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PRELIMINARY PETROGRAPHIC AND CHEMICAL ANALYSES OF PREHISTORIC CERAMICS FROM CARRIACOU, WEST INDIES

Scott M. Fitzpatrick
Department of Sociology & Anthropology
North Carolina State University
scott_fitzpatrick@ncsu.edu

Jennifer A. Carstensen
Department of Geological Sciences
California State University—Northridge
eitsyrc@aol.com

Kathleen M. Marsaglia
Department of Geological Sciences
California State University—Northridge
kathie.marsaglia@csun.edu

Christophe Descantes
Archaeological Research Facility
University of California–Berkeley
cdescantes@berkeley.edu

Quetta Kaye
Institute of Archaeology
University College London
quettakaye@hotmail.co.uk

Michael D. Glascock
Archaeometry Laboratory
University of Missouri Research Reactor
glascockm@missouri.edu

Michiel Kappers
In-Terris Site Technics
Netherlands
michiel@in-terris.com

Petrographic and chemical analysis of prehistoric ceramic sherds from the island of Carriacou in the southern Grenadines, West Indies offers preliminary insight into resource exploitation, manufacturing techniques, and the distribution of pottery from ca. AD 400–1200. Thin-section petrography of two different suites of sherds (Suite 1: n=24 from six sites; Suite 2: n=54 from five of the same sites plus three others) indicates that there are at least five temper groups, all or most of which appear to be exotic to Carriacou. Instrumental neutron activation analysis (INAA) of 56 sherds from Suite 2 reveals the existence of two main geochemical compositional groups. This may be a reflection of prehistoric potters selecting clays derived from two geochemically different substrates in the location(s) of manufacture. A comparison of these findings suggest that: 1) exotic materials are predominant in manufacture; 2) both local and regional transport of ceramics occurred prehistorically; 3) the correspondence between the temper and INAA compositional groups is unclear, suggesting that the paste geochemistry might mask minor temper differences; and 4) clay and temper preferences may have changed through time, although this will require further testing.

The analysis of ceramics from archaeological sites, both on the surface and excavated from stratified deposits, can help us explore issues related to the production, distribution, and movement of artifacts across time and space. In the Caribbean, most ceramic studies have focused on examining stylistic motifs and morphological attributes of pottery (e.g., Righter 1997; Roe 1989; see also Keegan 2000), whereas technological aspects of production such as firing temperature, porosity, and density have only been cursorily studied (for one exception see Curet 1997). Unfortunately, there has been a paucity of research dedicated to investigating the mineralogical and chemical composition of pottery in general (but see Carini 1991; Donahue et al. 1990; Fuess et al. 1991; Fuess and Donahue 1992;Lambert et al. 1990; Mann 1986; Winter and Gilstrap 1991; van As and Jacobs 1992), despite the usefulness of such approaches for answering a number of important provenance and manufacturing/technology-related questions and their widespread use in other regions worldwide.

To remedy this situation and provide the first compositional analysis of ceramics from the island of Carriacou in the southern Grenadines, we conducted thin-section petrography and INAA on nearly 80 sherds (Suite 1: n=24 sherds, detailed petrography only; Suite 2 = 56 sherds, all INAA and 54 cursory petrography). This study is one component of the Carriacou Archaeological Survey Project and part of a larger regional effort by researchers at the University of Missouri Research Reactor (MURR) to develop a database of Caribbean ceramics that will be beneficial to the greater Caribbean archaeological community. In this paper, we first provide a brief archaeological and environmental background to contextualize research thus far conducted on Carriacou. We then discuss the methods we used for sampling and analyzing prehistoric ceramics. Our results suggest that there are at least five major geological sources of temper components, with two major chemical groups (paste?) identified using INAA. Both types of analyses indicate that prehistoric Carriacouan pottery was produced using primarily exotic materials however, there does not appear to be any direct correlation between the temper and chemical groups. Nonetheless, the data still have implications for understanding local manufacturing techniques, the movement of pottery and other raw materials within the Lesser Antilles, how cultural interactions and resource exploitation may have changed over time, and the utility of combining these two methods for examining prehistoric pottery production.

Archaeological Research on Carriacou

Jesse Fewkes (1907:189–190) was one of the first scholars to investigate Carriacou and adjacent islands and described the ceramics found there as “among the finest West Indian ware that has yet come to the Smithsonian Institution.” Bullen (1964) investigated Grenada in the 1960s and made several short trips to St. Vincent and the Grenadines to collect artifacts and excavate exploratory trenches, including the Sabazan site on Carriacou (Bullen and Bullen 1972). Sutty (1990) surveyed portions of Carriacou and recorded surface finds at Grand Bay, Sabazan, and a number of other prehistoric sites, but did not conduct any excavation.

In July 1999, Kappers visited the Grand Bay site on Carriacou and noted a substantial amount of cultural material visible on the surface. The project’s field directors (Kaye, Kappers, and Fitzpatrick) later surveyed nearly the entire coastline of Carriacou in March–April 2003, as well as interior areas that were relatively flat or easily accessible. The team recorded 11 locations with evidence for prehistoric occupation, six of which had significant finds (primarily ceramics and faunal refuse) that were indicative of long-term settlement activities (Kaye et al. 2004). Of these six sites, Sabazan and Grand Bay had the most extensive stratified coastal profiles and an abundance of faunal remains, artifacts, and archaeological features, although other sites were also thought to have good potential for further study. As part of a long-term plan to investigate Carriacou's prehistoric occupation, the research team has focused on conducting limited testing at Sabazan and large area excavations at Grand Bay since 2004 (Fitzpatrick et al. 2004; Kappers et al. 2005; Kaye et al. 2004, 2005).

A total of 20 radiocarbon dates (charcoal, marine shell, and human bone) from Grand Bay, Sabazan, and Harvey Vale suggest that the island was first settled by ceramic making peoples during the terminal Saladoid period around A.D. 400, with later periods of cultural development characteristic of the Troumassan Troumassoid (ca. A.D. 600–1000) and Suazan Troumassoid (ca. A.D. 1000–1400) subseries of ceramics (Fitzpatrick et al. 2004, in press; Harris 2005). Material recovered from excavations at Grand Bay includes a vast array of mostly undecorated pottery sherds, ceramic adornos (modeled appliqué of animals or zoomorphs attached to the rims of vessels), two rare stone cemís, bone needles and tools, carved turtle plastron, shell beads and adzes, charred seeds, an enormous amount of fishbone (LeFebvre 2005), turtle bone, and mollusk shells, at least ten human burials, and numerous posthole, pit, and hearth features.

Environmental Background

Carriacou is located in the southern Lesser Antilles approximately 250 km north of Venezuela and 30 km north of Grenada (Figure 1). Politically, Carriacou is part of the tri-island nation of Grenada along with Petite Martinique, but also includes the smaller islands of Petite Dominica, Petite St. Vincent, Saline, and Frigate. Carriacou is the largest island in the Grenadines chain measuring 10.4 km from north to south, 8.7 km across at its widest point, and roughly 32 km^2 in area—it has a maximum elevation of 290 m.

Geologically, Carriacou lies on the southern Lesser Antilles platform between the two most active volcanoes of the Lesser Antilles magmatic arc, the subaerial St. Soufriere volcano on St. Vincent (Heath et al. 1998b) and the submarine volcano Kick'em Jenny near the volcanic island of Grenada (Heath et al. 1998a). Outcrops of Neogene (2.7 to 11.2 Ma) magmatic rocks dominate the western half of Carriacou, whereas outcrops of older Miocene to Eocene sedimentary units dominate the eastern half (as summarized by Speed et al. [1993]). These outcrops include basaltic to andesitic intrusive, extrusive, and epiclastic volcanic rocks and fossiliferous limestone (Caldwell 1983; Donovan et al. 2003; Jackson 1980; Pickerall et al. 2001, 2002; Robinson and Jung 1972; Speed et al. 1993).

Methods

One of the research goals of archaeological investigation on Carriacou is to determine how pottery, the most ubiquitous artifact class found on the island (and the Caribbean in general), was manufactured by native groups, used for domestic or other activities, and perhaps transported either across or between islands through time. A fundamental

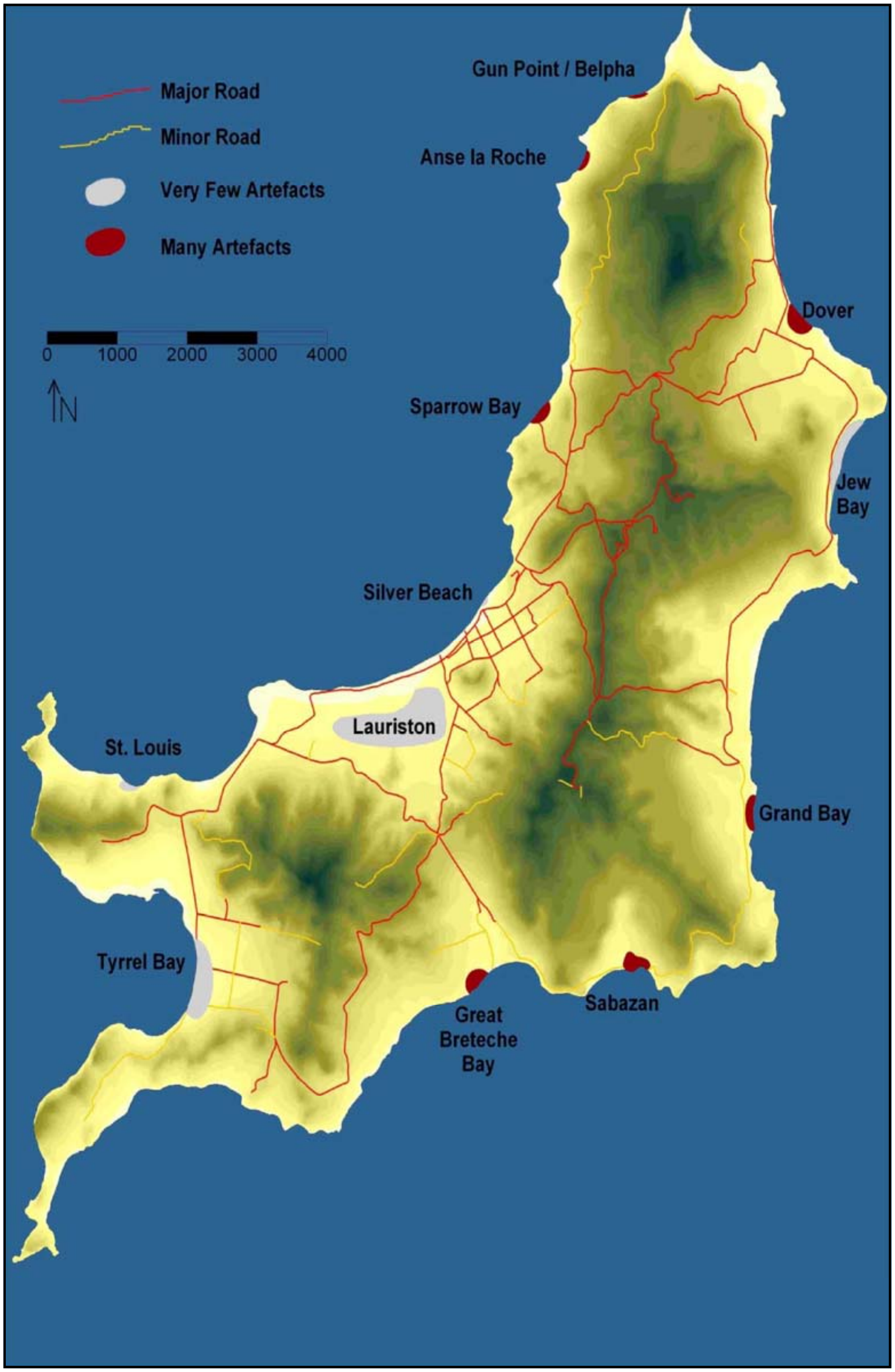

Figure 1. Map of Carriacou with locations of sites mentioned in this study.

part in answering these questions is conducting mineralogical and chemical analyses on sherds found at archaeological sites to examine whether there are any differences in sherd composition that are spatially or temporally distinct. For this study we used two techniques—thin section petrography and INAA. Both of these have had limited application, or in the case of the latter, have never been used in the Caribbean prior to MURR's initiation of the current regional study. Both of these analytical techniques have been successfully used elsewhere for deciphering patterns of clay and temper provenience and resource use prehistorically (e.g., Bishop et al. 1982; Dickinson 2001; Fitzpatrick et al. 2003; Glascock 1992; Harbottle 1976; Neff 1992, 1994, 2000, 2001; Stoltman 2001) and provide a strong foundation for examining changes to ceramic assemblages over time and space. Below we briefly discuss the analytical procedures, followed by the results of our analyses.

Petrography

A total of 78 sherds were examined petrographically. The first suite of samples (n=24) were undiagnostic surface finds from the sites of Anse la Roche, Jew Bay, Grand Bay, Sabazan, Great Bretache Bay, and Tyrell Bay (Figure 1). The second suite consisted of 54 thin sections of the same 56 sherds analyzed by INAA (described in the section below). Many of the sections prepared from the sherds were stained to enhance the recognition of calcium and potassium feldspars. All thin-sections were petrographically examined and sherds were classified into groups based on their composition (Table 1). A representative subset of 11 stained thin sections from suite 1 were point counted using a petrographic microscope equipped with a Swift automated stage and counter to better define group compositions; up to ~1000 points were counted on each thin section using the Gazzi-Dickinson method (Ingersoll et al. 1984). Sand-sized temper components were classified as individual mineral grains or rock fragments according to criteria discussed in Marsaglia (1992), with the addition of carbonate and matrix silt/clay paste categories (see Tables 2 and 3).

INAA

A total of 56 ceramic sherds from eight sites on Carriacou (Lauriston, Sabazan, Jew Bay, Tyrell Bay, Great Bretache Bay, Dover, Grand Bay, and St. Louis), as well as the nearby island of Petite Martinique, were sent to MURR for INAA analyses (see Table 1). Samples were primarily undiagnostic surface finds with the exception of Grand Bay sherds which were recovered from stratified deposits during excavation of the site in 2004. A selected portion of the sherd suite included specimens that were identified by Harris (2005) as Saladoid, Troumassan, or Suazan Trousmassan. The ceramics were prepared for INAA using standard MURR procedures that are explained in detail in Descantes et al. (this issue).

Results

Petrographic Analyses

Temper to matrix ratios in the 11 point-counted sherds range from 1:2 to 1:6. The samples contain mainly rock tempers with carbonate debris and grog, rare to absent (Figure 2). The main monomineralic temper components in the sherds are plagioclase feldspar and dense minerals such as pyroxene and amphibole. Quartz is predominant in one unusual sample and potassium feldspar is predominant in another. Volcanic rock

Table 1. Petrographically analyzed sample sets. Group 1 = Volcanic/Pyroclastic; Group 2 = Igneous Basement; Group 3 = Placer; Group 4 = Potassic Volcanic; Group 5 = Quartzose. FG = Fine Grained, CG = Coarse Grained, VL = Volcaniclastic Lathwork, VM = Volcaniclastic Microlitic.

SUITE 1

Sample	Site	Cultural period	Petro group	Detailed petro group	INAA group
Site 1-GB-1	Grand Bay	---	1	CGVL	---
Site 1-GB-2	Grand Bay	---	1	CGVM	---
Site 1-GB-3	Grand Bay	---	1	CGVL	---
Site 2-SZ-1	Sabazan	---	1	CGVL	---
Site 2-SZ-2	Sabazan	---	1	CGVL	---
Site 2-SZ-3	Sabazan	---	1	CGVL	---
Site 2-SZ-4	Sabazan	---	3	Placer	---
Site 2-SZ-5	Sabazan	---	1	CGVL	---
Site 4-AR-1	Anse La Roche	---	1	Fine-grained Volcan. lathwork	---
Site 4-AR-2	Anse La Roche	---	1	FGVL	---
Site 4-AR-3	Anse La Roche	---	1	CGVM	---
Site 4-AR-4	Anse La Roche	---	1	FGVL	---
Site 5-GTBB-1	Great Bretache Bay	---	4	K-rich volcaniclastic	---
Site 5-GTBB-2	Great Bretache Bay	---	1	CGVL	---
Site 5-GTBB-3	Great Bretache Bay	---	1	CGVL	---
Site 5-GTBB-4	Great Bretache Bay	---	1	CGVL	---
Site 5-GTBB-5	Great Bretache Bay	---	5	Quartzose	---
Site 6-TB-1	Terrell Bay	---	1	FGVL	---
Site 6-TB-2	Terrell Bay	---	1	CGVL	---
Site 6-TB-3	Terrell Bay	---	1	CGVL	---
Site 10-JB-1	Jew Bay	---	1	FGVM	---
Site 10-JB-2	Jew Bay	---	2	Basement	---
Site 10-JB-3	Jew Bay	---	2	Basement	---
Site 10-JB-4	Jew Bay	---	1	FGVL	---

SUITE 2

Sample	Site	Cultural period	Petro group	Detailed petro group	INAA group
SMF001	Dover	Saladoid	1	CGVL	1
SMF002	Grand Bay	Troumassan	1	FGVL	2
SMF003	Grand Bay	---	1	CGVL	2
SMF004	Grand Bay	---	1	CGVM	2
SMF005	Grand Bay	---	---	---	1
SMF006	Grand Bay	Suazan	2	Basement?	1
SMF007	Grand Bay	Suazan	1	CGVL	1
SMF008	Grand Bay	---	1	CGVL	1
SMF009	Grand Bay	---	1	CGVL	1
SMF010	Grand Bay	---	1	tuff or tephra sample	U
SMF011	Grand Bay	---	---	---	2
SMF012	Grand Bay	---	1	CGVM	2

Table 1 continued.

SMF013	Grand Bay	---	1	CGVL	2
SMF014	Grand Bay	---	1	CGVL	2
SMF015	Grand Bay	---	1	CGVL	2
SMF016	Grand Bay	---	1	CGVM	U
SMF017	Grand Bay	Saladoid	1	CGVM	1
SMF018	Grand Bay	---	1	FGVL	2
SMF019	Grand Bay	---	3	Placer	2
SMF020	Grand Bay	Suazan	1	CGVL	1
SMF021	Grand Bay	Suazan	1	CGVL	U
SMF022	Grand Bay	Suazan	1	CGVL	1
SMF023	Grand Bay	---	1	CGVL	1
SMF024	Grand Bay	---	1	CGVM	2
SMF025	Jew Bay	---	2	Basement?	2
SMF026	Jew Bay	---	1	CGVL	2
SMF027	Lauriston	Suazan	1	FGVL	1
SMF028	Lauriston	---	1	CGVL mixed CGVM	1
SMF029	Lauriston	---	1	CGVL	1
SMF030	Lauriston	---	1	CGVL	1
SMF031	Lauriston	---	1	FGVL	1
SMF032	Petite Martinique	---	1	CGVM	U
SMF033	Petite Martinique	---	1	FGVL	1
SMF034	Petite Martinique	---	1	CGVL	1
SMF035	Petite Martinique	---	1	CGVL	1
SMF036	Petite Martinique	---	2	Basement?	2
SMF037	Sabazan	Saladoid	1	CGVL	1
SMF038	Sabazan	---	1	CGVL	1
SMF039	Sabazan	---	1	FGVL	1
SMF040	Sabazan	---	1	CGVL w/ common carbonate	1
SMF041	Sabazan	---	1	CGVL	1
SMF042	Sparrow Bay	---	1	CGVL	1
SMF043	Sparrow Bay	---	2	Basement	1
SMF044	Sparrow Bay	---	1	FG mixed volcaniclastics	1
SMF045	Sparrow Bay	---	1	CGVL	U
SMF046	Sparrow Bay	---	1	CGVL	1
SMF047	Sparrow Bay	Suazan	4	K-rich volcaniclastic	U
SMF048	Sparrow Bay	---	1	FGVL	U
SMF049	Sparrow Bay	---	3	Placer	1
SMF050	Sparrow Bay	---	1	CGVL	2
SMF051	Sparrow Bay	Saladoid	1	FGVM	U
SMF052	St. Louis	---	1	CGVL	U
SMF053	Tyrell Bay	---	1	FGVL	1
SMF054	Tyrell Bay	---	1	CGVL	1
SMF055	Tyrell Bay	Suazan	4	K-rich volcaniclastic	U
SMF056	Tyrell Bay	Troumassan	1	FGVL	2

U: group indeterminable
---: undiagnostic or analysis not conducted

Table 2. Definition of counted categories and recalculated petrographic parameters.

Sand-Sized Temper Categories

Qm	Monocrystalline quartz
Qp	Polycrystalline quartz
P	Plagioclase feldspar
K	Potassium feldspar
Op	Opaque dense mineral
Cpx	Dense mineral - clinopyroxene
Opx	Dense mineral - orthopyroxene
Hbl	Dense mineral - amphibole
Lvv	Volcanic lithic with vitric texture
Lvml	Volcanic lithic with microlitic texture
Lvl	Volcanic lithic with lathwork texture
Lvo	Holocrystalline volcanic lithic composed of plagioclase and dense minerals
Lm	Metamorphic lithic
Biocl	Calcareous bioclast
Biot	Biotite
Musc	Muscovite
Unk	unknown Grain
Grog	Grog (recycled ceramic fragment)

Recalculated parameters

QFL%Q=100*((Qm+Qp)/(Qm+Qp+P+K+Lvo+Lvv+Lvml+Lvl+Lm))
QFL%F=100*((P+K)/(Qm+Qp+P+K+Lvo+Lvv+Lvml+Lvl+Lm))
QFL%L=100*((Lvo+Lvv+Lvml+Lvl+Lm)/(Qm+Qp+P+K+Lvo+Lvv+Lvv+Lvml+Lvl+Lm))

QmKP%Qm=100*(Qm/(Qm+P+K))
QmKP%K=100*(K/(Qm+P+K))
QmKP%P=100*(P/(Qm+P+K))

LvvLvmlLvl%Lvv=100*(Lvv/(Lvv+Lvml+Lvl))
LvvLvmlLvl%Lvml=100*(Lvml/(Lvv+Lvml+Lvl))
LvvLvmlLvl%Lvl=100*(Lvl/(Lvv+Lvml+Lvl))

fragments are present in most samples; these exhibit microlitic to lathwork textures with variable proportions of glass, plagioclase, and dense minerals. Volcanic debris ranges from fresh to altered. The compositional variability of the tempers is represented in Figure 3 where modal results are displayed on a series of ternary plots used in sandstone provenance studies.

Overall the samples fall into five general groups as illustrated by the photomicrographs in Figure 2 and the descriptions outlined below. Groups are roughly listed in their order of importance:

Group 1 (n= 65): Volcanic/Pyroclastic Temper. This is the most varied of the groups and could be further divided into several subgroups depending on volcanic lithic types and proportions present. Temper variability is

Table 3. Petrographic data and recalculated parameters.

Sample	**Qm**	**Qp**	**P**	**K**	**Op**	**Cpx**	**Opx**	**Hbl**	**Lvv**	**Lvml**	**Lvl**	**Lvo**	**Lm**	**Biocl**	**Biot**	**Musc**	**Unk**	**Grog**
1-GB-1	0	1	229	4	13	14	0	0		1	15						11	
1-GB-2	2	1	45			2		15		12	4	18					8	
2-SZ-4			31		2	161	4	81	3					9	1		11	
6-TB-1			144	3	2	2					7				1		46	
10-JB-2	1	1	149	5	6	11				1			3	1	3		19	
10-JB-1			147		2	11				2	8							
5-GTBB-5	116	10	11	2								1?	4		3	4	15	
6-TB-3			126	5						1	29							
10-JB-4			117	1		21				31	21							
4-AR-1			270		4	11		3	1	1	5				2		18	
5-GTBB-1			2	104	1	1				29	43			2				

						QFL%			QmKP%			LvvLvmlLvl%		
Sample	**Total Grains**	**Matrix Clay**	**Matrix Silt**	**Total Matrix**	**Total Count**	**Q**	**F**	**L**	**Qm**	**K**	**P**	**Lvv**	**Lvml**	**Lvl**
1-GB-1	**288**	518	186	704	**992**	0.4	93.2	6.4	0	1.7	98.3	0	6.3	93.8
1-GB-2	**107**	331	100	431	**538**	3.7	54.9	41.5	4.3	0	95.7	0	75	25
2-SZ-4	**303**	409	21	430	**733**	0	91.2	8.8	0	0	100	100	0	0
6-TB-1	**205**	285	318	603	**808**	0	95.5	4.5	0	2	98	0	0	100
10-JB-2	**200**	362	199	561	**761**	1.3	96.3	2.5	0.6	3.2	96.1	0	100	0
10-JB-1	**170**	115	104	219	**389**	0	93.6	6.4	0	0	100	0	20	80
5-GTBB-5	**165**	621	224	845	**1010**	88.1	9.1	2.8	89.9	1.6	8.5			
6-TB-3	**161**			287	**448**	0	81.4	18.6	0	3.8	96.2	0	3.3	96.7
10-JB-4	**191**	311	112	423	**614**	0	69.4	30.6	0	0.8	99.2	0	59.6	40.4
4-AR-1	**315**			0	**315**	0	97.5	2.5	0	0	100	14	14.3	71.4
5-GTBB-1	**182**	750	69	819	**1001**	0	59.6	40.4	0	98	1.9	0	40.3	59.7

a function of the proportions of volcanic glass, plagioclase, and dense minerals within individual volcanic fragments, as well as degree of alteration and grain size of the temper. The more holocrystalline varieties are consistent with epiclastic sand derived from basaltic to andesitic lava flows, whereas the glassy varieties are consistent with derivation from andesitic to basaltic pyroclastic ash. Where altered, they could have been mined from weathered outcrops or diagenetically modified older units.

Group 2 (n= 6): Igneous Basement Temper. These tempers are composed of angular plagioclase and dense minerals without volcanic glass. Some are limited to plagioclase crystals only, whereas others consist of plagioclase with minor dense minerals. These suggest anorthosite to diorite igneous source rocks.

Group 3 (n= 3): Placer Temper. These are thought to be concentrated dense mineral deposits derived from intermediate igneous rocks based on their mineralogy (clinopyroxene, amphibole, plagioclase) and small amounts of intermediate volcanic rock fragments. A high-energy beach environment is indicated by the moderately-well sorting, the high degree of grain rounding, and the presence of calcareous bioclastic debris.

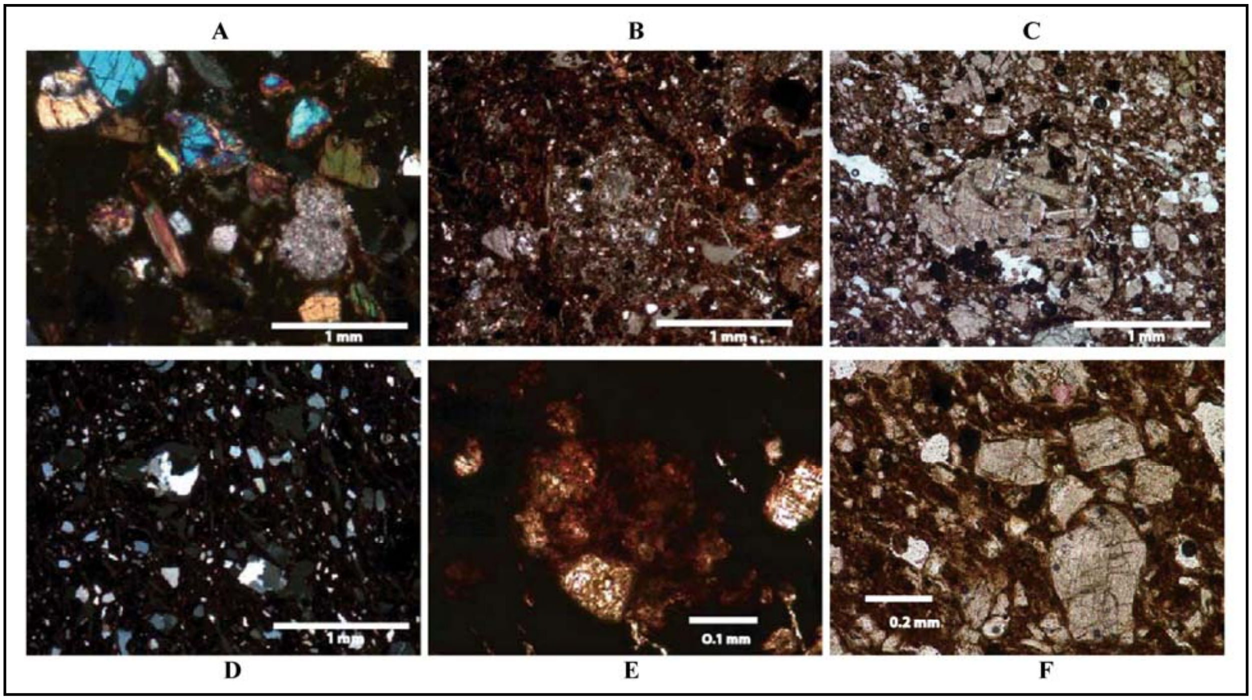

Figure 2. Photomicrographs of sherds illustrating temper provenance groups defined in this study [Temper Groups: A = placer; B = Coarse-grained microlitic; C = Coarse-grained lathwork; D = Quartzose; E = K-spar volcanic; F = Basement]. Top left (A) is a placer temper with grains of brightly birefringent carbonate bioclasts and strongly colored dense minerals highlighted under crossed nicols. Top middle (B) is a volcanic temper of volcanic fragments with microlitic texture under crossed nicols. Top right (C) is a temper of volcanic fragments exhibiting lathwork texture under plane light. Bottom left (D) is a quartzose temper under crossed nicols to highlight the low birefringence (grey to white) and shapes of the quartz temper grains surrounded by nonbirefringent paste. Bottom center (E) shows the yellow stained, postassium feldspar crystals set in black paste under plane light. Bottom right (F) shows a temper dominated by coarse euhedral (rectangular) to subheadral plagioclase crystals set in a dark paste.

Group 4 (n= 3): Potassic Volcanic Temper. This temper is limited to potassium feldspar and traces of volcanic lithic fragments. Volcanics/pyroclastics with high potassium feldspar are very unusual, but may be related to hydrothermal alteration of tuffs.

Group 5 (n= 1): Quartzose Temper. This sand temper is mineralogically mature (~90% monocrystalline and polycrystalline quartz), moderately sorted, with angular to subrounded grains. The grains suggest some mechanical abrasion and transport. Such sediment is associated with a continental provenance.

Discussion of Temper Provenance

The dominance of plagioclase feldspar (QmKP plot, Figure 3), pyroxene, amphibole, and microlitic to lathwork volcanic lithic textures in temper Groups 1, 2 and 3 is consistent with intermediate to basaltic igneous sources. Overall, these tempers are more feldspar enriched than natural basaltic/andesitic sands from beach, fluvial, and deep marine environments (e.g., Marsaglia 1993; Marsaglia and Ingersoll 1992), suggesting that many may represent rock ground up by prehistoric potters, rather than sand gathered from streams or beaches. Sherds with high concentrations of dense minerals (Group 3), however, can be explained as beach/stream placers derived from volcanic and/or plutonic igneous rocks. There is no evidence of volcanic lithics being recycled from older sedimentary units. Hypothetically, some of the Group 1, 2, and 3 tempers could have been derived from crushing shallow intrusive to extrusive magmatic rocks on Carriacou, but work in progress (Pavia, in prep.) indicates little textural similarity between Carriacou volcanic outcrops and Carriacou tempers implying an extra-Carriacou source.

The “local” regional geology can be subdivided into three main potential sources of volcaniclastic temper: 1) the active volcanic center to the north (e.g., St. Vincent); 2) the active volcanic center to the south (Kick’em Jenny, Isle de Caille, and Grenada); and 3) the Grenadine islands on the intervening southern Lesser Antilles arc platform (SLAAP). The SLAAP includes larger (e.g., Carriacou, Union, Canouan, Mustique, and Bequia), as well as numerous smaller islands (e.g., Petite Martinique, Mayreaus, Jamesby). The series of islands on the SLAAP between Grenada and St. Vincent (the Grenadines), are distinctly different in their geology, being mainly composed of older Tertiary intrusive to extrusive igneous rocks, epiclastic arc-derived volcaniclastic units, chert, marl, and limestone. There is no source for fresh pyroclastic debris on the SLAAP islands, so the volcaniclastic temper or pottery must have been imported from active volcanic centers, the St. Vincent or Grenada centers being the most proximal.

The surface of St. Vincent is mainly covered by late Pleistocene pyroclastic deposits, red oxidized scoria, and flows and scoria falls from historic (1718, 1812, 1902, 1971, 1979) eruptions associated with explosive eruptions of the Soufriere stratovolcano (Heath et al. 1998a). The latter consists of basaltic and basaltic andesite lava flows and a significant rapidly deposited scoriaceous to pumiceous yellow tuff unit (Rowley 1978) that erupted 3600 to 4500 years B.P. (Heath et al. 1998a). Younger overlying pyroclastic deposits were produced by as many as 20 subsequent vulcanian explosive eruptions. Thus, there are ample sources of fresh pyroclastic temper on St. Vincent. The St. Soufriere volcano also ejected blocks of plagioclase-rich anorthosite (Lewis 1973), a source rock that when crushed could perhaps best explain the pure plagioclase end member tempers.

In contrast, fresh pyroclastic sources associated with the Grenada volcanic center are not as extensive. Grenada is composed of Pliocene to Pleistocene basaltic to andesitic volcanic centers, the youngest of which is Mt. St. Catherine. Young (1000 yrs. B.P.) fresh pyroclastic outcrops available to prehistoric potters would have been limited to a glassy basaltic scoria cone near Radix village and small volcanic centers on nearby Isle de Caille (Arculus 1976; Devine 1995; Devine and Sigurdsson 1995).

Future work on the geochemistry of glassy pyroclastic tempers and plagioclase phenocrysts may help to fingerprint the volcanic source(s) of this material. The St. Soufriere basaltic-andesitic magmas of St. Vincent are calc-alkaline to tholeiitic (Heath et al. 1998a, 1998b), whereas to the south in the southern Grenadines and Grenada the lavas are alkaline (Brown et al. 1977). Volcanic islands north of St. Vincent are calcalkaline, but show no tholeiitic tendencies (Heath et al. 1998b). There are also distinct changes in the Sr isotopes of plagioclase phenocrysts in volcanic centers

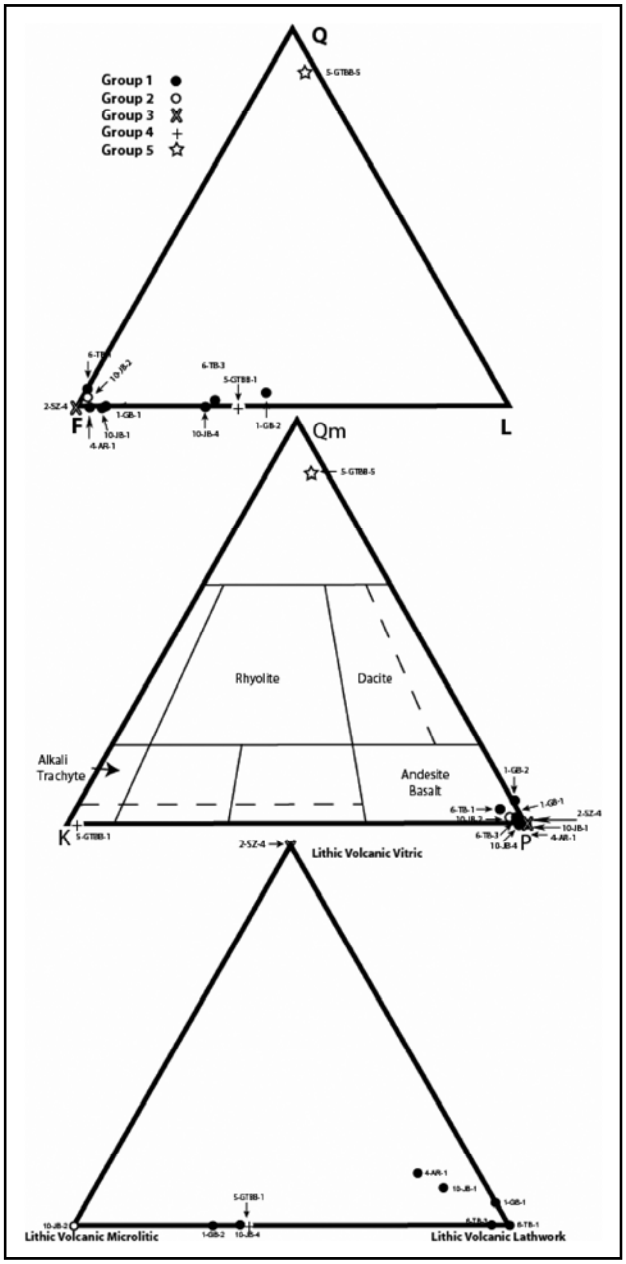

Figure 3. This series of ternary plots illustrates some of the compositional variability of the temper groups pictured in Figure 2 and discussed in the text. Top is a QFL ternary plot where Q= total quartz grains, F = total feldspar grains, L = total lithic or rock fragments. Note that in the case of these temper samples the lithics are all of volcanic origin. This plot best discriminates the quartzose Group 5 from the other groups. Middle is a QmKP ternary plot where Qm = monocrystalline quartz, K = potassium feldspar, and P = plagioclase feldspar with fields after LeMaitre (1989). This ternary discriminates Groups 4 and 5 from the other groups. Bottom is a ternary plot of different volcanic lithic groups, those with vitric (glassy), microlitic and lathwork textures. This illustrates lithic texture variability within Group 1 samples. These are the standard plots used in sand provenance studies, and so do not completely discriminate the five groups because they do not include key components such as dense minerals, carbonate, or grog. For example, the placer group (3) which is dominated by dense minerals shows significant overlap with the other groups.

along the Lesser Antilles chain (Van Soest et al. 2002)

The Group 4 temper is likely volcanic, but with anomalously high potassium feldspar content. In the Caribbean, such potassium-rich rocks have only been described in the literature in hydrothermally altered igneous rocks from Puerto Rico (e.g., Pease 1976). This does not preclude a local, here-to-fore undocumented source on one of the Lesser Antilles volcanic islands.

The high quartz content of the Group 5 temper (single sample) implies a continental rather than a magmatic arc source. Interestingly the island of Barbados is partly constructed of quartzose sediments shed off the South American continent into the Atlantic Ocean basin and then scraped off during the subduction process that has produced the Lesser Antilles magmatic arc (Kasper and Larue 1986). This accretionary prism has grown to the surface and outcrops of such quartzose sediments are present on Barbados, which have and still serve as temper sources for potters (Drewett and Fitzpatrick 2000). Alternatively, the temper could be from the parent South American source. Unfortunately, the two Great Bretache Bay samples were part of Suite 1 and thus not analyzed with INAA, which might give us a better indication of whether it was part of one of the two main compositional groups identified chemically. Furthermore, given that only one sample with this temper type was found and it was a surface find, there is also the possibility that it represents an historic/modern fragment. In sum, the temper compositions suggest that all of the sherds from Carriacou appear to have been produced outside of Carriacou and imported to the island.

INAA

Exploratory data analyses of the 56 sherds from Suite 2 were conducted on 33 elemental abundance measurements before identifying compositional groups (elemental concentrations of nickel were removed from subsequent analyses due to low detection limits). Of the 33 elements, thorium, potassium, rubidium, cesium, and antimony created the most variance between groupings. A two-group structure was identified in the ceramic specimens: Group 1 (n=30) and Group 2 (n=16). The compositional groups can be graphically represented in principal component space (Figures 4 and 5) and in elemental space (Figure 6). Statistical tests based on Mahalanobis distance-derived probabilities using eight principal components were conducted subsuming 90.7% of the total variance (see Tables 5–8) to support the graphical representation of the group structure (Figures 4–6). A cut-off of 1% was generally used to refine the membership of Groups 1 and 2. However, exceptions were made based on the graphical representation of the data. Ten specimens (18%) could not be assigned to any of the identified compositional groups (Figures 5 and 6; Table 8). It is highly probable that analyzing more samples could identify additional compositional groups more clearly in the Carriacou ceramic assemblage.

Chemical characteristics for the compositional groups are represented in Figure 4. Relative to Group 2, Group 1 clearly has elevated concentrations of antimony, dysprosium, and ytterbium. Antimony is a semi-metal whereas the other several are rare earth elements. Antimony can be enriched in soils developed on volcanic materials (e.g., Terashima et al. 2002). Group 2, on the other hand, is enriched in several rare earth elements, an actinide, and a transition metal (that is Cs, La, Th, and Ta), when compared to Group 1. Within the St. Vincent rocks, feldspar phenocrysts contain much less Th (~10%) as compared to the volcanic groundmass (Heath et al. 1998a). Thus, some of the temper chemical variation could be explained by different proportions of glassy groundmass versus plagioclase crystals in sherd tempers. Furthermore, this suggests that soils developed on more glass-rich units might contain higher Th concentrations than those developed on plagioclase-rich units. Additional chemical analyses of sherd paste and temper components are needed to clarify these relationships.

Given the relatively small sample size, only tentative statements can be made about the relationship between the provenance of the sherds and their group assignments (see Table 8). Interestingly, the Grand Bay site has almost equal amounts of both compositional types. Another possibly significant observation is that only Group 1 ceramics were collected from the sites of Dover, Lauriston, and Sabazan, while Jew Bay only has compositional Group 2 ceramics. However, these distributions do not appear to be geologically constrained (i.e., based on site location within a particular geological formation). Finally, the Troumassan sherds with potassic tempers (SMF047, SMF055) do show unusual chemistries and fall outside the compositional range of the INAA Groups 1 and 2.

In sum, INAA of the 56 samples has identified two distinct ceramic compositional

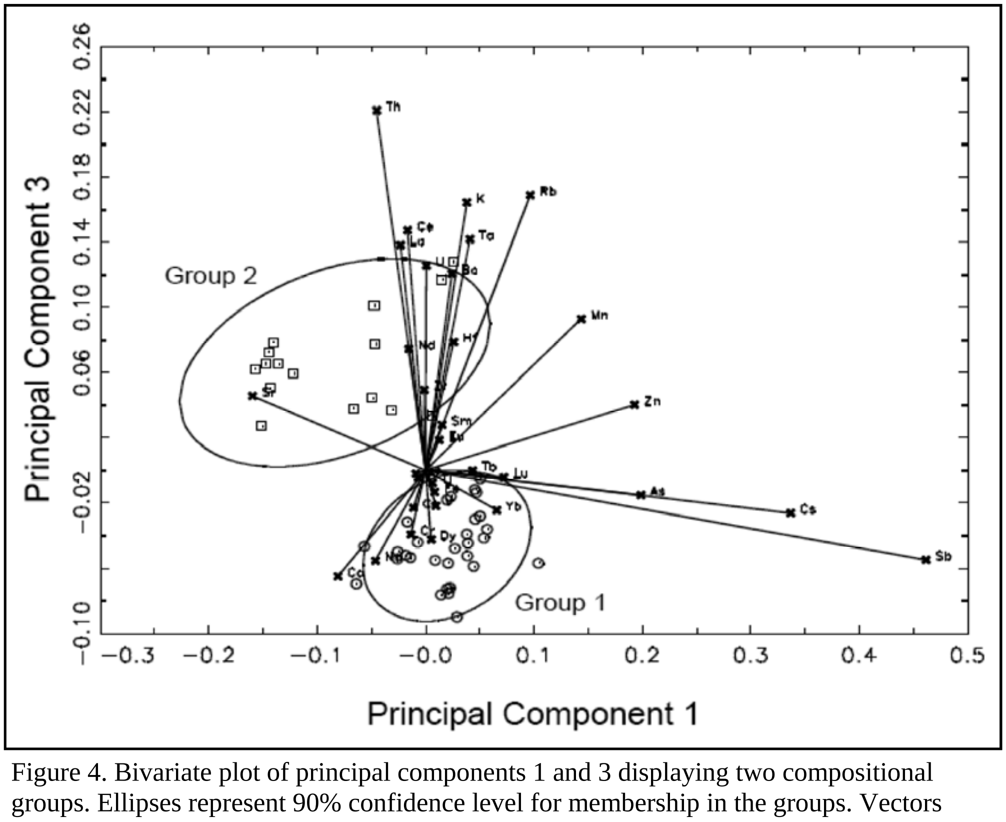

Figure 4. Bivariate plot of principal components 1 and 3 displaying two compositional groups. Ellipses represent 90% confidence level for membership in the groups. Vectors denote elemental influences on the ceramic data. Unassigned specimens are not shown.

Table 4. Principal components analysis of 56 specimens. Simultaneous R-Q factor analysis based on variance-covariance

PC	*Eigenvalue*	*%Variance*	*Cum. %Var.*
1	0.4868	32.4368	32.4368
2	0.3097	20.6338	53.0705
3	0.2395	15.9603	69.0308
4	0.0938	6.2468	75.2776
5	0.0754	5.0249	80.3025
6	0.0605	4.0321	84.3346
7	0.0500	3.3312	87.6658
8	0.0457	3.0464	90.7122
9	0.0252	1.6769	92.3891
10	0.0233	1.5510	93.9401
11	0.0181	1.2067	95.1468
12	0.0159	1.0570	96.2038
13	0.0114	0.7624	96.9661
14	0.0105	0.6986	97.6647
15	0.0081	0.5397	98.2044
16	0.0059	0.3947	98.5992
17	0.0046	0.3039	98.9031
18	0.0035	0.2359	99.1390
19	0.0034	0.2275	99.3665
20	0.0021	0.1366	99.5032
21	0.0019	0.1241	99.6272
22	0.0012	0.0796	99.7068
23	0.0011	0.0712	99.7780
24	0.0009	0.0633	99.8413
25	0.0006	0.0409	99.8822
26	0.0005	0.0337	99.9159
27	0.0004	0.0277	99.9436
28	0.0003	0.0183	99.9619
29	0.0002	0.0140	99.9759
30	0.0002	0.0115	99.9873
31	0.0001	0.0088	99.9961
32	0.0001	0.0039	100.0000

Table 5. Mahalanobis distance calculated probabilities and posterior classification for compositional Group 1 members. Eight principal components were used. Probabilities are jackknifed for specimens included in each group.

ID. NO.	*Group 1*	*Group 2*
SMF001	84.322	2.143
SMF005	88.743	1.224
SMF006	94.633	2.335
SMF007	17.885	0.104
SMF008	35.883	0.523
SMF009	28.550	0.694
SMF017	53.663	3.327
SMF020	44.278	3.244
SMF022	99.172	1.422
SMF023	14.475	0.303
SMF027	52.882	2.843
SMF028	74.355	0.244
SMF029	96.047	0.777
SMF030	19.257	0.117
SMF031	77.422	0.950
SMF033	28.140	3.970
SMF034	4.634	0.914
SMF035	35.558	2.375
SMF037	48.573	1.747
SMF038	7.878	0.328
SMF039	25.094	0.466
SMF040	86.945	1.037
SMF041	53.455	0.349
SMF042	2.478	0.533
SMF043	90.214	0.463
SMF044	10.815	0.020
SMF046	51.148	1.051
SMF049	26.230	1.004
SMF053	47.917	0.091
SMF054	82.972	2.220

Table 6. Mahalanobis distance calculated probabilities and posterior classification for compositional Group 2 members. Eight principal components were used. Probabilities are jackknifed for specimens included in each group.

ID. NO.	*Group 1*	*Group 2*
SMF002	0.000	78.209
SMF003	0.000	55.485
SMF004	0.000	87.512
SMF011	0.000	26.309
SMF012	0.000	97.785
SMF013	0.000	16.903
SMF014	0.000	47.163
SMF015	0.000	70.300
SMF018	0.000	59.265
SMF019	0.000	4.147
SMF024	0.000	81.479
SMF025	0.000	84.574
SMF026	0.000	31.292
SMF036	0.000	37.114
SMF050	0.000	1.010
SMF056	0.000	31.923

groups. Possible tendencies or associations between the chemical compositions of the sherds and their site provenance were found. The submission of more samples from these contexts could further test these identified patterns as well as delineate more groups (7 of the 10 unassigned samples clearly have no affinity with the two compositional groups) and subgroups. Determining whether the identified compositional groups refer to local or exotic sources will require either the chemical analysis of raw clay samples or the mineralogical analysis of raw clay samples and ceramics.

Discussion and Conclusions

Thin-section petrography (n=78) and INAA (n=56) of two suites of ceramic sherds from archaeological sites on Carriacou suggest that pottery was made from primarily or even exclusively exotic materials using volcanic sand as temper with minor amounts of carbonate and/or grog. The Quartzose and Potassic groups suggests that some samples may have tempers possibly derived from quartzose outcrops on Barbados and potassic outcrops on Puerto Rico. The identification of two major chemical groups using INAA is not suggestive of Carriacouan pottery having either a local or exotic source; at least 10 of the 56 (17.8%) samples in Suite 2 are outliers that could not be assigned to either compositional group, perhaps indicating that they were produced and transported from another source. Four of the five sherds from Petite Martinique analyzed with INAA fell into compositionally defined groups (n=3 [Group 1]; n=1 [Group 2]), indicating that inter-island transfer of ceramics was occurring at least on a local scale.

Table 7. Mahalanobis distance calculated probabilities and posterior classification for unassigned members into compositional Groups 1 and 2. Eight principal components are used.

ID. NO.	*Group 1*	*Group 2*
SMF010	0.000	0.000
SMF016	0.000	0.001
SMF021	40.016	8.913
SMF032	0.000	0.168
SMF045	0.148	0.540
SMF047	0.000	0.000
SMF048	0.002	0.166
SMF051	0.000	0.001
SMF052	0.000	0.000
SMF055	0.000	0.839

Only 14 of the sherds from both suites were stylistically identified; of these, none appear to fall into any compositional pattern based on temporality or cultural design, with both early (Saladoid), middle (Troumassan Troumassoid), and late (Suazan

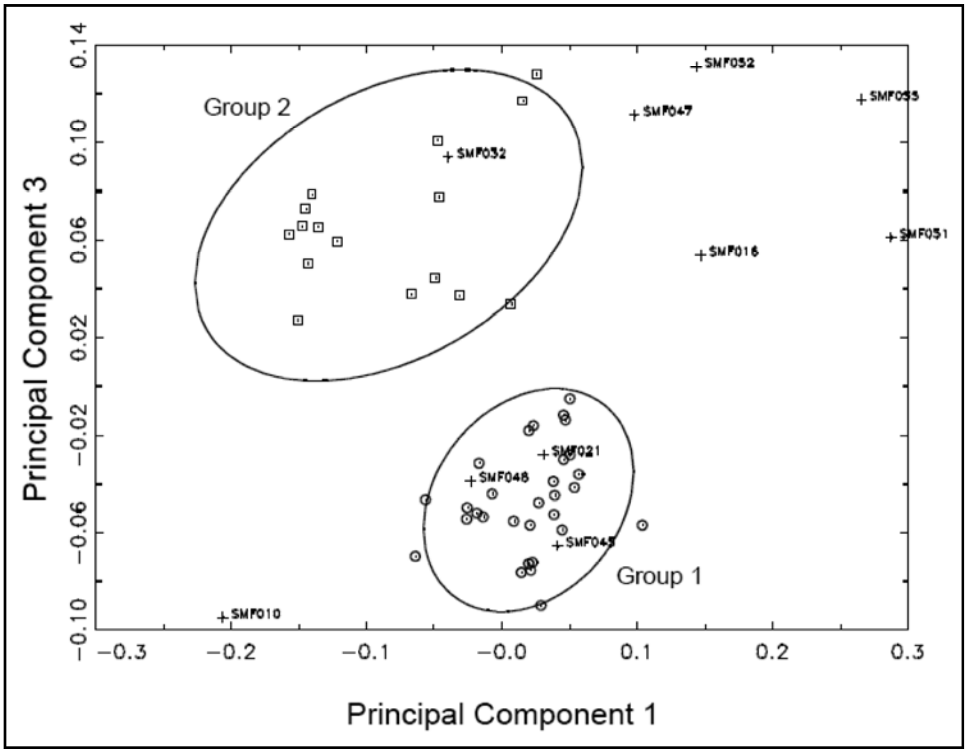

Figure 5. Bivariate plot of principal components 1 and 3 displaying the two compositional groups and labeled unassigned specimens (+). Ellipses represent 90% confidence level for membership in the groups.

Table 8. Compositional group assignments and site provenience.

Site	*Group 1*	*Group 2*	*Unassigned*
Dover	1	0	0
Grand Bay	9	11	3
Jew Bay	0	2	0
Lauriston	5	0	0
Sabazan	5	0	0
Sparrow Bay	5	1	4
St. Louis	0	0	1
Tyrrel Bay	2	1	1
Petite Martinique	3	1	1
Total	30	16	10

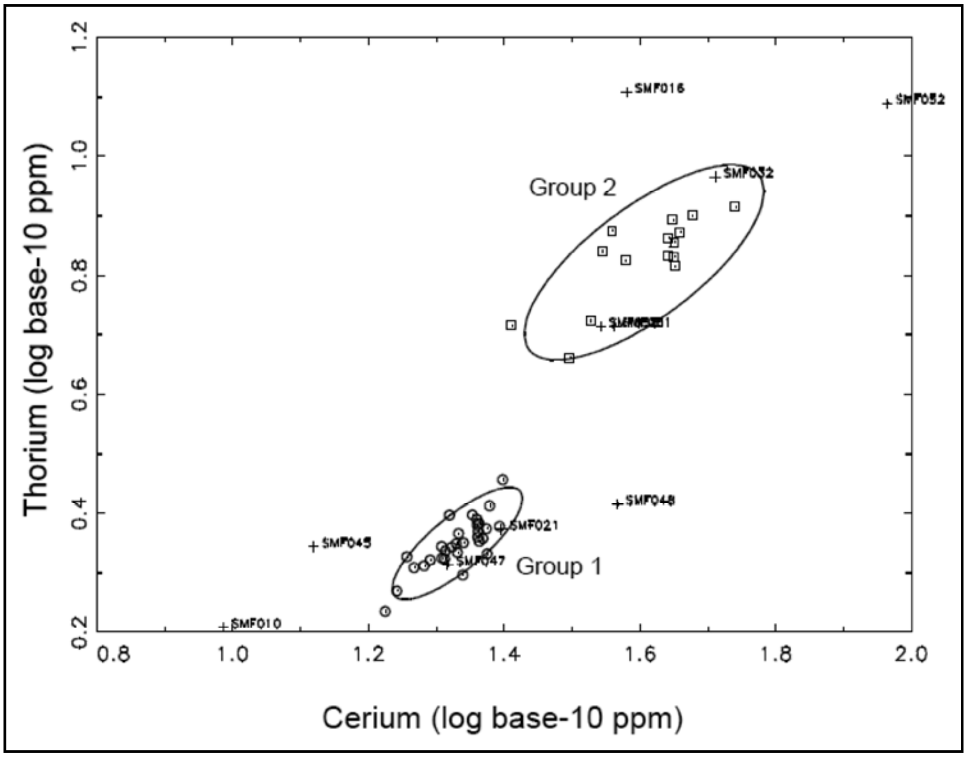

Figure 6. Bivariate plot of base-10 logged cerium and thorium concentrations showing the chemical distinctiveness of the two compositional groups. Ellipses represent 90% confidence level for membership in the groups. Unclassified samples (+) are labeled.

Troumassoid) periods falling into Group 1 using either petrography or INAA, for example. This could indicate that there was little preference by prehistoric potters in seeking out specific clay or temper resources. It is interesting to note, however, that all sherds from Sabazan and Lauriston in Suite 2, as well as the four Saladoid samples, fell into the same petrographic and INAA groups (as did four out of the five Sabazan sherds analyzed petrographically in Suite 1; Saladoid sample SMF051 could not be grouped using INAA). It is also notable that three of the six Jew Bay samples present in both Suites 1 (n=4) and 2 (n=2) fell into petrographic Group 2, of which only six are known from the total number of sherds analyzed. Whether these represent real cultural preferences for potting is unknown.

Although the results are preliminary, thin-section petrography, used in conjunction with INAA, has provided a means for explaining how ceramics were manufactured prehistorically, the compositional diversity of geological materials used in production, and the differences between sherds found at various archaeological sites. QFL and QmKP ternary plots suggest that there are at least five different possible sources of material, most of which appear to be exotic. INAA suggests two main chemical groups. However, these observations will have to be confirmed by additional testing of these and other sherds. Without more information, if the ceramics were made using non-local resources, it would appear at this stage to signify two distinct clay sources. Alternatively, the geochemical groupings may be related to the chemistry of the volcanic temper components.

Research now in progress is focused on petrographically analyzing the INAA suite of sherds in more detail and comparing the geochemisty from sherds and source material from lavas and volcanic centers in the Lesser Antilles. This will allow us to infer whether the exotic sherds are anomalous or are a ubiquitous component to sherd suites from archaeological sites on Carriacou. The analysis should also help us test models of interisland interaction between Carriacouan groups and those on other islands. The preliminary data now suggests that all of the sherds within the total Carriacou sherd suite could be exotic, suggesting that movement of these artifacts was widespread. This phenomenon is not unheard of in the Caribbean. Cordell (1998), for example, estimated that all of the pottery found at the Coralie site (GT-3) on Grand Turk, in the Ostionan style dating from AD 700–1100, was imported from Hispaniola nearly 200 km away. In addition, three ceramic inhaling bowls (one recovered from deposits at Grand Bay dating between ca. AD 1000–1300 and two unprovenienced from the Carriacou Historical Society Museum) were dated with luminescence to 430 ± 192 BC (weighted average). This is several hundred years older than the earliest ^{14}C dates of ca. AD 400 from the island, suggesting that they may have been heirlooms transported from elsewhere. This hypothesis is supported by petographic analysis which shows that these samples were likely produced with non-local materials, and luminescence dating of two diagnostic sherds recovered from stratified deposits at Grand Bay that overlap with the existing radiocarbon chronology (Fitzpatrick et al. n.d.).

Further examination of sherds that are stylistically identifiable, versus undiagnostic (which provided the bulk of samples used in this study) will be critical for testing whether Carriacou, or some communities within, had greater access to imported goods versus others and if these varied through time.

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