soil of Jamaica) and comparison with Neutron Activation Analysis at the International Centre for Environmental and Nuclear Sciences (ICENS)." The agreement obtained was better than ± 10 %.

Table 2. Measurement conditions used to analyse pottery and clay samples.

Measurement conditions	Ti secondary target, 3.0 mA, 15 kV	Zr secondary target, 3.0 mA, 40 kV	Ag secondary target, 1.5 mA, 35 kV
Elements analyzed	Al, Si, K, Ca	Mn, Fe, Cu, Zn, Br, Rb, Sr	Mo, Zr, Y

Results

Copies of the full dataset of elemental analyses have been deposited in the Archaeology Laboratory and Geology Museum at the University of the West Indies. Summary statistics for pottery samples from the ten sites are presented in **Table 3** and for clays in **Table 4**.

Table 3. Summary statistics for elements analysed from the potsherds at the ten sites.

Site		A19	C1	C5	CC15	E5	J1	JC7	M8	S1	Y25
Si[a]	mean	33.83	28.26	25.78	18.06	28.64	35.67	26.00	25.03	28.17	30.89
	SD	4.38	3.13	4.19	7.69	3.79	4.97	6.04	6.65	4.69	3.55
Mn	mean	217.64	391.79	351.25	447.79	341.07	241.99	317.46	516.31	206.47	216.09
	SD	130.07	150.16	137.57	127.32	209.70	73.84	271.89	220.31	179.00	49.51
Mo	mean	0.46	1.06	1.30	1.13	0.62	0.50	1.38	1.39	0.46	0.86
	SD	0.70	0.43	0.25	0.39	0.72	0.48	0.13	0.78	0.59	0.83
Rb	mean	33.26	21.91	23.26	23.49	25.54	36.79	27.75	25.38	40.89	66.59
	SD	12.41	6.52	10.66	3.46	6.86	5.51	5.31	5.51	12.55	13.09
Sr	mean	144.61	264.13	315.75	320.20	319.15	212.65	99.11	190.57	150.69	264.79
	SD	93.99	77.02	57.55	50.52	81.24	132.86	39.70	72.37	40.94	62.75
Y	mean	9.67	10.52	7.57	10.25	9.18	9.62	32.62	13.83	7.94	9.01
	SD	6.42	3.39	1.36	2.51	3.72	1.73	43.25	7.13	3.93	2.53
Cu	mean	26.57	40.06	32.80	59.60	22.23	24.39	89.18	41.47	38.18	40.23
	SD	11.11	8.91	6.70	12.89	8.08	6.43	49.66	14.43	9.76	9.25
Zn	mean	114.14	201.48	112.35	312.56	95.69	125.98	280.95	225.92	230.31	129.69
	SD	43.08	105.08	17.02	180.08	25.31	35.88	92.57	152.01	199.41	23.47
Br	mean	10.67	12.89	12.19	11.51	44.75	13.49	17.67	8.09	13.83	6.67
	SD	6.49	10.91	4.17	4.05	27.46	11.42	5.54	6.67	5.31	3.46
Zr	mean	169.04	169.01	150.68	138.57	140.34	159.38	198.50	197.69	151.08	223.88
	SD	40.80	36.52	19.37	15.81	39.43	29.23	53.16	81.94	22.40	57.63
Al[a]	mean	9.35	8.47	8.31	7.14	10.23	8.54	7.41	10.44	9.11	9.20
	SD	1.93	0.72	1.29	1.97	1.68	0.92	1.14	1.90	0.99	1.18
K[a]	mean	0.93	1.03	0.98	1.27	0.92	1.74	1.08	0.82	1.04	2.11
	SD	0.35	0.24	0.13	0.38	0.22	0.52	0.53	0.21	0.28	0.36
Ca[a]	mean	1.75	1.61	1.15	6.12	2.05	2.05	1.96	1.41	1.58	1.68
	SD	1.05	0.39	0.21	5.56	1.89	1.17	0.65	0.39	0.73	0.65
Fe[a]	mean	2.61	3.65	3.49	3.12	2.69	2.56	3.46	4.15	2.82	2.75
	SD	0.64	0.55	0.47	0.77	0.60	0.48	1.57	0.80	0.54	0.44

[a]percentages, others in ppm

Table 4. Results of elemental analysis of the four clay samples ([a]percentages, others in ppm).

Element	Porus	Six Miles	Hodges	Frenchman
Si[a]	12.82	33.31	38.61	34.34
Mn	311.59	845.31	124.29	165.06
Mo	2.44	1.39	4.35	2.48
Rb	8.53	91.83	5.98	5.27
Sr	151.58	290.66	40.79	50.53
Y	59.88	18.17	9.90	8.88
Cu	41.36	63.61	22.97	19.85
Zn	238.58	199.71	73.17	46.38
Br	8.05	12.27	5.10	3.45
Zr	376.19	179.03	524.98	424.68
Al[a]	18.80	9.52	9.50	9.41
K[a]	0.09	2.03	0.13	0.10
Ca[a]	0.15	1.56	0.20	0.22

Fe[a]	8.66	3.35	0.61	0.36

Interpretation

The results were subjected to univariate, bivariate and multivariate analysis in order to understand the relationships of the concentrations of elements at the ten sites analyzed.

Univariate Analysis

Plots of the range of variation in each element for the pottery samples were created in Microsoft Excel. Sample plots for K, Rb and Sr are shown in **Figure 3**. These plots show that there is considerable variation within and between sites, but insufficient variation to distinguish between sites. For instance, K is high in J-1 (1.2 – 3.0%) and S-1 (1.6 – 3.0%) and Rb is high in S-1 (60 – 85 ppm). This suggests possible bivariate plots to look at the relationships between sample sites and these elements.

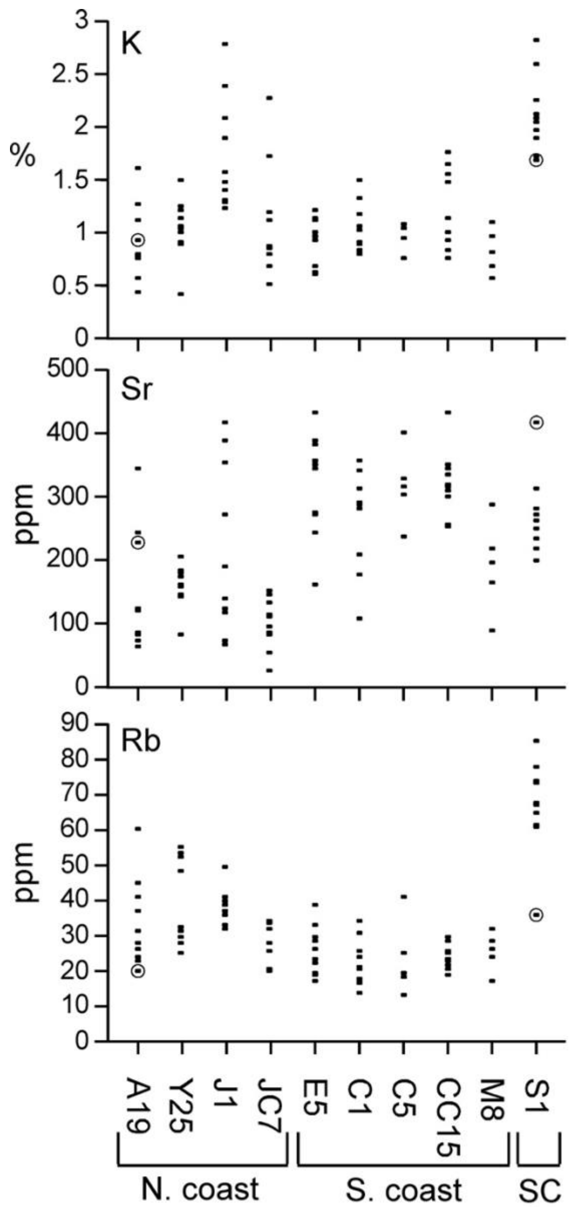

Figure 3. Univariate plots of potassium (K), Strontium (Sr) and rubidium (Rb) for each archaeological site. Note the relatively great variability in elemental composition at each site. The water jug in A-19 (ringed) does not differ

significantly from other pottery samples, but the water jug (ringed) in S-1 is a distinct outlier suggesting it was formed from a different clay source and has been imported from elsewhere in Jamaica. Site S-1 is distinct (other than for the water jug) from all other sites based on the Rb concentrations.

Bivariate Analysis

Bivariate analyses were undertaken from visual inspection of the results of the univariate analyses. Bivariate plots were produced for Rb versus K (**Figure 4**), Rb versus Sr (**Figure 5**) and Si versus RB (**Figure 6**).

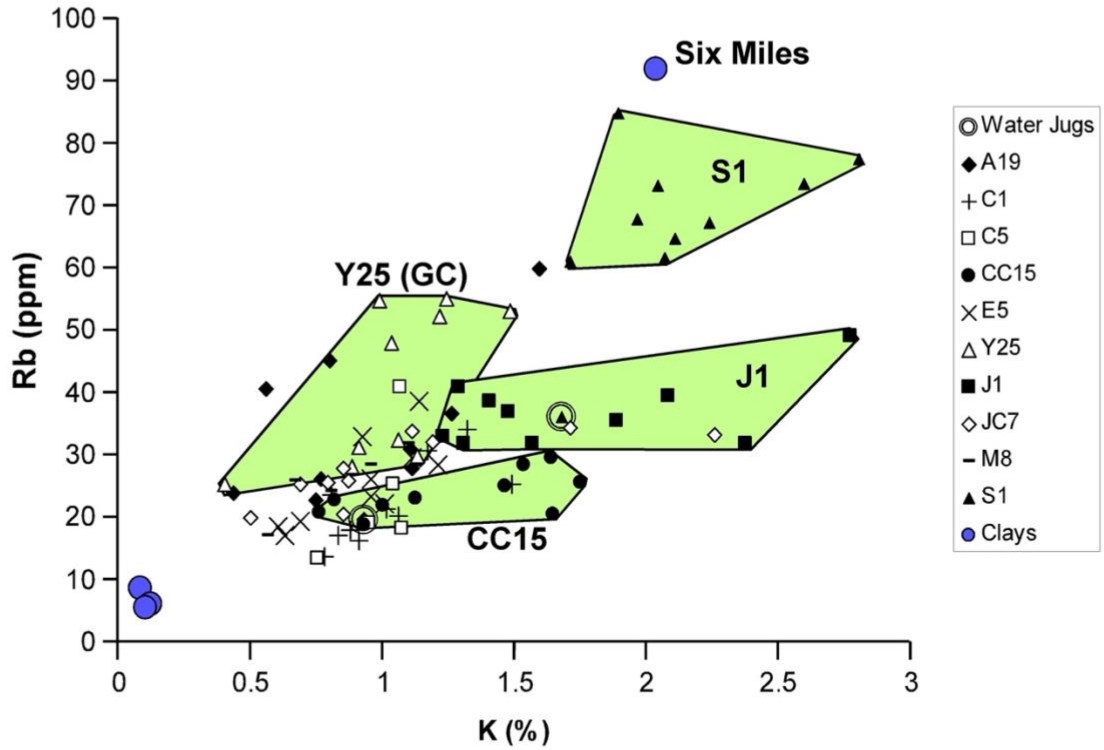

Figure 4. Bivariate plot of rubidium versus potassium of pottery samples. Three clay samples (Porus, Hodges and Frenchman) plot close to the origin and one clay sample (Six Miles) plots in the upper right central area of the diagram. Pottery samples (other than for the water jug) from S-1 plot in a distinct field and the fields for Y-25 (GC) (with two subplots – low Rb and high Rb), CC-15 and J-1 are largely distinct. Fields for other sites overlap.

The plot of Rb versus Sr (**Figure 4**) clearly distinguishes pottery (excluding water jugs) from some sites. Sites S-1, Y-25 (GC) (with two subfields), J-1 and CC-15 plot in virtually separate fields (**Figure 4**); this indicates that different clay sources were being used at each site (and probably two clay sources at Y-25(GC) and that the pottery from these sites was not traded. Pottery from the other sites clusters in a relatively similar field that probably indicates a similar kind of clay deposit rather than a single unique clay source. It is notable that the S-1 pottery samples (excluding the water jug) plot close to the Six Miles clay sample. With addition of binding material to the clay (reducing the Rb content) this could be similar to or the source of the pottery from S-1 (White Marl). What is particularly noticeable is that the water jug from S-1 plots in a separate field compared to the pottery from S-1. This demonstrates that the water jug was from a separate clay deposit and was probably brought to the site by travelers or through trading.

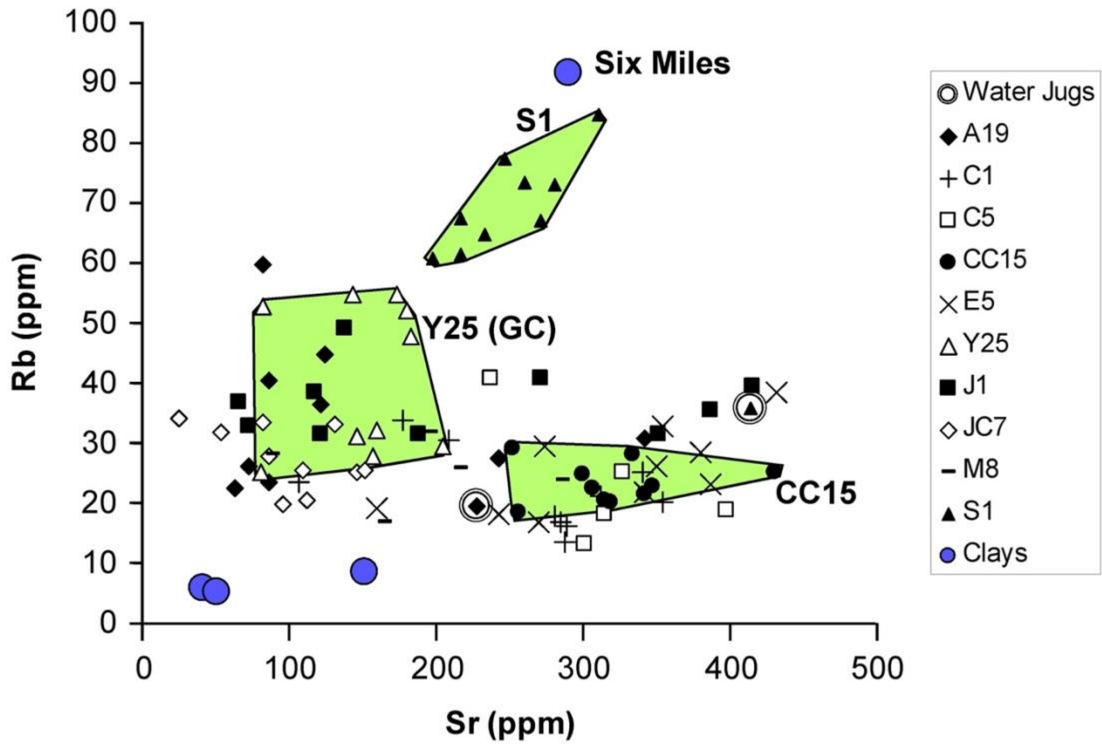

Figure 5. Bivariate plots of rubidium versus strontium showing separating of samples from pottery from site S1. Three clay samples (Porus, Hodges and Frenchman) plot close to the origin and one clay sample (Six Miles) plots in the upper right central area of the diagram. Pottery samples (other than for the water jug) from S1 plot in a distinct field and the fields for Y-25 (GC) and CC-15 are largely distinct. Fields for A-19, J-1, C-5, E-5 and M-8 plot along a trend from Y-25 (GC) towards CC-15. The water jug from A-19 plots just outside the pottery field for A19.

The plot of Rb versus Sr (**Figure 5**) shows a similar separation of pottery samples, but not as well as the plot of Rb versus K (**Figure 4**). A similar trend is seen with one trend towards higher Rb values (as in **Figure 4**) and one trend towards low Rb values. Samples from sites such as, Y-25 (GC), J-C7, most samples from A-19 and several samples from J-1, plot with low Rb and low Sr values. These sites are located on the northern coast of Jamaica.

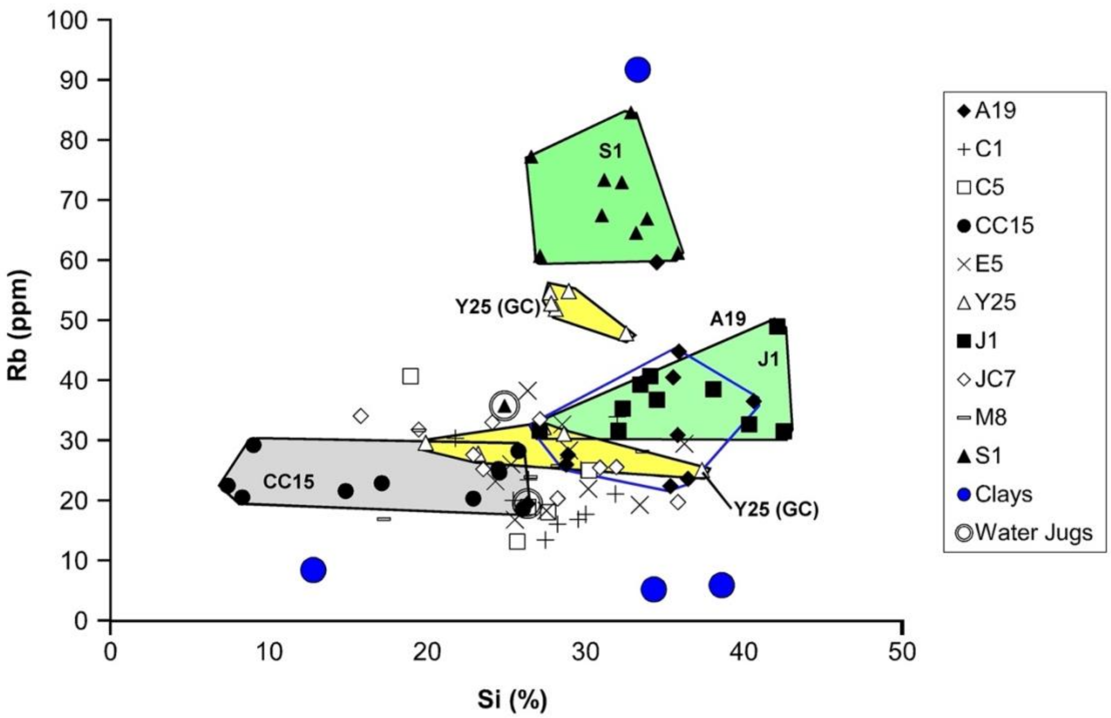

Figure 6. Bivariate plot of rubidium versus silicon for pottery samples from Jamaica. Three clay samples (Porus, Hodges and Frenchman) plot close to the x axis and one clay sample (Six Miles) plots in the upper right central area of the diagram. Note the clear separation of pottery from S-1, CC-15 and J-1, the clear distinction of pottery from Y-25 (GC) into two fields (based on Rb content) and that the two water jugs plot away from respective fields of the sites where they were recovered.

The Rb versus Si plot (**Figure 6**) shows a similar pattern, with many sites having pottery that plots in separate fields (e.g., S-1, CC-15 and J-1). Pottery from Y-25 (GC) clearly plots in two fields suggesting two different clay sources. Pottery from other sites shows more overlap as in the other diagrams. In this plot the two water jugs plot in different places to the pottery from the sites where they were collected, and it would seem they were not made at the sites where they were found.

Bivariate plots clearly help distinguish the pottery from different sites, although for some sites there is a certain amount of overlap. It is particularly notable that S-1 is distinguished in nearly all plots. The high Rb content can be explained by the weathering of the Above Rocks granodiorite which is likely to add significant amounts of Rb to clays. It is also notable that the clay sample from Six Miles also has high Rb contents (higher than the pots), 'but with the addition of filler material to the clays prior to pot manufacture this clay could well be considered as the source material for this site. The close proximity of this clay site to the S-1 (White Marl) locality indicates that the majority of clay for pottery production was locally sourced. Elsewhere, the pottery from several sites plots in distinctive fields suggesting that the source clays are from separate sources. Of particular note is the Green Castle (Y-25) site that has two separate fields relating to pottery. This suggests that two different clay sources were used for the construction of pottery at this locality. **Figure 6** also shows convincingly that the water jars do not have the same elemental composition as the pottery from the sites where they were collected. Undoubtedly, water jars were carried when Pre-Columbian people travelled from site to site, and therefore were more likely to be transported or traded. The two water jars analyzed clearly demonstrate this convincingly. The other three clay samples have very low Rb contents, well below any of the pottery samples, and clearly were not used for the manufacture of pottery.

Multivariate Analysis

Factor Analysis was undertaken on the pottery dataset and the first four factors and components are shown in **Tables 5** and **6**, respectively. The first two components account for 41% of the variance in the dataset. The first factor shows a strong positive correlation with Mn, Mo, Y, Cu, Zn and Fe and a strong negative correlation with Si. This can best be attributed to the influence of the leaching of Si during the formation of Jamaican bauxitic soils (Robinson 1971). The second factor shows a strong positive correlation with Rb, Y and Zr and a strong negative correlation with Sr and Ca. This is likely to be due to the influence of the weathering of igneous rocks within the Cretaceous inliers of Jamaica (Mitchell 2013, 2021).

Table 5. First 4 Components from Factor Analysis.

Component	Total	% Of Variance	Cumulative
1	3.267	23.334	23.334
2	2.518	17.989	41.323
3	1.755	12.534	53.857
4	1.472	10.514	64.371

Table 6. Component Matrix for first four Factors.

Element	1	2	3	4
Si	-0.694	0.447	-0.238	-0.169
Mn	0.671	-0.014	-0.116	0.549
Mo	0.541	0.215	-0.180	-0.129
Rb	-0.390	0.583	0.570	0.169
Sr	-0.118	-0.587	0.184	0.579
Y	0.579	0.422	-0.059	0.108
Cu	0.606	0.191	0.155	-0.414
Zn	0.687	0.026	0.311	-0.112
Br	-0.026	-0.201	-0.468	0.198
Zr	0.119	0.801	0.072	-0.053
Al	-0.315	0.319	-0.401	0.437
K	-0.194	0.391	0.672	0.451
Ca	0.317	-0.558	0.499	-0.053
Fe	0.669	0.353	-0.290	0.354

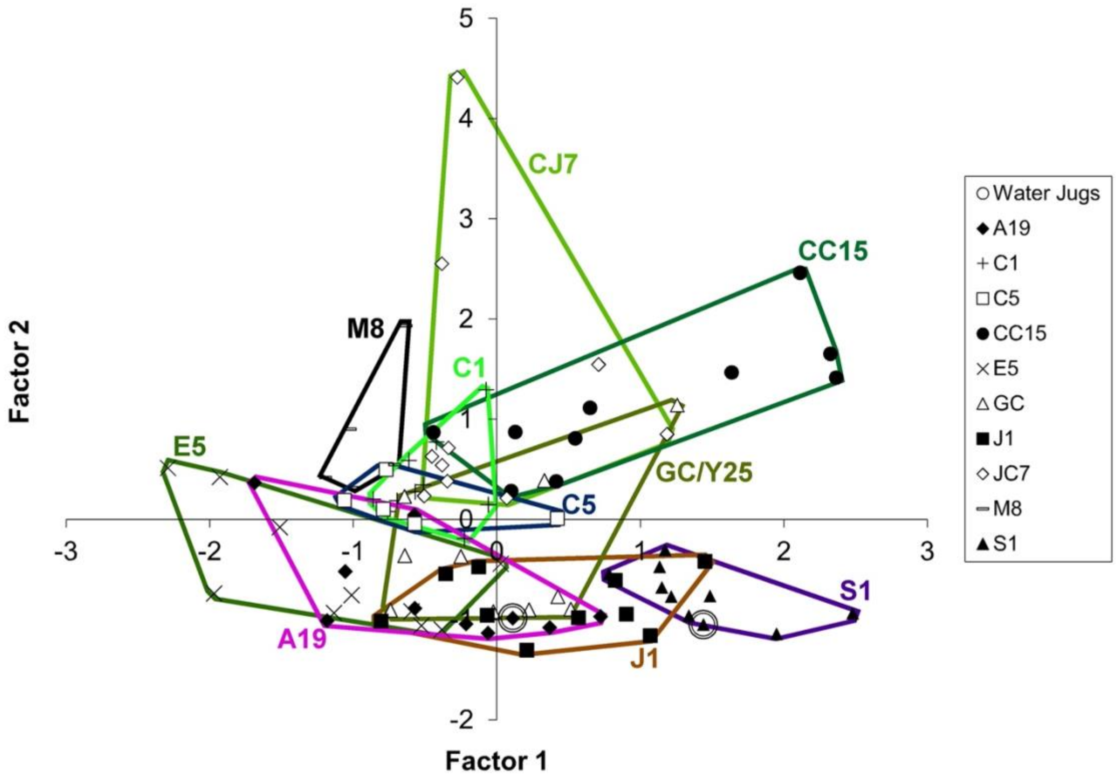

Figure 7. Plot of scores on a cross plot of Factor 2 against Factor 1 for the pottery samples from Jamaica. Although there is overlap, pottery samples from different sites plot in different fields. Interestingly, the water jars plot within their sites of collection. However, it is notable that the water jar from S-1 plots close to the field of J-1 (as it does in Figure 4-6) and the water jar from site A-19 plots within the fields of J-1, GC/Y-25 and close to E-5.

Factor analysis helps separate more of the sites into separate, but overlapping, fields (**Figure 7**). This suggests that the elemental composition of pottery does vary between sites and that local clays may have been used for pottery production. This plot, however, does not separate site S-1 from site J-1 and the water jars do not plot in separate fields away from the sites where they were collected. This is likely due to these two factors not picking up sufficiently the differences in Rb concentrations, particularly in the water jar from S-1. Clearly, both bivariate and multivariate analyzes have their uses.

Comparison with other clays in Jamaica

Figures 8-10 shows the addition of all the clay samples together with the potsherds (Rb vs Si; Rb vs Sr and Rb vs K). Visual inspection of these plots showed significant overlap in sites, except for S-1 and Y-25. S-1 in all cases plotted as a distinct population, Y-25 showed a cluster of five samples in the Rb vs K plot. The Stony Hill Samples did not have any signatures in common with the potsherds or any other clay deposits and as such plotted as outliers. Three samples from site A-19 plotted away from the main cluster, two very close to Y-25 and one close to the sample from S-1. All other samples clustered together within the Rb 40 ppm and K 2% segment of the graph. **Figure 8** shows similar trends to **Figure 9**, in that S-

1 plots as a distinct population and Y-25 shows a small cluster. The clay samples plot within the cluster of sites with only the Hunts Bay sample showing any relationship to S-1. Hampstead samples appear to plot with sites from both the north coast and south coast of Jamaica, namely C-1, Y-25. Cave Valley clays plots with C-5; Dromily sample plots in a cluster with sites CC-15, C-1, E-5 and A-19. Generally, the clay samples and the potsherds show significant overlap as in **Figure 8**.

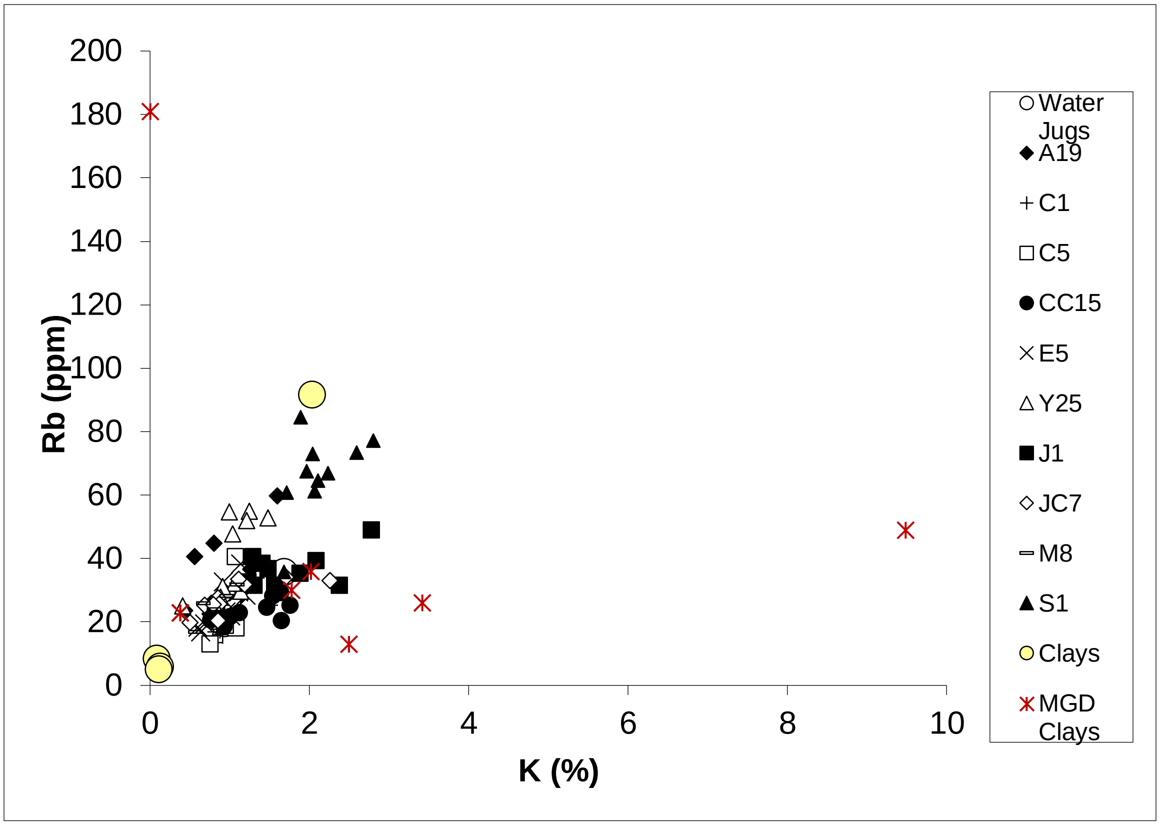

Figure 8. Plot of Rubidium vs Potassium for clay samples (both original and MGD) and pot sherds.

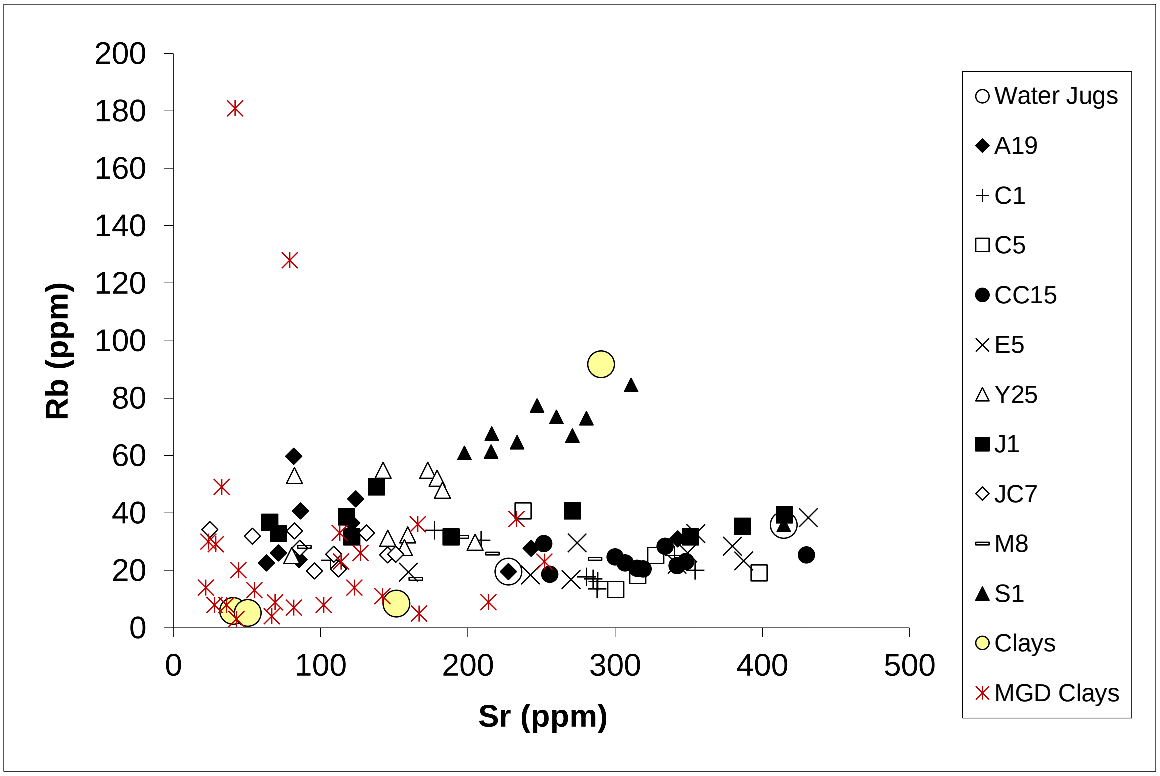

Figure 9. Plot of Rubidium vs Strontium for clay samples (both original and MGD) and pot sherds.

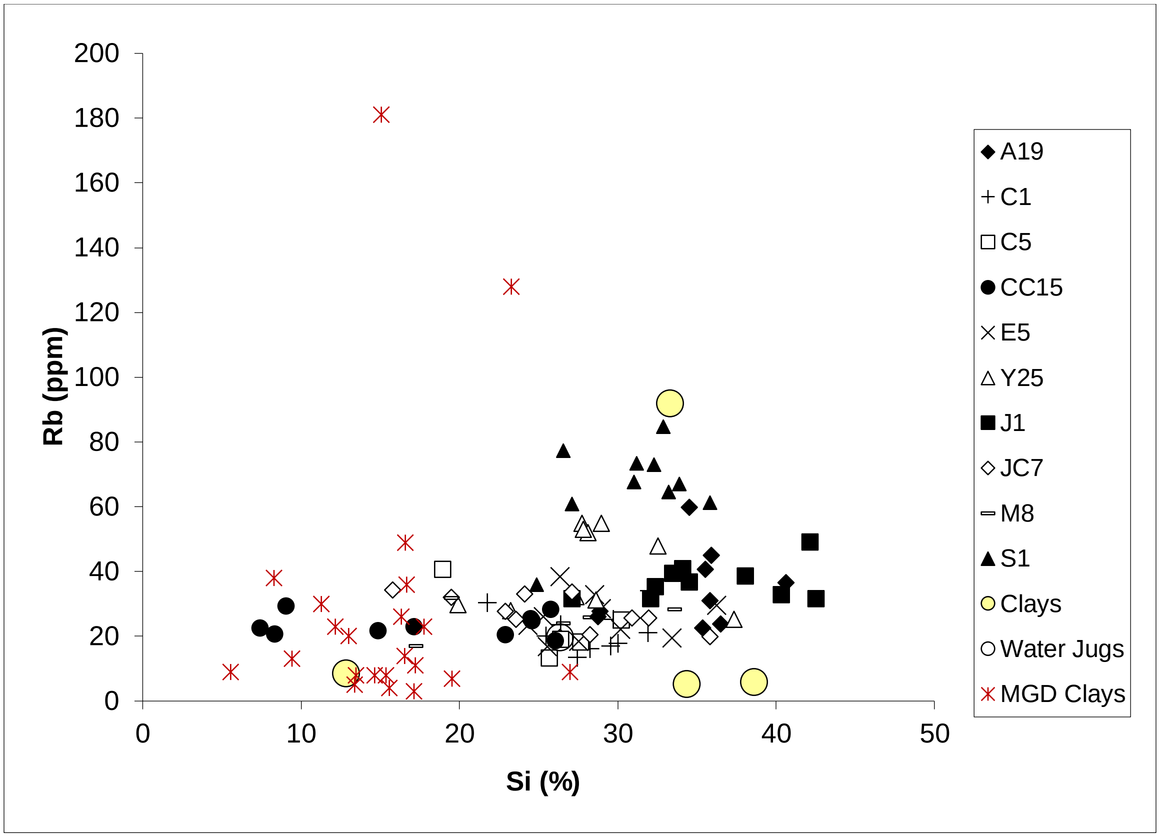

Figure 10. Plot of Rubidium vs Silicon for clay samples (both original and MGD) and pot sherds.

Discussion/Conclusion

This study has demonstrated that it is possible to distinguish pottery samples from different sites in Jamaica using elemental analysis. Although our analysis used relatively few elements, the results are very encouraging. Some sites clearly show distinct elemental compositions of their pottery and do not overlap with the elemental compositions of pottery from other sites. For other sites, there is more overlap. These results have to be interpreted in terms of the potential clay sources at each site. For the sites analyzed three broad clay sources are likely.

First, the weathering of the granodiorite in the Above Rocks Inlier which would have supplied high concentrations of Rb, is demonstrated in the pottery from White Marl (site S-1) and the clay sample from Six Miles. The lack of this distinctive signature in pottery analyzed from elsewhere in Jamaica indicates that pottery from White Marl was not exported or traded to other sites in Jamaica. In contrast, the water jar from White Marl shows an anomalous elemental composition and matches better sites such as E-5, J-1 or CC-15. This suggests that water jars were more mobile, either being carried from site to site by travelers, or containing goods that were traded.

The second source of clays would be from the weathering of the rocks from the Cretaceous inliers. Many of these consist of volcanic rocks (Jackson et al. 1989; Mitchell 2003).

The third source would be from the remobilization of bauxitic clays produced from the weathering of volcanic ash that fell on Jamaica in the Miocene (Comer 1974). Such clays would be strongly leached of mobile elements.

It is likely that pottery from the other sites studied in this work was derived from clay deposits from a combination of clays from the Cretaceous Inliers and bauxite deposits. The three clay samples analyzed from south-central Jamaica had composition that did not match any of the pottery from our sites. It would seem that these clay deposits were either not available at the time or were unsuitable for the construction of pottery.

Plots of Rb, Sr and K were useful as they showed differentiation. Both the sherds and clay samples show relationships between Sr and Rb and K and Rb. Unfortunately, the data does not show sufficient discrimination to definitively correlate individual sources and specific sites. Except for site S-1 (White Marl) where the Six Miles sample correlates well and plot in the same cluster. For example, clay samples from Kellits, Clarendon, Norwood and Thatch Walk, St Ann and Stony Hill, St Andrew were outliers and plotted away from the sample clusters. This suggests that there is no relationship between these deposits and the analyzed potsherds (Rb vs K). However, plots of Rb vs Sr showed significant overlap of clay samples and potsherds, with Stony Hill samples remaining as outliers.

Our initial conclusions are that clay for the manufacture of pottery by the Pre-Columbian population was locally sourced. This would fit with the need for cooking utensils, which had a short life and a low value. It was only water jars, which might be needed by travelers or used to transport commodities that travelled or were traded and are found on sites where they were not manufactured. This study provides a window into how elemental analysis can be used to help with understanding archaeological problems. This was a preliminary study and should be followed up with a study consisting of many more pottery samples and with analyses of many more elements.

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Contributions: *The initial work carried out by Allsworth-Jones, Voutchkov, Lalor and Mitchell presented results of an analysis of ninety pottery samples from ten sites across Jamaica, identified from the Lee Collection (housed at the UWI Mona Archaeology Lab), together with four specific clay samples analyzed from four select sites across Jamaica. This work was extended by James-Williamson, Mitchell, and Dolphy to include analysis available from the Mines and Geology Division of an island-wide assay of clay deposits to mirror the Bailey 1970 publication plus additional locations where clays have been discovered since the Bailey study.*

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