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Re-examining the Egyptian colonial encounter in Nubia through a compositional, mineralogical, and textural comparison of ceramics

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ABSTRACT

Textural, mineralogical, and X-Ray fluorescence (XRF) analyses are used as a cost effective method to distinguish for the first time ancient Egyptian and Nubian-style ceramics found in Nubia. Textural and mineralogical data suggest that Nubian-style sherds are mixtures of sand, silt, and clay sediment that is generally finer grained and poorer in quartz than is the sediment mixture used to produce Egyptian-style pottery. Chemical data also establish a significant difference in the amount of chemical variation found within each style population, but nonetheless supports a considerable overlap in the possible provenance of both styles. Observations and data obtained during this study indicate that standardized, Egyptian-style manufacturing was introduced into Nubia under colonialism, without substantially altering the diversity of native methods of production.

1. Introduction

While the study of colonialism has always been of major interest to archaeologists, until recently studies of ancient empires generally had a core-based bias. Colonialism was seen as a one sided act of domination and was subsequently investigated almost exclusively by analyzing the motives and strategies of the colonizers (Comaroff and Comaroff, 1997). This bias was often exacerbated in areas such as Egypt, in which textual sources were prioritized; the lack of written records from the indigenous people of the colonies meant that their role was largely ignored (Adams, 1977; Arkell, 1961). Such an imbalance also stemmed from the common assumption that colonialism entailed the rule of a more complex society over a considerably less developed one (Santley and Alexander, 1992; Stein, 2005).

However, the universal applicability of such a core-periphery model, and the world-systems theory that accompanies it, has increasingly been called into question by cross-cultural comparisons that reveal great diversity in the practices, goals, and effects of colonialism (Alcock, 1993; Stein, 2005). Rather than unidirectional domination, most archaeologists now admit that culture contact is more appropriately conceptualized as a frontier of identity arbitration, in which ethnicity, class, and power are negotiated (Alcock, 1993, 2002, 2005; Comaroff and Comaroff, 1997; Jones, 1997; Moreland, 2001; Van Dommelen, 2005). Ceramic analysis in particular has proven useful for exploring this situation, as ceramics were both reflections of, and instruments for, changing identities (Janusek, 2002; MacEachern, 1998; Nichols et al., 2002). In this paper, we present evidence from a mineralogical and chemical composition study of ceramic vessels from three Nubian sites, Askut, Tombos, and Hannek, which we believe can contribute to a more nuanced understanding of the interaction between Egypt and Nubia from the New Kingdom to the Late/Napatan Period (1550–650 BCE).

1.1. Background: Egyptian/Nubian interactions

The history of Egyptian influence in Nubia is extensive, dating from c. 3000 BCE, when Egypt began to organize into a complex polity and exert pressure on its neighbors (Adams, 1977; Arkell, 1961; Trigger, 1976; Fig. 1). During both the Middle Kingdom (2050–1650 BCE) and the New Kingdom (1550–1050 BCE), much of Nubia came under direct Egyptian imperial control, with a short hiatus between these two periods in which the indigenous Kerma civilization flourished (O'Connor, 1993). The Egyptian imperial presence was particularly strong in Lower Nubia, and the archaeological record indicates that at least some aspects of society were reorganized along the Egyptian plan, including the adoption of

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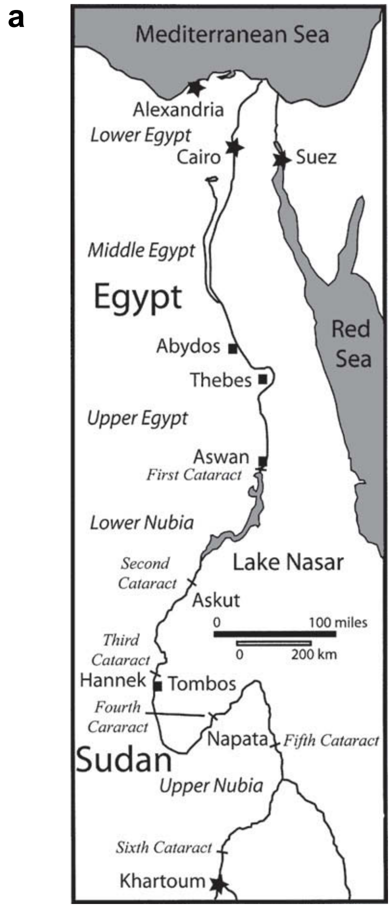

b

DATE BC	EGYPT	LOWER NUBIA	UPPER NUBIA
2050-1650	Middle Kingdom (11-13)	C-Group	Middle Kerma
1650-1550	Second Intermediate Period (14-17)	C-Group	Classic Kerma
1550-1050	New Kingdom (18-20)	C-Group	Recent Kerma
1050-750	Third Intermediate Period (21-24)	Uncertain	Pre-Napata
750-332	Late Period (25-30)	Uncertain	Napata

Fig. 1. (a) Map of Egypt and the Sudan, (b) relevant chronology [after Buzon, 2004].

religious and pharaonic ideology and the use of Egyptian production techniques, tomb construction, etc. (Kemp, 1991; Smith, 1995).

However, not long after the Egyptians abandoned their empire in Nubia during the Third Intermediate Period, the powerful complex indigenous polity of Napata arose. The new Napatan polity, the early stages of which are not well known, was a complicated cultural mixture of characteristic elements of Egyptian architecture, regalia, and religion, long-lasting indigenous traditions that withstood Egyptian influence, such as hand-made ceramics, tumuli burials, and stone weaponry, and distinctly *hybrid* practices, including the use of small, narrow pyramid tombs and syncretistic gods, which appear to have no direct predecessors in either cultural tradition (Edwards, 1996; Török, 1991; Welsby, 1996). Thus, it is clear that Egyptian colonialism permanently altered Nubian cultural practices; what is less clear is what transformations occurred in local communities during the colonial period to result in such a unique cultural mixture.

Three models of long-term cultural interaction can be posited. First, some scholars argue that the prolonged contact with Egyptian colonists resulted in *acculturation* by the Nubians (Adams, 1977; Arkell, 1961; O'Connor, 1993). Because it is obvious that Nubian culture did not entirely disappear, it is hypothesized that by the time Nubia gained its independence this acculturation had led to a hybridization of Egyptian and Nubian cultures (a sort of "ethnogenesis"). Alternatively, it is possible that the Egyptian colonists in Nubia remained largely separated from the local populations. As a result, while Nubian culture may have been relegated to more private matters and have lost its viability as a status marker, the Nubians were able, on the whole, to maintain their *cultural continuity* until it could gain ascendancy again in the Napatan period (see e.g., Brumfiel, 1996; Comaroff and Comaroff, 1997; Dobres and Robb, 2000). Finally, a third hypothesis is that Egyptian influence was pervasive only among the elite Nubians, who had much to gain from ingratiating themselves with their overlords. The long-term impact of colonialism in this view was a form of *cultural imperialism*, i.e. the entrenching of deep inequalities based upon cultural affiliation, that produced divisions later incorporated into the post-colonial society of Napata (see e.g., Clark, 1997; for an anthropological perspective, see Chatterjee, 2001; Hardt and Negri, 2000). Below we discuss how the relative legitimacy of each of the three models can be evaluated in part by an analysis of Egyptian and Nubian ceramics.

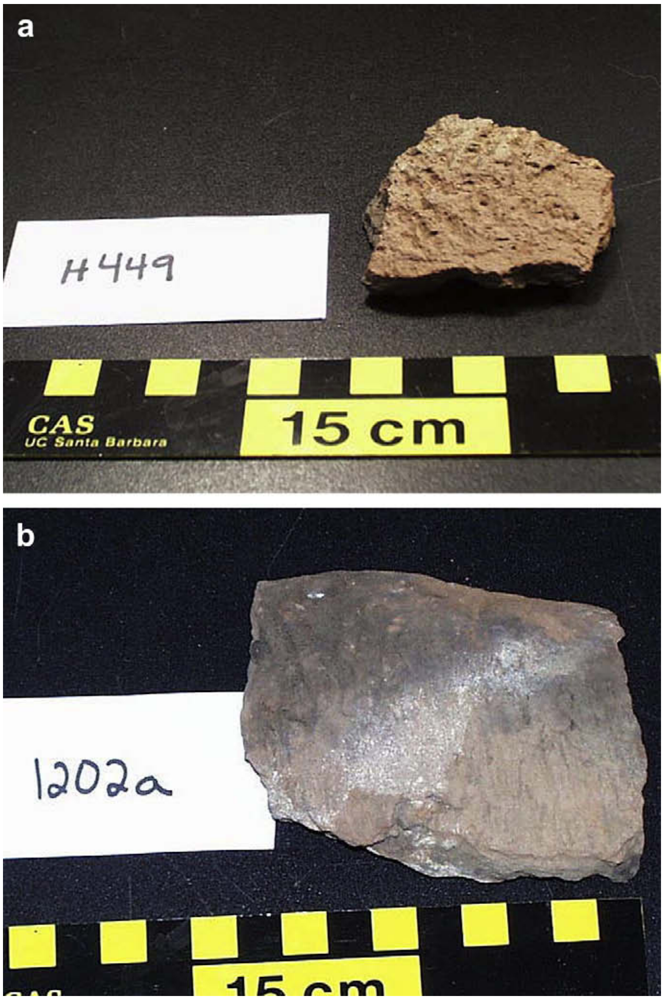

Fig. 2. (a) Fragment of hand-formed Nubian-style vessel with impressed decoration from Hannek, ES-449, sample #22, (b) Typical hand-formed Nubian-style pot from Askut, ES-1202a, sample #23.

Table 1
Sample sherds analyzed via X-ray fluorescence.

#	Sample name	Site	Site context	Period	Culture	Fabric/inclusions	Vessel form	Decoration
1	ES-00-13	Tombos	Unit 4	New Kingdom	Egyptian	B2-C	Jar	Plain
2	ES-00-132A	Tombos	Unit 6	New Kingdom	Egyptian	B2	Base	Plain
3	ES-00-132B	Tombos	Unit 6	New Kingdom	Egyptian	B2	Base	Plain
4	ES-00-134	Tombos	Unit 6	New Kingdom	Egyptian	C	Jar	Plain
5	ES-1391A	Askut	SE ext.	New Kingdom	Egyptian	B2	Base	Plain
6	ES-00-174	Tombos	Unit 4	New Kingdom	Egyptian	B2		Plain
7	ES-00-30	Tombos	Unit 6	New Kingdom	Egyptian	B2	Bowl	Plain
8	ES-00-47A	Tombos	Unit 4	New Kingdom	Egyptian	limestone	Cup	Plain
9	ES-00-47B	Tombos	Unit 4	New Kingdom	Egyptian	B2	Bowl/pot	Plain
10	ES-00-73	Tombos	Unit 6	New Kingdom	Egyptian	B2	Pot	Plain
11	ES-05-131A	Tombos	Unit 9	Late/Napatan	Egyptian	Fine, B2?	Cup	Red burnished
12	ES-05-131B	Tombos	Unit 9	Late/Napatan	Egyptian	B2-C	Cup/small jar	Plain Hand-made
13	ES-05-387A	Tombos	Unit 9	Late/Napatan	Egyptian	C	Cup	Plain hand-made
14	ES-05-387B	Tombos	Unit 9	Late/Napatan	Egyptian	C	Cup	Plain hand-made
15	ES-1189A	Askut	SE ext.	New Kingdom	Nubian		Pot	Stamped
16	ES-1189B	Askut	SE ext.	New Kingdom	Nubian		Small jar	Plain
17	ES-1391B	Askut	SE ext.	New Kingdom	Egyptian	C	Small jar?	Plain
18	ES-2042	Askut		New Kingdom	Egyptian	B2	Cup	Plain
19	ES-2049	Askut		New Kingdom	Egyptian	B2	?	Plain
20	ES-2063	Askut		New Kingdom	Egyptian	B2	Shallow bowl/plate	Plain
21	ES-194	Hannek		Kerma-P	Nubian		Cup	plain
22	ES-449	Hannek		Kerma-LP	Nubian		?	Impressed
23	ES-1202A	Askut	SE ext.	New Kingdom-TIP	Nubian		Pot	Plain
24	ES-439	Hannek		Kerma-LP	Nubian		?	Plain
25	ES-462	Hannek		Kerma-LP	Nubian		?	Plain
26	ES-1202B	Askut	SE ext.	New Kingdom-TIP	Nubian		Jar? restricted pot	Incised
27	ES-434C	Hannek		Kerma-LP	Nubian	limestone	?	Plain
28	ES-1423A	Askut		New Kingdom-TIP	Nubian		Cup	Plain
29	ES-434A	Hannek		Kerma-LP	Nubian		?	Plain
30	ES-1423B	Askut		New Kingdom-TIP	Nubian		Cup	Plain
31	ES-434B	Hannek		Kerma-LP	Nubian	limestone	Pot?	Plain
32	ES-438	Hannek		Kerma-LP	Nubian		?	Impressed

Note: Egyptian-style vessels are wheel-thrown unless otherwise noted (samples 12–14 are hand-made but possess all other characteristics of wheel-thrown Egyptian-style vessels, such as surface finishing, shape, and fabric, and are therefore classified as Egyptian-style); Nubian-style vessels are hand-made. Egyptian fabric types B2 and C are defined as Arnold and Bourriau (1993); Nubian-style sherds are not classified in relation to a typology but are generally medium fine to medium coarse.

1.2. Pottery in Nubia from the New Kingdom to the Late/Napatan Period

Beginning during the Middle Kingdom and lasting into the Late/Napatan Period, there were two common ceramic styles used in Nubia—Egyptian and Nubian. Nubian-style pottery was hand-formed, probably from Nile silt clay (e.g. Nile alluvium). Many pieces were decorated with red burnish, incised lines, or mat impressions (Robertson and Hill, 1999; Williams pers. comm.; Fig. 2a). The tradition ranged from extremely coarse cookpots, e.g. Fig. 2b, to extraordinarily beautiful and refined pieces during the Kerma interlude.[1] Nubian wares were often black in color from firing in a reduced environment. By contrast, the Egyptian-style ceramics found in Nubia were wheel-thrown, oxidized, and with only rare use of decoration—in sum, virtually identical to the vessels used contemporaneously in Egypt itself. By far the greatest quantity of Egyptian-style ceramics found in Nubia, as in Egypt, appear to be made from Nile alluvium (mainly Nile Silt B and C in the Vienna System). Vessels made from marl or mixed clays, which are found in the wadis and cliffs of certain areas of Egypt and were thus certainly imported, have also been found but are much less common (Arnold and Bourriau, 1993).

The two pottery styles, Egyptian and Nubian, remained visually distinct throughout the period of colonialism and Nubian independence, leading archaeologists to surmise that they were manufactured through different production techniques, used by different social groups, and circulated in different patterns of trade and consumption. The Nubian hand-made wares were considered the product of local female potters, who (it is supposed) made them predominately for local use. By contrast, the Egyptian vessels were made by professional male potters, as was the custom in Egypt, and were intended for longer distance trade and distribution (Adams, 1986; for cross-cultural and ethnographic parallels see Stark, 2003). However, we know there must have been some overlap in the general areas of production because sites in Nubia such as Askut have evidence of the local manufacture of Egyptian-style vessels, including unfired sherds and vessels that have a unique mica-filled fabric only found in Nubia (Smith, 2003). In fact, most of the assumptions about the non-stylistic differences between the two types of wares remain to a large degree untested, including the basic but crucial question of whether the styles were made from different clay sources.

Comparing the source and method of manufacturing of the two ceramic styles can help evaluate the models of cultural interaction described above. If Nubia were largely acculturated, we would expect to see substantial production of Egyptian-style vessels in Nubia as well as a convergence of the ceramic styles and manufacturing methods as the two cultures blended. By contrast, if the Egyptians remained essentially foreign colonizers, we would expect to see a distinct separation in style and function between the ceramic traditions, a substantial percentage of imported Egyptian-style vessels, and a decline in locally produced Egyptian-style pottery after the Egyptian withdrawal. Finally, in the case of cultural imperialism, we would expect that as in the case of pure colonization, Egyptian and Nubian-style vessels would remain distinct, but there would be a larger percentage of Egyptian-style vessels produced locally in Nubia and this would continue even into the Late/Napatan Period.

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[1] This paper does not specifically address the fine ceramics diagnostic of the Kerma period; unfortunately it is still unclear how these ceramics relate to the larger and longer tradition of Nubian-style ceramics discussed here. De Paepe et al. (1992) presents a chemical and petrographic analysis of Kerma ceramics, which would be a good starting point for comparison.

Table 2
Point count results, Egyptian-style sherds.[a]

No.[b]	Quartz	Feldspar	Biotite	Mica[c]	Amphibole	Epidote	Plant	Rock fragments			Calcite	Chlorite	?[d]	Opaque	Void	Matrix
								Vol[e]	Meta[e]	Car[e]						
00-13	8.8	3.5	1.3	0.0	0.3	0.5	0.5	0.5	0.0	0.0	0.0	0.0	1.3	6.3	5.5	71.8
00-132	8.3	4.0	3.5	0.3	0.5	0.0	0.8	0.5	0.5	1.0	0.0	0.0	0.8	5.5	7.3	67.3
00-134:1[f]	6.3	4.8	0.5	0.3	0.0	0.0	3.0	1.8	0.0	0.0	0.0	0.0	0.8	0.0	6.8	76.0
00-134:2[f]	6.3	5.0	0.5	0.3	0.0	0.3	3.0	3.5	0.0	1.5	0.0	0.0	1.3	0.5	5.3	72.8
00-134:3[f]	6.8	3.5	1.0	0.0	0.3	0.3	4.5	0.0	0.0	1.0	0.0	0.0	0.5	0.0	5.8	76.5
1391a	3.0	2.3	0.3	0.0	0.3	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.8	3.5	2.8	86.5
00-174	6.8	3.3	1.0	0.0	0.0	0.0	1.8	1.8	0.0	0.0	0.0	0.0	0.5	5.0	3.8	76.3
00-30	8.8	3.3	1.0	0.5	0.0	0.3	0.3	0.0	0.0	0.3	0.0	0.0	0.8	4.5	2.5	78.0
00-47a	6.5	5.8	0.0	0.0	0.3	0.0	3.8	0.5	0.0	0.0	0.0	0.0	0.8	2.5	8.8	71.3
00-47b	6.3	1.0	0.0	0.0	0.3	0.3	1.3	0.0	0.0	1.0	0.0	0.3	1.3	3.0	3.8	81.8
00-73	7.0	4.3	0.5	0.0	0.3	0.0	1.8	0.3	0.0	1.8	0.0	0.0	1.0	2.8	6.8	73.8
05-131a:1[f]	6.0	5.8	0.3	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.3	0.3	8.8	77.0
05-131a:2[f]	7.5	3.3	0.5	0.0	0.3	0.0	2.5	0.3	0.0	0.0	0.0	0.0	0.3	1.0	6.8	77.8
05-131b	6.5	3.8	0.5	0.0	0.3	0.0	2.5	0.3	0.0	0.3	0.0	0.3	0.3	1.3	15.5	68.8
05-387	2.0	3.0	0.8	0.5	0.0	0.5	2.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	9.8	80.8
1189a:1[f]	16.5	3.3	2.0	0.3	0.0	0.8	3.5	0.0	0.0	1.8	0.5	0.3	0.0	1.3	9.3	60.8
1189a:2[f]	13.8	2.3	0.0	0.3	0.0	0.0	2.3	0.3	0.0	0.8	0.8	0.5	0.5	1.0	7.0	70.8
1189b	11.3	1.8	2.0	0.0	0.0	0.3	0.3	0.0	0.0	1.3	0.0	0.0	0.3	0.5	10.8	71.8
1391b	6.0	3.3	0.0	0.0	0.5	0.5	2.5	0.3	0.0	0.0	0.0	0.0	1.0	1.5	7.8	76.8
2063	8.8	1.8	0.8	0.0	0.0	0.8	0.5	1.0	0.0	0.0	0.0	0.0	2.5	3.5	4.0	76.5

[a] Data are percentages of each category in each sample and are based on counting 400 points in each specimen.
[b] For brevity the prefix ES for all sample names is not shown.
[c] White mica.
[d] Uncertain grain or fragment type.
[e] Vol = volcanic, Meta = metamorphic, Car = carbonate.
[f] Multiple thin sections of the same sherd counted.

1.3. Geochemical analysis of Egyptian and Nubian pottery

Unfortunately, because of the homogeneity of Nile alluvium in most areas of Nubia and Egypt, it has proved difficult to determine to what extent the provenance of the styles actually coincide and therefore to test these hypotheses (Bourriau et al., 2000; De Paepe et al., 1992). Given the difficulties in using traditional methods of categorization to fully address the complexities of ceramic production and distribution in colonial Nubia, we turn to geochemical characterization methods, which have been used with some success to separate Egyptian Nile silt vessels by provenance (e.g. Bourriau, 1998; Bourriau et al., 2006; Mallory-Greenough et al., 1998; Redmount and Morgenstein, 1996; Tschegg et al., 2008) and even to suggest possible local Nubian imitations of Egyptian-style ware in the Kerma period (De Paepe et al., 1992).

These studies found that variables other than provenance, such as time period or quantity of temper, do not predict most geochemical variation in Nile silts. For instance, while researchers have detected some differences in the geochemistry of both archaeological sherds and raw Nile silt sediment from different time periods (Krom et al., 2002; Mallory-Greenough et al., 1998), results from tests on modern Egyptian pottery found that divisions between certain modern manufacturing locales were clearer than between ancient and modern sherds from similar locales (Redmount and Morgenstein, 1996). Similarly, De Paepe et al. (1992) suggests basic compositional continuity among Nubian Kerma ceramics from different time periods.

In addition, so far no study has linked particular ceramic fabrics used for classification by archaeologists (such as those used in the Vienna System) to particular geochemical signatures. Rather, Bourriau et al. (2006: 277) points out that geochemically, within-site variation between different fabrics is less than between-site variations in the same fabric type. Because fabric types are differentiated by the relative quantity and size of their most common inclusions, sand and straw, it appears that these tempers do not heavily influence the geochemical profile of a sherd. Therefore, it seems that the major source of geochemical variation in Nile silt ceramics is probably the production locale, making it reasonable to suppose that if Nubian and Egyptian-style ceramics were manufactured at the same production sites and from similar clay, they should show greater geochemical similarity than if they were produced from different clay sources.

2. Sample selection and analytical methods

Samples were taken from three sites in Nubia—Askut, Tombos, and Hannek (Fig. 1). Askut was an Egyptian fort in Lower Nubia, built to help administer and control the Egyptian empire during the Middle Kingdom (Smith, 1995). It was reused and modified throughout the life of the empire, and was inhabited into the Napatan period. The site shows evidence of both native Nubian and Egyptian imperial populations. In addition, as mentioned previously, it is one of the few Nubian sites that possess conclusive evidence for local manufacture of Egyptian-style ceramics.

Tombos, lying at a strategic point at the Third Cataract in Upper Nubia, was a bureaucratic colonial center and southern outpost for the Egyptians during the New Kingdom, continuing as a community into the Napatan period (Smith, 2003). Not surprisingly, excavations at the cemetery in 2000 and 2005 revealed burials that largely reflected Egyptian practices, with some Nubian influences (Buzon, 2004). Also at the Third Cataract, Hannek is almost directly across the Nile to the west of Tombos. However, this site probably remained an essentially native Nubian town, as evidenced by the predominance of Nubian-style pottery and burials. It is thought to have been occupied from at least the Kerma period into the time of the Napatan kingdom (Smith, 2003).

Thirty-two samples were selected from these sites (Table 1), including variability in time (New Kingdom or Late/Napatan Period) and style (Nubian or Egyptian).[2] All samples underwent XRF and Loss on Ignition (LOI) analyses. XRF was used to measure 10 major elements (measured as compounds and expressed as percentages of total weight) and 23 trace elements (expressed in

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[2] As an internal control on the consistency of the method, one redundant sample was run; that is, samples 13 and 14 are actually from the same sherd. Since their elemental chemistries did indeed turn out to be almost identical, in subsequent interpretation and analysis they are treated as a single sherd 13/14.

Table 3
Point count results, Nubian-style sherds.[a]

No.[b]	Quartz	Feldspar	Biotite	W.Mica[c]	Amphibole	Epidote	Plant	Rock fragments			Calcite	Chlorite	?[d]	Opaque	Void	Matrix
								Vol[e]	Meta[e]	Car[e]						
194	1.3	1.3	0.0	0.3	0.0	0.0	2.0	0.5	0.0	1.0	0.0	0.0	0.3	0.0	10.3	83.3
1202a	11.5	4.8	0.5	0.3	0.0	0.3	0.0	0.0	0.0	1.0	0.0	0.0	0.3	0.3	20.3	61.0
439	3.5	4.0	0.8	0.3	0.3	0.3	1.0	0.3	0.3	2.3	0.0	0.0	1.3	0.0	13.0	73.0
1202b	5.3	6.0	0.8	0.3	0.3	0.0	0.0	0.0	0.0	4.3	0.0	0.0	0.8	5.3	13.3	64.0
1423a	3.3	1.8	0.8	0.0	1.0	0.3	2.5	0.5	0.0	0.0	0.0	0.0	0.8	0.0	8.8	80.5
434c	4.3	5.8	1.0	0.3	0.8	0.0	3.5	0.3	0.3	0.5	0.0	0.0	0.3	1.3	14.3	67.8
1423b	2.8	1.5	0.5	0.0	0.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	7.0	84.3
438	4.8	4.3	2.0	0.5	1.0	0.5	0.0	0.3	0.3	1.3	0.0	0.0	0.0	3.0	15.8	66.5

[a] Data are percentages of each category in each sample and are based on counting 400 points in each specimen.

[b] For brevity the prefix ES for all sample names is not shown.

[c] White mica.

[d] Uncertain grain or fragment type.

[e] Vol = volcanic, Meta = metamorphic, Car = carbonate.

parts per million). The remaining portion of 18 of the samples were set aside for subsequent INAA analysis as part of a larger project intended to verify and extend the geochemical data established in this study (see Carrano et al., in press). Each sample was wrapped in paper and then was broken into pieces less than 0.6 cm^2 by gentle tapping with a hammer. Representative ~7 to ~98 g samples were weighed and powdered for 1 min in a Spex Certiprep tungsten carbide shatterbox. The shatterbox was cleaned three times with acetone, and then with silica sand in between each run. Resulting powdered samples were sealed in plastic containers. Approximately 5–20 g of each powdered sample were weighed into a Petri dish and subsequently dried for 24 h in an oven at ~100 °C to remove any absorbed water. A 6:1 mixture of lithium tetraborate and dried sample powder was then placed into platinum crucibles and fused using a HD Elektroniks VAA2 Autofuser.

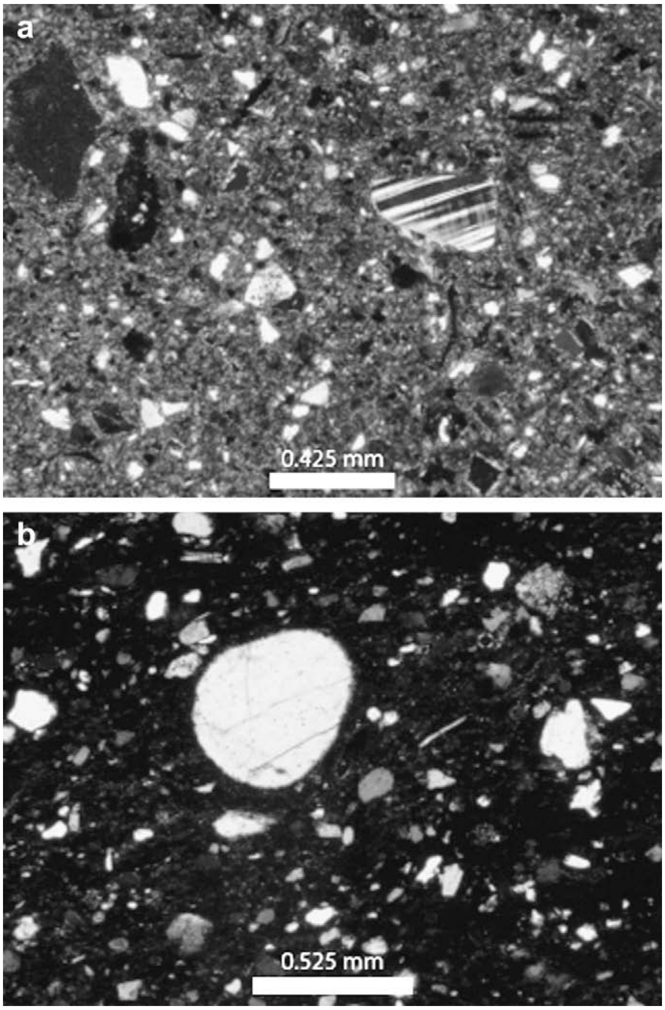

Fig. 3. Photomicrographs taken with cross polarized light of thin sections of (a) Egyptian-style sherd #9 (the large grain in the upper right is microcline), (b) Nubian-style sherd #23 (large rounded grain in center is monocrystalline quartz).

If sufficient powder remained after making the fused discs, then trace elements were analyzed using powder pressed pellets. Approximately 13 g of powder was mixed with 4 ml of elvacite using a mortar and pestle. This mixture was then pressed under ~25 tons of pressure using a Spex CertiPrep 3624B X-Press.

Both fused glass discs and pressed pellets were analyzed for major and selected trace elements using conventional techniques on a Phillips MajiX Pro spectrometer. Loss on Ignition (LOI), representing the sum of all volatile components in each sample, was determined first by weighing a Coors ceramic crucible. Weighed portions of each sample were placed into Coors crucibles and then were inserted into an oven that was gradually heated to ~1000 °C. This temperature was continuously maintained for 1 h. Following heating, samples were cooled overnight in an oven at ~100 °C, and then were reweighed. LOI was calculated as the difference in weights prior to and after heating for 1 h at 1000 °C.

Due to the ongoing controversies regarding the correlation of chemical composition analysis with other more traditional ceramic techniques (Neff et al., 2006a,b; Sharer et al., 2006), as well as our own outstanding questions, the samples were also studied petrographically (Tables 2 and 3). For petrography thin section billets were cut from epoxy casts of each sherd. Four hundred points were counted per thin section at a spacing of ~0.3 mm and a magnification of 400×. During point counting average grain shape was visually determined and average grain size was measured using the micrometer (reticule) built into the right binocular microscopic eyepiece (ocular).

For statistical analysis and the creation of bivariate plots, JMP 5.1.2 was used. In particular, the data were explored through hierarchical Ward's clustering and discriminant analysis (Drennan, 1996); the inherent difficulty in obtaining accurate results from such a small sample size dissuaded us from attempting more sophisticated statistical manipulation.

3. Results

3.1. Petrographic characteristics

Microscopic observations indicate that both Egyptian- and Nubian-style pottery sherds consist of a coarse-grained (~0.02 to ~2.30 mm) framework composed mostly of the silicate minerals quartz and feldspar, a fired matrix of black to red-brown cryptocrystalline material (<∼0.01–0.02 mm) surrounding the framework, the scattered remains of plant fragments, and voids (Fig. 3a and b). Silicate minerals other than quartz and feldspar identified as part of the framework include biotite, amphibole, chlorite, epidote, and white mica. Augmenting the silicate minerals in the framework are calcite, an opaque phase, and rock fragments.

Rock fragments make up ∼0.0% to ∼5.5% and ∼0.0–4.3% of the framework population in Egyptian- and Nubian-style sherds respectively (Tables 2 and 3). They are a ubiquitous component of the larger sized framework population, and are mostly subround to subangular pieces of carbonate and volcanic rock and lesser quantities of fragments derived from metamorphic rock. Carbonate fragments reach ∼2.30 mm in size. In such large fragments angular grains of quartz silt are common. If carbonate fragments are present in a given specimen, then the largest observed grain in that specimen typically is part of the carbonate fragment population.

Voids are of three varieties. In the first variety, remnants of plant fragments are commonly still preserved in some part of the void cavity, while the shape of the second variety is suggestive of air or gas pockets produced during the production process. In the third variety, the shape of the void and the occasional remnant of a mineral species clearly points to its origin through dissolution or plucking during the making of the thin section or during wear from pot use or storage. The greatest proportion of void space is derived from the first variety (∼>50%), while the smallest proportion is derived form the last category.

The size distribution of silicate minerals in the framework of both Egyptian- and Nubian-style sherds appears to be very to poorly bimodal, consisting of one population composed of grains ranging in size between ∼0.15 to ∼1.30 mm (fine to very coarse-grained sand), and another consisting of grains ranging in size between ∼0.02–0.10 mm (silt to very fine grained sand). Quartz grains in the larger sized group include large over sized well rounded to rounded grains, but are otherwise subround to angular. Grains in the smaller sized group are generally very angular to subangular.

The average grain size for the population of smaller framework grains was estimated visually. For Egyptian-style sherds it ranges from silt to very fine-grained sand (∼0.05 to ∼ 0.10 mm). Of the 14 samples used to derive this estimate, seven have an estimated average grain size of ∼0.10 mm (very fine grained sand). The largest observed framework grain in the population of larger grain sizes of Egyptian-style sherds, other than carbonate fragments, is commonly quartz. It ranges in size from medium to very coarse-grained sand (∼0.45 to ∼1.30 mm).

Visually estimated average grain sizes of the population of smaller framework grains in Nubian-style sherds also range from silt to fine-grained sand (∼0.05 to ∼ 0.10 mm). However, of the 11 samples representative of the Nubian-style studied under the microscope, only one has an estimated average grain size of 0.10 mm (i.e., #15 in Table 1). Eliminating this sample, the range in visually estimated average grain sizes for the smaller framework grain population is reduced to ∼0.05 to ∼0.08 mm (silt to very

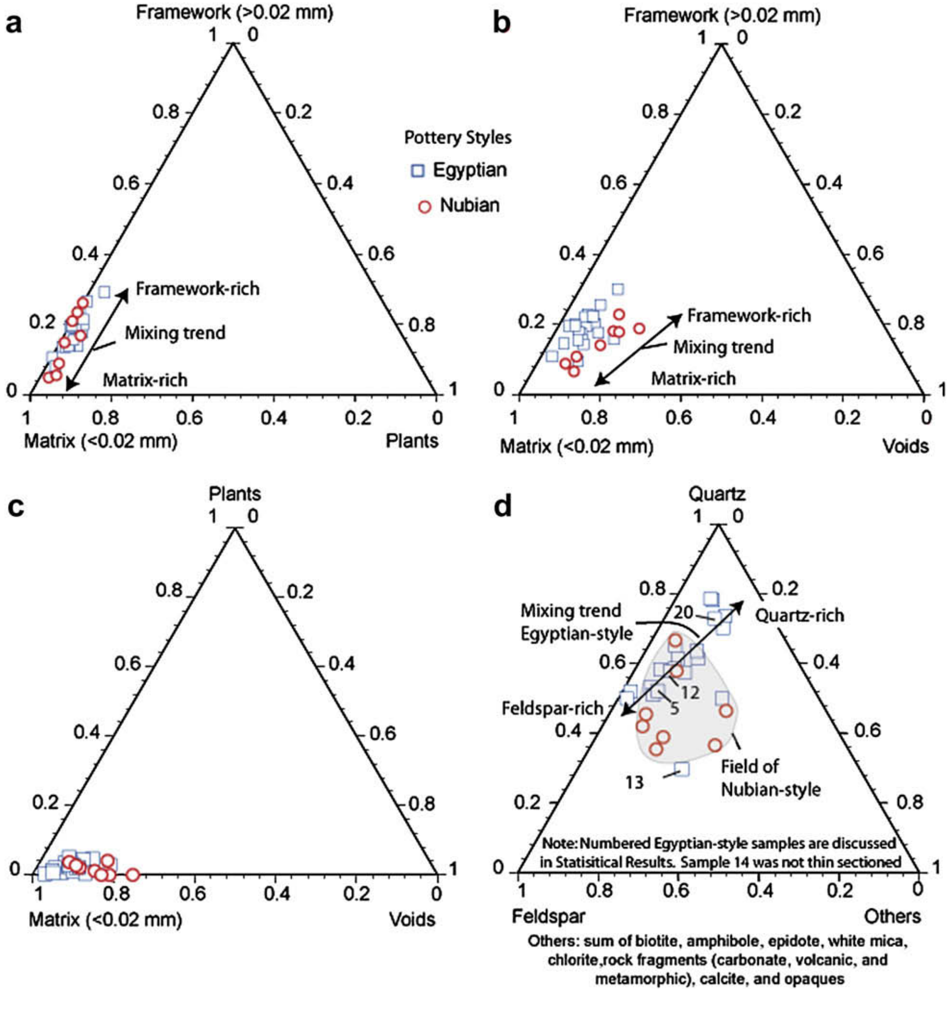

Fig. 4. Ternary diagrams based on point-count data in Tables 2 and 3. (a) Framework–Plants–Matrix, (b) Framework–Voids–Matrix, (c) Plants–Voids–Matrix, (d) Quartz–Others–Feldspar. Note that linear trends in data are interpreted to be the result of mixing two end member compositions approximated by the two most extreme samples plotting at opposite ends of the array. See text for further discussion.

Table 4
XRF analysis of major elements, reported as percentages of total.

Sample name	Sample number	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	TiO_2	P_2O_5	LOI	Total
ES-00-13 NKE	1	58.4	14.9	9.62	4.24	2.89	2.10	1.72	0.18	1.71	0.63	2.85	99.2
ES-00-132A NKE	2	59.2	15.0	9.73	4.22	2.81	1.62	1.88	0.18	1.76	0.42	2.45	99.2
ES-00-132B NKE	3	59.7	15.2	9.87	4.30	2.86	1.67	1.78	0.19	1.78	0.43	2.13	99.9
ES-00-134 NKE	4	59.5	15.1	9.81	4.60	3.05	2.21	1.68	0.18	1.75	0.67	1.66	100.2
ES-1391A NKE	5	57.4	15.7	10.8	4.89	3.23	1.35	1.59	0.19	2.05	0.36	1.58	99.0
ES-00-174 NKE	6	55.8	14.3	9.42	4.46	3.27	3.42	3.41	0.17	1.70	0.61	3.17	99.7
ES-00-30 NKE	7	57.8	15.1	9.8	4.21	2.87	1.70	2.38	0.17	1.74	0.56	3.27	99.6
ES-00-47A NKE	8	57.6	14.8	9.68	4.03	2.84	1.76	1.79	0.16	1.73	0.81	2.89	98.1
ES-00-47B NKE	9	55.9	15.0	9.83	4.44	2.92	1.88	1.74	0.19	1.75	0.80	4.46	98.9
ES-00-73 NKE	10	60.6	14.9	9.68	4.10	2.93	2.08	1.71	0.19	1.75	0.52	1.19	99.6
ES-05-131A LPE	11	59.6	15.2	9.47	4.09	2.80	1.76	1.37	0.16	1.65	0.70	1.85	98.6
ES-05-131B LPE	12	58.6	14.9	9.6	3.64	2.85	1.50	1.62	0.17	1.73	0.46	3.47	98.5
ES-05-387A LPE	13	55.1	16.3	10.8	4.05	3.11	1.41	2.17	0.18	1.90	0.41	3.41	98.8
ES-05-387B LPE	14	55.2	16.3	10.8	4.03	3.13	1.42	2.26	0.18	1.91	0.41	3.72	99.3
ES-1189A NKN	15	59.5	12.0	7.19	4.76	2.58	1.73	1.62	0.11	1.40	0.26	7.51	98.7
ES-1189B NKN	16	57.0	13.1	8.24	3.87	2.61	2.34	1.73	0.14	1.50	0.25	8.09	98.9
ES-1391B NKE	17	58.4	15.0	9.99	4.27	3.16	2.19	1.79	0.15	1.81	0.61	1.84	99.2
ES-2042 NKE	18	56.4	15.5	9.73	5.04	3.15	1.64	2.02	0.13	1.63	0.42	3.05	98.7
ES-2049 NKE	19	58.4	14.4	9.31	4.95	2.80	2.08	1.37	0.16	1.71	0.81	1.48	97.4
ES-2063 NKE	20	56.8	13.6	8.89	3.67	2.47	2.23	1.78	0.14	1.62	0.59	4.60	96.4
ES-194	21	54.9	16.9	11.6	4.33	3.24	1.45	1.54	0.19	2.07	0.41	2.68	99.3
ES-449	22	60.3	14.1	8.17	3.43	2.49	1.86	1.74	0.19	1.53	0.35	5.06	99.2
ES-1202A	23	61.2	12.5	7.51	4.74	2.39	1.65	1.56	0.12	1.37	0.29	5.86	99.2
ES-439	24	57.4	15.2	10.3	4.06	3.16	1.08	2.03	0.21	1.99	0.31	3.24	98.9
ES-462	25	59.3	14.2	8.45	5.01	2.67	1.72	1.49	0.15	1.55	1.14	3.54	99.2
ES-1202B	26	53.5	15.7	10.8	4.47	3.57	1.47	1.91	0.18	1.93	0.38	5.72	99.6
ES-434C	27	56.4	16.4	11.0	4.06	3.17	1.38	1.71	0.17	1.93	0.38	2.78	99.3
ES-1423A	28	54.3	18.3	10.7	3.09	2.97	1.65	1.89	0.14	1.48	0.29	5.06	99.9
ES-434A	29	54.0	15.7	10.7	3.62	2.82	1.46	1.61	0.14	1.83	0.43	3.36	95.6
ES-1423B	30	56.2	17.3	10.47	3.02	3.307	1.559	2.21	0.154	1.614	0.27	2.97	99.1
ES-434B	31	55.7	16.2	10.85	3.98	3.329	1.418	2.32	0.165	1.911	0.322	3.44	99.7
ES-438	32	58.3	15.7	9.72	3.69	2.947	1.452	2.16	0.146	1.723	0.297	3.94	100.1

fine-grained sand). The largest observed framework grain, other than carbonate fragments, observed in Nubian-style sherds is commonly quartz. Within the larger grain size population its size fell between medium and coarse-grained sand (~0.42 and ~0.80 mm).

The medium to coarse-grained sand sizes of grains included in the large framework grain size population in both styles of sherds point to a source other than Nile River silt and clay. In contrast, the smaller framework grain size population contains mostly angular to subangular grains that grade downward in size into the fired red to black clay matrix. These relationships suggest that both styles of sherds are mixtures of sand, silt, and clay, and that the framework in Nubian-style sherds is generally finer grained than in Egyptian-style sherds.

To explore further possible differences in texture and mineralogy, point-count data were plotted on ternary diagrams with apices of Framework–PlantsMatrix (Fig. 4a), Framework–Voids–Matrix (Fig. 4b), Plants–Voids–Matrix (Fig. 4c), and Quartz–Others–Feldspar (Fig. 4d). Resulting plots suggest that the Framework–Plants–Matrix compositions of Egyptian- and Nubian-style sherds are similar (Fig. 4a). In contrast, in plots of Framework–Voids–Matrix (Fig. 4b) and Plants–Voids–Matrix (Fig. 4c) Nubian-style sherds tend to contain a higher proportion of the Voids category than do Egyptian-style sherds. Moreover, linear trends are evident in each of these plots (i.e., Fig. 4a–c). For example, data in Fig. 4a form a linear trend oriented parallel to the Matrix–Framework join. Such linear relationships are commonly interpreted to represent mixing lines. In such an interpretation, the sample plotting highest on Fig. 4a is composed of more framework material than is the sample plotting lowest on the diagram and nearer the matrix apex. All other samples lying between these two extremes are mixtures of the material represented by the two end member components.

Replacing the Plants category with Voids in Fig. 4b pulls out the Nubian-style sherds but retains the linear attribute for both styles. Given the observation that most (>50%) of the Voids category was due to disintegration or dissolution of plant fragments, this result further implies that Nubian-style sherds may have been mixed with a greater proportion of plant fragments than were Egyptian-style sherds. This conclusion is reinforced by the Plants-Voids-Matrix plot in Fig. 4c where, though there is some overlap due to the higher proportion of void space in Nubian-style sherds, they tend to cluster toward the right of Egyptian-style samples. In short, Nubian-style sherds tend to be composed of finer grained framework components, and more plant and void space than do Egyptian-style sherds.[3] In addition, on a Quartz–Others–Feldspar ternary diagram (Fig. 4d), they tend to form a scattered plot, and generally contain less framework quartz than do Egyptian-style sherds. In contrast, on the same plot all but two samples of Egyptian-style sherds form a linear mixing trend with one member being quartz-rich and the other feldspar-rich (Fig. 4d). Hence, petrographic data and microscopic observations suggest distinctive, but not necessarily unique differences in the mineralogy and texture of Egyptian- and Nubian-style sherds. An analysis of the geochemical data further drew out these differences.

3.2. Discrimination of pottery groups based on geochemistry

The raw data from our analyses are presented in Table 4 (percentages of major elements and LOI values) and Table 5(trace element values). For all of our samples, the values of both major and

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[3] The LOI results support the conclusion that Nubian-style sherds contain a greater percentage of organic plant material. LOI, as a measure of the total volatile material in a sherd, usually corresponds with the quantity of liquid and organics in the sherd matrix. Not surprisingly, then, Nubian-style sherds on average have both a higher LOI value and a greater percentage of plant material in the point-count data (Redmount and Morgenstein, 1996: 745).

Table 5

XRF analysis of trace elements, reported in ppm (those samples missing values did not have sufficient material to allow for trace element measurements).

Sample name	Sample number	Sc	V	Cr	Co	Ni	Cu	Zn	Rb	Sr	Y	Zr	Nb	Mo	Ba	La	Ce	Nd	Sm	Yb	Hf	Pb	Th	U
ES-00-13 NKE	1	26.8	195.2	142	44.8	82.3	69	113	50.6	321.8	37.3	287.1	24.1	1.8	542.5	27.9	71.5	34.4	9.9	5.2	8.5	9.8	5.9	2.7
ES-00-132A NKE	2	26.5	200.4	150.7	50.2	80.4	61.9	105	47.9	326.5	37.6	300	24.7	1.9	590.4	35.1	79.3	35.1	8	3	7.5	8.5	5.6	2.6
ES-00-132B NKE	3	26.1	199.2	151.7	45.3	81.1	60.8	105.7	48.8	320.4	38.2	303.9	25.3	1.5	580.8	32.3	82	39	9.7	6.8	9.7	8.8	7.3	3.3
ES-00-134 NKE	4	27.2	198.2	146.9	42	79.9	64.2	116	53.9	316	37.2	295.9	25.1	2.3	494.8	29.7	78.7	36.8	9	4.7	8.3	9.6	7.1	2.2
ES-1391A NKE	5	27.3	217.1	160.5	62.6	86.3	69.1	117.3	44.1	321.5	38.5	292	24.6	1.5	473.6	36.9	77.1	37.5	6.5	7.7	7.2	8	6.7	2.2
ES-00-174 NKE	6																							
ES-00-30 NKE	7																							
ES-00-47A NKE	8	26.2	204.3	149.1	61	79.6	60.4	127.6	51.3	330.2	37.7	293.1	24.9	2.1	537	30.5	73.3	35.1	9.9	7.9	8.5	6.6	7.5	2.5
ES-00-47B NKE	9																							
ES-00-73 NKE	10																							
ES-05-131A LPE	11																							
ES-05-131B LPE	12	26.4	200.1	151.7	56.5	82.3	62.3	107.7	45.6	285.1	37.2	302.3	24.9	1.4	509.2	35.5	72.3	35.3	8.4	5.4	7.9	9.2	6.5	3.2
ES-05-387A LPE	13	27.2	213.7	148	56.7	87.9	63.8	121	49.1	308.9	40.3	275.6	26.7	1.4	494.4	29.2	75	36.6	9.9	5.6	8.2	8.4	8.1	2.5
ES-05-387B LPE	14	28.8	210.5	147.3	56.3	87.5	63.6	120.4	50.4	294.5	39.9	271.8	26.5	1.3	485.9	30.1	78.7	36.8	7.2	5.6	8.1	8.4	7	2
ES-1189A NKN	15	21.9	171.3	126	35	60	44.3	81.7	38.9	256.4	35.6	425.8	21.6	2.1	388.9	32	72.3	36.6	8.9	5	10.9	9.4	6.5	2.5
ES-1189B NKN	16	25.8	195.4	137.2	40.4	73.6	55.3	93	49.1	226	34.8	316.4	22.7	1.7	413.6	35.9	72.5	35.4	8.4	3.8	8.9	9.2	5.7	2.3
ES-1391B NKE	17	25	201.1	159.9	51	80.5	55.4	117.2	51.1	301.3	36.6	293.9	24.8	2.2	437.8	32.3	68.9	32.8	5.6	6.8	8.4	8.8	7.3	2.4
ES-2042 NKE	18																							
ES-2049 NKE	19	26.2	200.6	144.1	57.3	76	65.9	123.6	52.8	321.5	36.7	296.6	24.2	1.9	471.2	30	70.7	33.6	12.9	6.8	8.3	9.9	7	2.9
ES-2063 NKE	20																							
ES-194	21	31.2	237	176.6	91.9	99.3	75.7	122	42.8	306.5	38.8	264.3	25.4	1.1	480.5	33.3	76.5	36.5	10.1	2.3	6.1	6.3	4.6	3.1
ES-449	22	21.4	168.6	131.8	49.2	72.3	47.4	97.2	51.9	367.6	36.7	427.3	23.8	1.2	932.9	37	83.8	35.9	9.3	3.2	9.3	8	6.8	3.3
ES-1202A	23	22.7	161	118.3	54.6	62.9	40.3	85.2	40.1	277.2	32.3	343.4	20	1.8	424.4	30.2	72.3	34.5	8	3.4	8.3	7.3	4.8	2.8
ES-439	24	27.6	231.6	174.9	109.8	86.3	49.4	118.6	37.1	351.5	36.5	314.8	24.9	1	543.8	37.2	77.4	37.2	9.5	3.8	7.3	7.3	4.9	2.8
ES-462	25	21.2	166.7	135.3	44.7	66.5	42	97	49.4	422.3	35.3	387.2	25	1.8	908.7	39.8	76.7	32.5	8.9	4.3	10	7.7	8	4.8
ES-1202B	26	30.3	236.5	166.3	69.3	95.9	73.3	115.6	40.4	348	37.5	262.6	22.9	0.4	476.5	31	70.3	37.4	11.2	2.5	6.1	7.8	3.9	2.3
ES-434C	27	29.3	243.3	168.1	96.2	95.4	59.7	115.3	45.4	310.2	39.7	282.2	24.8	0.8	537.2	27.6	81.2	38.5	6.1	2.9	6.2	7.6	4.8	4.1
ES-1423A	28	31.1	218.6	146	59.2	91.3	68	111.4	67.7	227.8	37.1	259.4	26.8	0.9	444.1	41.4	87.7	37.6	11.7	3.4	6.7	10.8	7	3.7
ES-434A	29	29.1	228	167.7	62.7	91.4	63.7	119.2	45.9	309.4	38.7	292.1	24.7	1	515.6	30.7	77.4	38.9	6	2.8	6.1	8	4.7	2.9
ES-1423B	30	27.4	206.9	133.8	50.8	84.5	63.6	117.6	62.8	356	37.6	296.9	29.6	1.8	437.6	37.2	87	38.2	9.7	3.3	6.5	9.7	7.8	5
ES-434B	31	29.2	240.2	164.7	51	93.5	67.7	110.4	45.1	312.3	38.4	280.7	24.3	1.4	513.5	29.4	75.3	35.2	8.7	1.2	7.9	8.1	5.2	3
ES-438	32	24.5	197.6	147.7	49.5	76.8	56.4	106.5	49.7	293.2	37.2	325.7	24.9	0.9	466.5	32	79.4	37.7	6.6	3.8	8.1	9.3	5.7	3.2

Table 6

Mean and standard deviation for samples grouped by style and site (major elements reported in %, trace elements in ppm).

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	MnO	TiO_2	P_2O_5	Sc	V	Zr	Mo	Ba	Yb	Hf	Th	U
Egytpian ($n = 18$)	57.8	15.07	9.82	4.29	2.95	1.89	1.89	0.17	1.76	0.57	26.7	203.67	292.02	1.75	510.69	5.95	8.24	6.91	2.59
	±1.65	±.64	±.50	±.39	±.20	±.48	±.46	±.02	±.11	±.15	±.96	±6.99	±10.27	±.35	±47.28	±1.43	±.64	±.71	±.41
Nubian ($n = 14$)	57	15.23	9.69	4	2.95	1.59	1.82	0.16	1.7	0.38	26.64	207.34	319.9	1.34	534.56	3.26	7.74	5.74	3.27
	±2.45	±1.85	±1.46	±.61	±.36	±.29	±.27	±.03	±.24	±.22	±3.69	±30.49	±56.97	±.52	±170.07	±.92	±1.58	±1.28	±.85
Askut ($n = 11,9$)	57.19	14.83	9.42	4.25	2.93	1.81	1.77	0.15	1.65	0.41	26.43	200.94	309.67	1.59	440.86	4.74	7.92	6.3	2.9
	±2.21	±1.97	±1.31	±.74	±.39	±.34	±.23	±.02	±.22	±.18	±3.11	±23.39	±50.38	±.58	±29.60	±1.9	±1.49	±1.26	±.91
Hannek ($n = 8$)	57.03	15.54	10.09	4.02	2.98	1.48	1.83	0.17	1.82	0.46	26.69	214.13	321.79	1.25	612.34	3.04	7.63	5.59	3.4
	±2.18	±.99	±1.23	±.49	±.30	±.23	±.31	±.02	±.2	±.28	±3.84	±31.95	±.41	±57.22	±192.25	±.98	±1.49	±1.21	±.69
Tombos ($n = 8,13$)	57.92	15.15	9.85	4.19	2.95	1.89	1.96	0.18	1.76	0.57	26.9	202.7	291.21	1.71	529.38	5.53	8.34	6.88	2.63
	±1.87	±.56	±.43	±.24	±.15	±.53	±.52	±.01	±.07	±.14	±87	±6.38	±.37	±12.1	±40.2	±1.44	±.64	±.83	±.45

trace elements, as well as LOI, fell within the range previously reported for Nile silts (Mallory-Greenough et al., 1998; Redmount and Morgenstein, 1996; compare geochemistry of Libyan Desert vessels, Klein et al., 2004).

The more challenging question, therefore, is the degree to which the geochemistries of the two styles are distinguishable. Bivariate plots revealed an interesting, if somewhat unexpected, pattern. Instead of the sample sherds separating clearly by style, the most common result was that the Egyptian-style sherds at the 90% confidence level were almost completely subsumed by the Nubian-style sherds at the same confidence level (Fig. 5). For instance, in a plot of Al_2O_3 by Fe_2O_3, the Egyptian-style sherds (particularly those from Tombos) clustered very tightly, while the Nubian-style samples fell into a much larger ellipse. A similar result occurred using trace elements. While a handful of plots, particularly Yb by Th and Yb by Hf, separated Egyptian and Nubian-style samples fairly well at an 80% confidence level (Fig. 6), more common were bivariate plots such as Sc by Th, in which the 90% confidence ellipse for Egyptian-style samples were almost completely subsumed by the much larger ellipse of Nubian-style samples.[4]

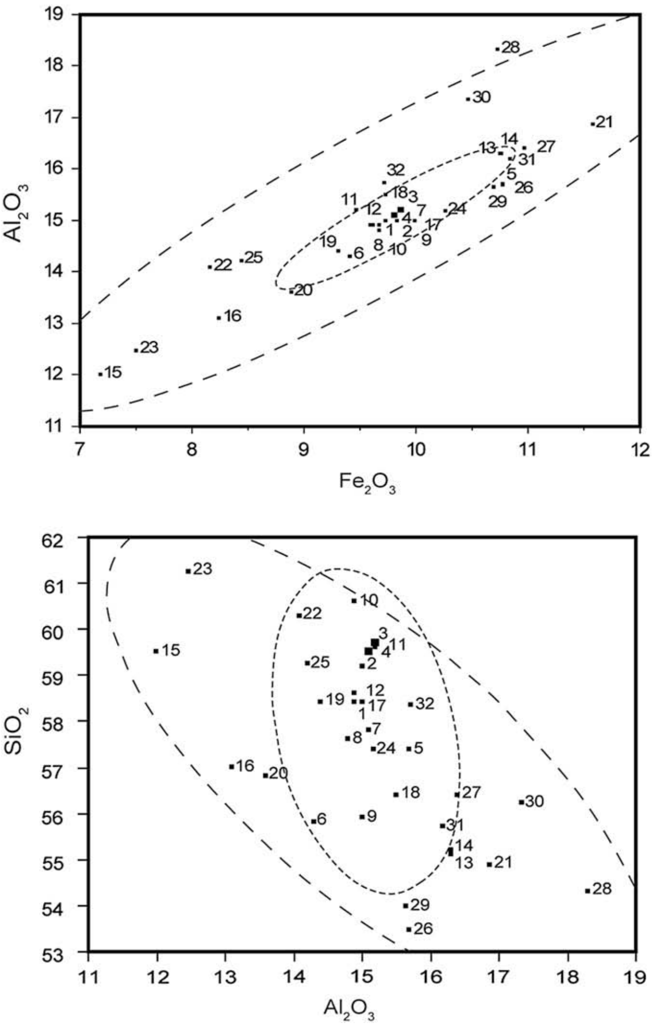

Fig. 5. Bivariate plots of major element percentages, samples grouped by style, density ellipses represent 90% confidence, Egyptian - - -, Nubian —.

The application of several multivariate statistical techniques to the same data provided further insight. The results obtained from hierarchical Ward's clustering and discriminate analysis are discussed here (k-means clustering did not provide significantly different results and is not discussed). We start with the application of the statistical methods to the major element percentages. In Ward's clustering, the majority of Egyptian-style sherds clustered into one group (Fig. 7). By contrast, the Nubian-style sherds fell into several clusters, some of which also contained Egyptian-style sherds. In addition, the results from both methods revealed that there were several samples whose major element percentages did not resemble those of samples from a similar style. In particular, samples 5, 13/14, and 20, though Egyptian in style, clustered with Nubian-style sherds and sample 6 was an outlier. In discriminant analysis, samples 12 and 13/14 were predicted as Nubian (see Table 1 for note on style), and 5 and 20 had relatively low probabilities as members of the Egyptian group. In addition, in both statistical analyses, sample 25 (Nubian-style from Hannek) had greater affinity to Egyptian-style sherds than to its fellow Nubian-style sherds.

The same multivariate techniques were also used to explore trace element values. Ward's clustering formed four clusters, with all Egyptian-style sherds falling into one cluster (Fig. 8). The Nubian-style sherds formed three clusters with one Nubian sherd from Hannek clustering with the Egyptian samples. Discriminant analysis was also successful, and while the large number of elements used in the analysis increases the likelihood that the derived function separates the input groups by chance alone (Mallory-Greenough et al., 1998), using only two elements (Yb and Cu) still resulted in efficient separation of sherds by style. In sum, there is strong evidence that trace element values can efficiently separate the two stylistic groups, and somewhat less indication that major element percentages are also diagnostic of style. In addition, the greater chemical homogeneity of Egyptian-style sherds is supported by the statistical analyses.

The next question addressed was whether sherds, regardless of style, could be separated by provenance using their geochemical compositions. In general, it appeared that differences in elemental

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[4] Greater chemical diversity between Nubian-style sherds was confirmed by the fact that the standard deviations (SD) for the elements, particularly the trace elements, were generally greater for Nubian-style sherds (Table 6). For example, the SD for Zr among Egyptian sherds is 10 while for Nubian sherds it is 57; for Ba the SD for Egyptian sherds is 47, while for Nubian it is 170.

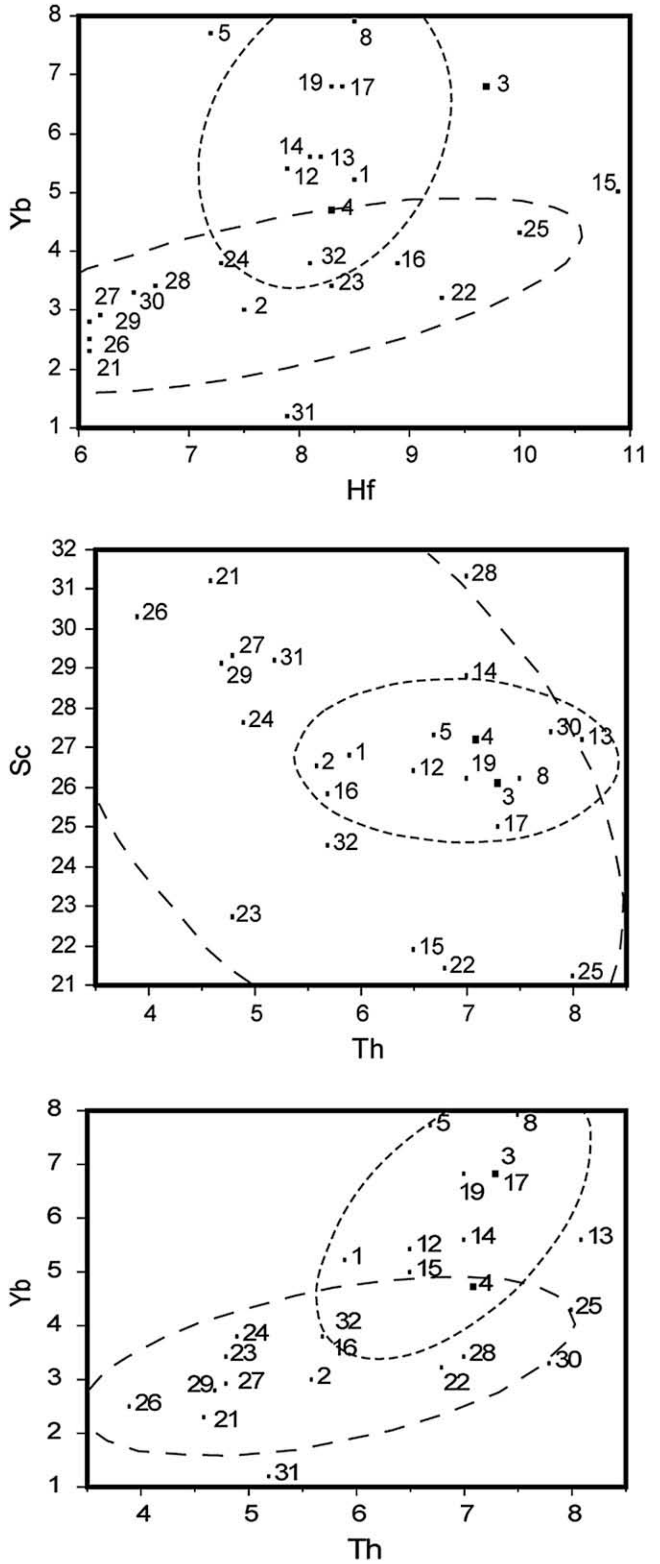

Fig. 6. Bivariate plots of trace elements, samples grouped by style, Egyptian - - -, Nubian ——, (a) density ellipses represent 80% confidence, (b) density ellipses represent 80% confidence, (c) density ellipses represent 90% confidence.

chemistry corresponded more closely to style than to site. For instance, redrawing the plot of Yb by Hf discussed above, this time grouping by site, the ellipse for Askut encompassed both the ellipses for Hannek and Tombos (Fig. 9), a result of the fact that this site, unlike the others, contained sherds of both styles and that these sherds grouped closer to other samples of the same style than to other Askut sherds. This pattern was seen in the plots of other trace elements as well as in plots of major element percentages.[5]

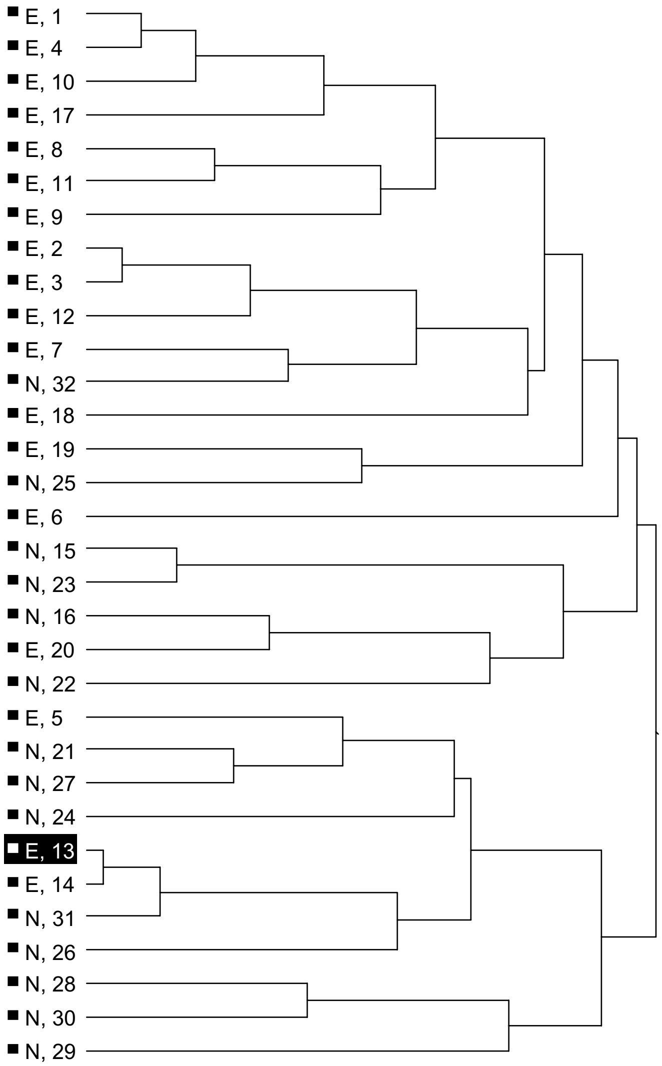

Fig. 7. Hierarchical ward's cluster analysis diagram using major elemental percentage.

On the other hand, in a Ward's cluster using trace elements most sherds from Hannek (all of which are Nubian-style) fell into group 3, while Nubian-style sherds from Askut generally made up groups 2 and 3. Discriminant analysis using provenance instead of style as the given grouping was also partially successful. There were some anomalies, including samples 12 and 13/14, both hand-made Egyptian-style sherds from the Late/Napatan Period at Tombos, which showed closer affinities with the sherds from Hannek than those from Tombos. This result likely reflects the similar textual and geochemical makeup of these sherds to Nubian-style samples (the samples from Hannek being entirely Nubian-style). In addition, the

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[5] Elemental mean values of the sherds from each of the sites did vary, but only by relatively small amounts (Table 6). For instance, SiO_2 varied by 0.9% between Tombos and Hannek, and most other major elements such as MgO varied by less than a tenth of a percent. For the trace elements, there was more than a 30 ppm difference in Zr between Tombos and Hannek; on the other hand, Sc and others had only tenths of a ppm difference. The only conclusions we can draw from this were that the mean values between-site groups were approximately as varied as those between stylistic groups, and that the difference in mean values were often greatest between the sites of Hannek and Askut. This last conclusion is what we would expect, given the proximity of Hannek and Tombos.

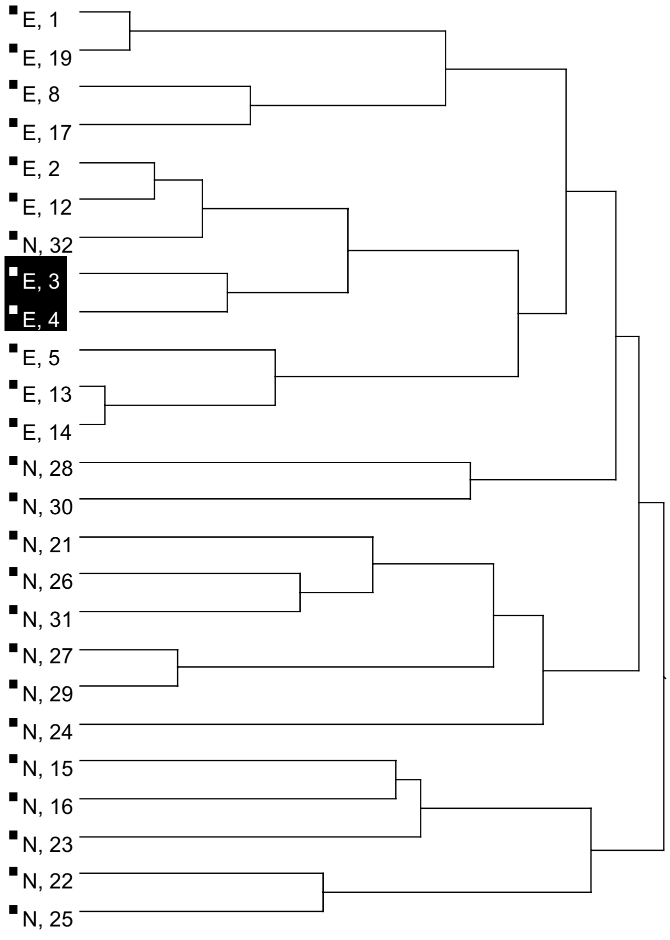

Fig. 8. Hierarchical ward's cluster analysis diagram using trace element amounts.

trace element values of some Egyptian-style sherds from Askut more closely resembled the samples from Tombos (all of which were Egyptian-style) than those from Askut. Thus, while statistical methods were perhaps capable of elucidating some meaningful distinctions between sherds from different provenances, the distinctions were less obvious than those between stylistic groups. The limited ability to separate by provenance was more pronounced for Nubian-style ceramics, which may be a result of their greater compositional diversity.

A final consideration was the degree of correlation between time period and sherd chemical composition; in our case, the conclusions were extremely limited, because most sherds came from either the New Kingdom or, in the case of the Nubian-style sherds, were not able to be dated with any certainty. Therefore, while no obvious correlation appeared to be indicated, we cannot rule out the possibility that some of the variation within the Nubian-style group may be correlated with time period. The one difference that can be noted was the geochemical signatures of the Late/Napatan Period Egyptian-style, hand-made ceramics from Tombos, samples 12 and 13/14. The anomalous values from these sherds may be correlated with their later time period, indicating that different clay sources were exploited during the Napatan era. Evaluating this hypothesis will require analysis of many more samples from the Late/Napatan Period, to determine if the average values of this group of vessels are statistically different from earlier periods.

4. Discussion and conclusions

Results indicated that using XRF along with petrography to separate Egyptian and Nubian-style ceramics was successful, thus suggesting that the styles correspond with real mineralogical, textural, and geochemical differences. However, the compositional differences were not as we originally anticipated. The Nubian and Egyptian-style samples did not neatly cluster together, indicating essentially one sample population, nor did they entirely separate, indicating different populations. Instead, the chief differentiation appeared to be differences in the proportions of quartz, feldspar, and plant material + voids, a slight disparity in the mean values of many elements, and a larger discrepancy between the amount of variation found within each population. The results have both a methodological and archaeological significance.

Methodologically, our comparison of geochemical and petrographic techniques helps to deflate the (sometimes acrimonious) claims by archaeologists of the superiority of one method over another by showing that the results tended to reinforce, rather than contradict, one another. In addition, the results largely predicted the conclusions subsequently obtained by the authors from a larger INAA study of 90 samples from the same three sites, including 18 samples that were also analyzed in the current project. The INAA results supported our findings here that (1) geochemistry groupings do not clearly correlate with archaeological site, ceramic style, or time period; and (2) there is a greater chemical variety in Nubian-style vessels (results appear in Carrano et al., 2008, in press).

Again, the mutually reinforcing results from all three methodologies are encouraging to archaeologists, suggesting that they can legitimately rely upon the use of smaller samples sizes and readily available techniques for geochemical analysis, such as XRF and thin-sectioning, even without the benefit of robust statistical analysis possible with more comprehensive and costly INAA projects. At the same time, our results in no way suggest that greater sample sizes and a variety of analytical methods are not invaluable, particularly in areas like the Nile river where mineral and chemical distinctions are hard to discern. For instance, INAA was able to separate the samples into chemical groups, which the other techniques did not do, while petrography and LOI elucidated additional aspects of ceramic production, such as the addition of organic temper and sorting techniques seen as mixing lines, which may be unreachable through chemical analysis. Ideally, therefore, ceramic composition studies at the initial stages would include several analytical techniques.

Ultimately for archaeologists, however, our interest in ceramic composition comes from what it can indicate not simply about pots, but about the behavior of past people (Carpenter and Feinman, 1998). Preliminary analysis indicates that Nubian-style vessels were probably manufactured alongside Egyptian-style vessels, if not from the exact same riverine sources, then at least from within a relatively small area. This means that many Egyptian-style ceramics were being produced locally in Nubia. While it is uncertain to what extent the manufacture of Egyptian-style ceramics at places like Askut and Tombos was conducted largely by the colonists themselves and not local Nubians, it seems clear that these colonial communities were not entirely reliant on trade with Egypt itself to supply manufactured goods. In addition, the apparent lack of change in ceramic composition throughout the New Kingdom and early Napatan period shows that there was no wholesale rejection of Egyptian-style manufacturing techniques with the gradual decline in imperial power. Together, this evidence supports at least limited acculturation.

At the same time, the considerable variability in the mineralogical and chemical composition of Nubian-style vessels stands in contrast to the relatively more homogenous composition of Egyptian-style ceramics. The distinction is probably due to the standardized, centralized manufacture of Egyptian wheel-thrown ceramics, evidence that while the entire Egyptian system of production (and possibly distribution) may have been transported by the Egyptian authorities into Nubia under colonialism and

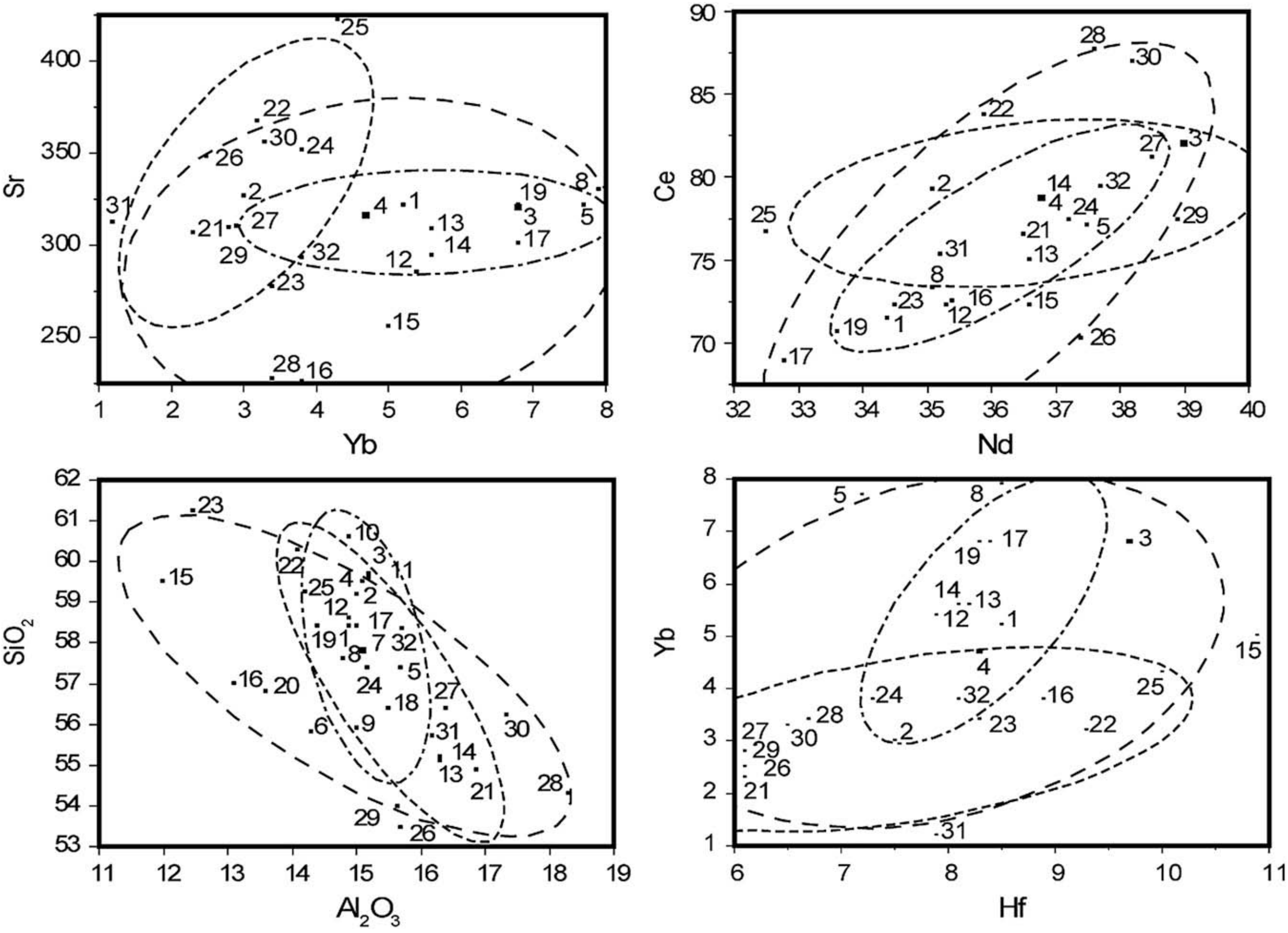

Fig. 9. Bivariate plots, samples grouped by site, density ellipses all represent 80% confidence; Askut —— Hannek - - -, Tombos — – —.

sustained into the Late/Napatan Period, the Nubian tradition of pottery production appears to have been only peripherally affected, if at all. The Nubian tradition remained more diverse, exploiting a variety of sources. For instance, the higher values of U and lower values of Yb in the Nubian-style sherds may be the result of potters selecting clay-silt sources in the areas around the river and then mixing them with a small coarser grained population derived from faster flowing portions of the river or from nearby aeolian dunes or wadis. In addition, the Nubian potters may have been producing smaller batches of pots from diverse locales and circulating the wares on a more local scale.

The maintenance of such distinct ceramic traditions suggests that acculturation was limited to only a segment of society and calls into question the Egyptian interest or ability to transform social and economic patterns in the areas not directly colonized. This evidence may support a model of cultural imperialism, in which the elite in Nubian society permanently adopted Egyptian ways (very possibly marrying within colonial families), while most of the local Nubian population carried on as before. Thus, status became associated with Egyptian culture, producing a socio-cultural divide that extended into the Napatan period.

It is clear from our results that instead of simply being viewed as a diagnostic tool to identify cultures, ceramic style can be analyzed as an important clue to understand cultural interaction. We think that combining petrographic studies and geochemical composition profiling via XRF provides one successful and cost-efficient way to examine these ceramic styles in archaeological contexts. Though the technique clearly has challenges, particularly as applied to the Nile river system, our current data indicate that finding meaningful patterns is possible and that the next step of expanded analysis, particularly of potential Nile River sediment, should be successful in refining the conclusions presented here.

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