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# *Characterizing the Stoneware "Dragon Jars" in the Guthe Collection: Chemical, Decorative, and Formal Patterning*

CARLA M. SINOPOLI, STEPHEN DUEPPEN, ROBERT BRUBAKER, CHRISTOPHE DESCANTES, MICHAEL D. GLASCOCK, WILL GRIFFIN, HECTOR NEFF, RASMI SHOOCONGDEJ, AND ROBERT J. SPEAKMAN

Ceramic vessels were important commodities in the extensive East and Southeast Asian maritime trade routes of the second millennium A.D. These vessels, which moved as containers and as objects of exchange in their own right, originated from multiple production locales in China and mainland Southeast Asia. Through complex mercantile and political distribution networks, they found their way to consumers on Mainland and Island Southeast Asia, as well as to South Asia, the Middle East, East Africa, Europe, and by the sixteenth century, the New World.

This paper addresses a small subset of Asian trade wares—large, brown-glazed stoneware storage jars recovered in archaeological research in the Philippines in the early decades of the twentieth century. Today, these vessels are part of the Guthe or Philippine Expedition Collection of the University of Michigan Museum of Anthropology (UMMA). Many were decorated, using a variety of techniques, with representations of dragons, botanical elements, lions, or demons. The decorated vessels are commonly referred to as "dragon jars" and are the primary focus of this study, although some undecorated vessels will also be included.

We have employed a variety of approaches in studying the Guthe dragon jars. We began the project interested in materials characterization of the stoneware jars in the Guthe collection and to that end employed instrumental neutron activation

Carla M. Sinopoli is Curator of Asian Archaeology, Museum of Anthropology, and Professor of Anthropology at the University of Michigan. Stephen Dueppen is a doctoral student in the Department of Anthropology, University of Michigan. Robert Brubaker is Visiting Assistant Professor at Grand Valley State University, Allendale, Michigan. Christophe Descantes is a postdoctoral fellow at the University of Missouri, Columbia. Michael D. Glascock is Director of the Research Reactor Center, University of Missouri, Columbia. Will Griffin is Assistant Professor of Anthropology at St. Charles Community College, St. Peters, Missouri. Hector Neff is Associate Professor of Anthropology at California State University, Long Beach. Rasmi Shoocongdej is Associate Professor of Archaeology at Silpakorn University, Bangkok. Robert J. Speakman is with the University of Missouri, Columbia.

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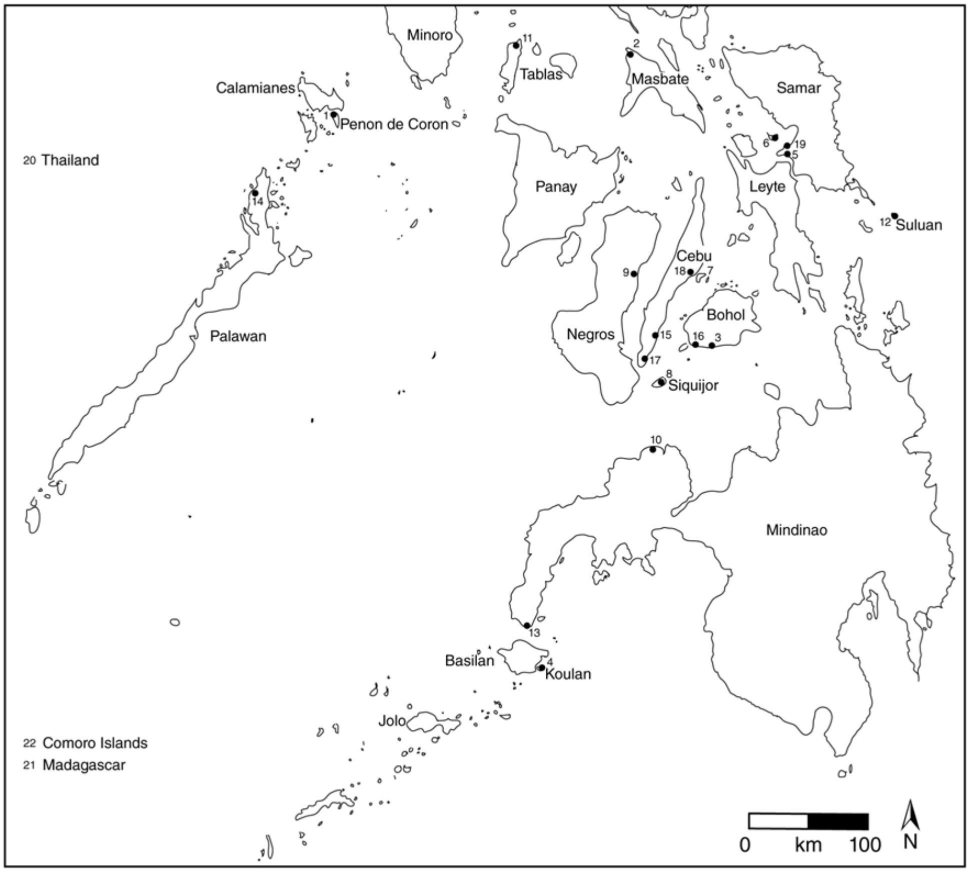
analysis (INAA) at the University of Missouri Research Reactor (MURR) laboratory in Columbia. That laboratory later conducted a laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) analysis on the glazes from sherds in the same sample. In Ann Arbor, we subsequently supplemented the characterization work with macroscopic ware analysis, morphological analysis, and stylistic studies. In this paper, we bring together all of these approaches to characterize these poorly understood materials.

The Guthe Collection derives from the endpoints of dragon jar exchange rather than their source areas or kiln sites. However, by identifying discrete coherent subgroups of vessels and integrating these with what is currently known about production locales, we hope to contribute to discussions of vessel production as well as consumption. Before presenting the results of our analyses, we provide some general background on the Guthe Collection and on the large stoneware jars that are the subject of our study.

## THE GUTHE COLLECTION

The Guthe Collection of the Museum of Anthropology, University of Michigan, provides a unique resource for the study of East and Southeast Asian trade ceramics. The collection is derived from the University's Philippine Expedition, directed by Harvard-trained archaeologist Carl Guthe, former curator of the Museum's Division of the Orient. From 1922 through 1925, Guthe explored the southern Philippines from the deck of the yacht owned by Dean Worcester, former secretary of the interior of the colonial government. Through excavation and acquisition from agents, Guthe collected archaeological materials from 542 sites distributed throughout the southern half of the Philippine archipelago (Guthe 1927:70; Fig. 1). Guthe divided the sites into three major categories: caves, burial grounds, and graves. Virtually all of the sites are mortuary contexts, containing both human remains and a wide range of artifacts, including locally produced earthenwares and imported porcelain and stoneware vessels, as well as iron implements, shell bracelets, glass and semiprecious stone beads, and gold ornaments. Materials from 485 of these sites (120 caves, 134 burial grounds, and 231 graves, plus some materials described as miscellaneous or "other"; numbers from Solheim 1964:79) were shipped to the University of Michigan, along with Guthe's original field notes and site catalogues. The provenience of each artifact in the collection is given to the site level; site location information records island and district and sometimes more precise reference to an associated village or geographic locale.

While Guthe's collection and documentation procedures leave much to be desired by contemporary standards, the collection nonetheless has considerable potential for current scholarship. Although largely interested in imported ceramics, Guthe did not limit his collection activities to those materials. Instead, he collected a broad range of fragmentary and complete artifacts.[1] This makes the assemblage rare among museum collections from Island Southeast Asia, which often comprise only valuable trade wares and "museum quality" pieces. In addition, the collection derives from a large number of sites that encompass a broad geographic area and temporal range. Datable ceramics span from the twelfth through nineteenth centuries, with the majority dating to the fourteenth through sixteenth




**Key: Recovery location of sherds used in compositional studies**

| | | | |
|---|---|---|---|
| 1 | CMS001 | | |
| 2 | CMS003, CMS008, CMS029 | 11 | CMS013 |
| 3 | CMS004, CMS018, CMS034 | 12 | CMS016, CMS017, CMS035 |
| 4 | CMS014, CMS015, CMS019, CMS020, CMS024, CMS025, CMS031, CMS038, CMS039, CMS040, CMS043, CMS042 | 13 | CMS027 |
| | | 14 | CMS032 |
| | | 15 | CMS044 |
| 5 | CMS002, CMS009, CMS037, CMS041, CMS045 | 16 | CMS046 |
| | | 17 | CMS028 |
| 6 | CMS006 | 18 | CMS048 |
| 7 | CMS007 | 19 | CMS006, CMS042 |
| 8 | CMS010 | 20 | CMS049, CMS050 |
| 9 | CMS011 | 21 | CMS030 |
| 10 | CMS012, CMS021, CMS022, CMS023, CMS026 | 22 | CMS036 |

Fig. 1. Map of Philippine sites documented by Carl Guthe, showing sources of dragon jars subject to chemical analysis.

centuries when the region played a central role in Southeast and East Asian trade networks (Valdes et al. 1992). Finally, the 10,000-plus vessels represented by sherds and complete pots that comprise the ceramic component of the Guthe Collection constitute one of the finest assemblages of East and Southeast Asian trade ceramics from archaeological contexts (excluding shipwrecks)—and one of the few collections that does not derive from looting and thus retains information on provenience.

The trade wares in the Guthe Collection include vessels from central and regional Chinese kilns. These consist of high-quality porcelains from imperial kilns such as Jingdezhen, as well as wares from export-oriented kilns in Zhangzhou. Interestingly, the collection includes a significant number of failures or wasters, including warped and overfired vessels, which largely date to the sixteenth-century late Ming period (Li 2005). A considerable portion of the trade wares were produced in Thailand at the well-known Si Satchanalai and Sukhotai kilns, as well as lesser-known production locales in northern Thailand, including Singburi (Brown 2000 : 95–96). Others come from Viet Nam, including the recently excavated Go Sanh kilns (Aoyagi 2002; Brown 2000 : 36–39; Morimoto and Ohashi 2002; Koezuka et al. 1996; Yamamoto 2002; Yamamoto et al. 1993).

The collection encompasses a very broad range of vessel forms that will be familiar to any scholar of Asian trade wares: small and large bowls and plates, jars, and covered boxes. From the sixteenth century and later, there are also some Spanish olive jars and other European wares (Skrownek 1997, 1998). The diverse sources and the wide range of quality and forms in the collection can provide valuable insights into changing maritime trade relations between Mainland Southeast and East Asia and Philippine polities and communities, on the creation of the early modern global economy from the sixteenth century on, and on internal consumption and disposal practices once the vessels reached their consumers.

Despite its tremendous potential for the study of changing patterns of maritime trade and internal social processes within the Philippines, the Guthe Collection remains to be fully analyzed or published. The Asian Division of the Museum of Anthropology is engaged in an ongoing project to develop a systematic computerized database and digital photographic record of the entire collection in order to make the materials more accessible to scholars and more amenable to quantitative and qualitative studies. Nonetheless, a number of published (e.g., Aga Oglu 1946, 1948, 1949, 1950, 1951, 1954, 1955, 1958, 1961, 1963; Gunn and Graves 1995; Guthe 1927, 1929, 1935, 1938; Skrownek 1997, 1998; Solheim 1964, 2002) and unpublished studies (Birch 1939; Bridges 2000, 2005; Chilakapathi 1996; Clark 2005; Dixon 1985, 1987; Dueppen 2004; Li 2005; Pratt 1955; Shepard 1942; Wagner 1975) have been conducted on specific subsets of the collection. The research presented here contributes another such study focused on a small subset of the collection—the large, brown-glazed stoneware storage and transport jars.

## "DRAGON JARS"

The large glazed storage and transport jars that are the object of this research have received relatively little attention in the extensive scholarly literature on Asian trade ceramics, which has focused more intensively on blue and white porcelains, white porcelains, and celadon-glazed stoneware. In 1967, Zaine referred to the stoneware jars as "a broad and difficult class . . . requiring further study" (79). With the exception of recent publications by Harrison (1986) and Valdes et al. (1992; also Valdes 1992) and ongoing research by Macherroni, Zaine's assessment remains accurate today. Nonetheless, these vessels constituted an important part of the Asian ceramic trade as both containers and commodities, and—as will be discussed below—they appear to have been especially valued objects in Island Southeast Asia.

As a general description, the vessels range from c. 40 cm to more than a meter in height, have low vertical or insloping necks, broad shoulders, and flat or convex bases (Fig. 2). They are typically fully glazed on the interior and are fully or partly glazed on the exteriors. Glaze colors range from a yellowish brown (7.5 YR 4/4; Munsell designation "dark brown") to very dark brown (10 YR 3/2; "very dark grayish brown") to olive brown tones. The vessels exhibit considerable variability in decorative treatment, vessel proportions, rim and handle forms, and in body, surface, and glaze colors.

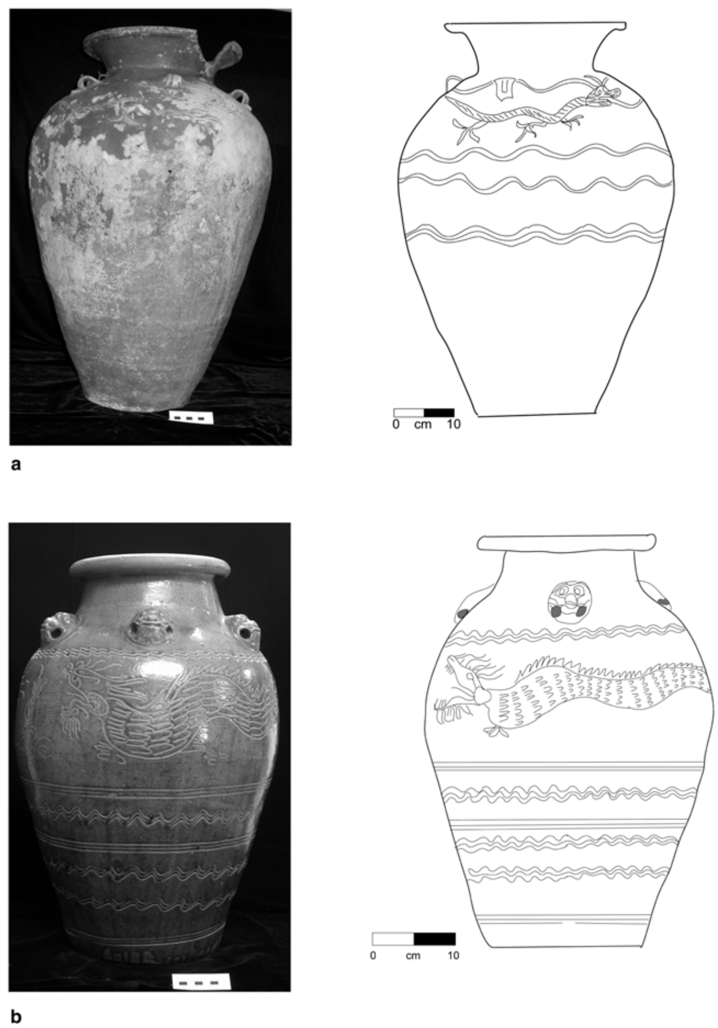



Fig. 2. Dragon jars in the Guthe Collection: a: UMMA36711, Compositional/Decorative Group 3; b. UMMA 2001-13-16, Decorative Group 5.

The most detailed classification for dragon jars was developed by Barbara Harrison (1986: chapter 7), who examined more than 2000 stoneware jar sherds from the site of Kota Batu on the Brunei River in Borneo. Dividing fragments into visually similar groups, Harrison grouped the sherds into seven classes on the basis of body color and texture, glaze color, rim and base forms, and available knowledge of production sites (Table 1). She provided a separate discussion of jar chronology and changing forms from the ninth through twentieth centuries, which we return to below.

TABLE 1. HARRISON'S CLASSIFICATION OF STONEWARE JAR SHERDS FROM KOTA BATU (HARRISON 1986:33–43)

| GROUP | CHARACTERISTICS |
|---|---|
| 1. Sawankhaloke | Porous body with pink, grey, white inclusions; gray to purple paste. Flat base with rough exterior surface. Most jars have four handles, which are hand rolled and affixed in a tightly curving loop. Glaze is semitransparent, dark brown to black, often with thick drip lines above the base. Undecorated except for parallel grooves on shoulders of some vessels. Similar vessels collected at Sawankhaloke kilns in Thailand and dated to fourteenth–fifteenth centuries. |
| 2. Coarse brown | Porous body with pink and purple inclusions; pink paste. Bases are massive, flat, without rough exterior surface. Some vessels have small, nonfunctional vertical loop handles. Provisionally attributed to Thailand or Cambodia. |
| 3. Wavy line | Body is gray to buff in color, with pink, purple, and white inclusions; body appears layered in section. Bases are flat or concave and rough surfaced on exterior. Low neck, with angled or flattened rims. Some vessels have small loop handles. No slip or glaze; vessels have pronounced shoulder band, consisting of flanges with incised wavy line elements. |
| 4. Go Sanh red | Coarse body, orange to purple in color, with red and white inclusions. Small vessels, 30 cm high is maximum. Bases are flat or slightly concave. Rims are rounded and folded; necks vary from low to vertical. Simple horizontal loop handles. Caramel-colored glaze, scraffiato incised decoration (after glaze application) or undecorated. Viet Nam, Go Sanh kilns? |
| 5. Coarse red | Orange to purple body, coarser than Go Sanh Red, with red and white inclusions. Jars are large in dimensions. Massive flat bases with rough exterior surfaces. Curved necks with rolled or carinated rims. Horizontal or vertical plain or grooved handles. Decorations include scraffito bands, swirls, impressed floral shapes, dragons. Glaze ranges from honey-colored to dark olive and was applied down to the base. Viet Nam? |
| 6. Brittle | Compact buff to gray body with black and white inclusions. Flat bases; various rim forms. Simple loop handles with finger impressions; some handles are molded lion heads, rabbits, or lion dogs. Incised and appliquéd patterns include floral and animal shapes. Glaze is medium brown to olive brown and semitransparent; with weak bond to paste. |
| 7. Guangdong | Fine-grained gray to buff body, with black and white inclusions. Two base shapes: concave on exterior with carved bands above foot and flat with cut marks visible. Diverse neck and rim forms. Handles are simple horizontal loops, and grooved and molded handles with shaped ends. Glaze is brown and semitransparent, poured in two coats. Carved and stamped decorations, including waves, scale elements, swirls and scrolls, impressed dragons, and studs. Guangdong, southern China (Shiwan kilns). |

The vast majority of glazed storage jars that have been recovered archaeologically come from sites in Indonesia, Malaysia, Japan, and the Philippines. Most archaeological specimens come from mortuary contexts or, more recently, shipwreck excavations (e.g., Loviny 1996; Quimpo 1982; Valdes 1993); many others have been acquired from local families who had sometimes owned the vessels for centuries. In Indonesia, they are referred to as *pesaka* or heirloom jars (Chin 1988; Harrison 1986), a term also applied by Valdes et al. (1992) to the Philippines. In both areas, these vessels were—and in some contexts continue to be—important objects of wealth and social prestige. Heirloom jars were traditional items in dowries, were used as burial vessels, and were used in domestic contexts for storage of food, water, and the brewing of rice wine consumed in rituals and feasts (Chin 1988:129). Genealogies of vessels were maintained by families in Borneo, and especially valued vessels could remain in domestic contexts for centuries after their production and acquisition. It is only in the last several decades that heirloom vessels from Indonesia or the Philippines have made their way into the international antiquities market and museum collections.

Valdes et al. (1992:70–92) summarize the history and current use of heirloom jars in the Philippines. As noted, when recovered archaeologically, they typically occur in burial contexts, where they are part of a long tradition of ceramic grave offerings. In addition, numerous nineteenth- and twentieth-century ethnographic reports provide evidence of their use by different ethnic and social groups in diverse ritual contexts, often as containers for rice beer, a necessary component of a variety of ritual feasts. Among the Tiguaian of Abra, for example, heirloom jars were transferred as bride price and were used to brew and serve rice beer in mortuary rituals. Stoneware jars count among the most valuable property of the Bontoc, where they are used to brew sugarcane wine and rice beer (Cawed 1981, cited in Valdes et al. 1992). Valdes et al. (75–90) report similar evidence for a variety of ethnic communities, including the Ibaloi, Ifugao, Kalinga, Tagbanwa, Pala'wan, and Subanen, among others.

Both the context of use and curation of these vessels and their apparent long-term production (from the twelfth through nineteenth centuries) create significant challenges for the construction of ceramic chronologies. As discussed below, few dated kiln sites are known. For the most part, chronological assignments have been based on informal assessments of stylistic attributes. Dating is further complicated by the fact that early design elements and forms sometimes became popular again several centuries after their initial use, resulting in a deliberate "archaism" and forms that are difficult to distinguish from their predecessors.

Relatively little is known about the production of glazed stoneware storage jars. Evidence from kiln sites in Viet Nam indicate that dragon jars were produced in these locations (typically as one of several wares fired at individual kiln sites). The kilns at Go-Sanh ("pottery mounds") in central Viet Nam were first identified in 1974 and are tentatively associated with the thirteenth-to-fifteenth-century Champa state (Brown 1977; Ha Van Tanh, personal communications). Excavations are now finished at these kilns, and a number of preliminary analyses have been published (Aoyagi 2002; Koezuka et al. 1996; Morimoto and Ohashi 2002; Yamamoto 2002; Yamamoto et al. 1993).

In Thailand, evidence for production of glazed stoneware jars has been found at Si Satchanalai and Sukhothai kilns and at other sites in north-central Thailand.

Most of the known Thai production sites are dated from the fourteenth to sixteenth centuries (e.g., Prichanchit 1988; Wilaikao 1988). In China, dragon jar production has been attributed to the Shiwan kilns in Guangdong Province, an area where jars are still produced today (Harrison 1986 : 42). Several other probable production areas are mentioned in the literature, including as yet unidentified locales in southern China, Thailand, Burma, and Viet Nam (see Chin 1988; Harrison 1986; Moore 1970).

Vessels are typically assigned to one or another of these varied source areas on the basis of stylistic or morphological traits. Often such assignments are quite broad and problematic; for example, "Southern China or Vietnam" (Harrison 1986 : 42), "Ming dynasty" (Locsin and Locsin 1967 : 196, figs. 219–221), "Thai-Cambodian border" (Harrison 1986 : 38), or "Northern Thailand." Clearly, much remains to be learned both about production locales and formal variability in this broad ceramic class.

## BROWN-GLAZED STONEWARE JARS IN THE GUTHE COLLECTION

The stoneware jar forms considered in this study comprise only a small portion of the Guthe Collection. They number approximately 200 individual vessels, of which approximately half are decorated (~85 fragmentary, 15 complete vessels).[2] The vessels derive from 30 archaeological sites distributed throughout the southern Philippines (see Fig. 1). Most sites yielding these vessels had easy access to the major maritime trade routes of the period. Almost all of the vessels come from mortuary contexts[3]—either burial caves, cemeteries, or isolated graves—and were found in association with locally produced earthenwares and other imported ceramics. The associated finds create the potential for helping to pin down the chronology of individual sites, though this is not without its difficulties. For example, according to data compiled by E. A. Bacus (personal communications), Burial Ground B1 on the island of Negros yielded ceramics dating from the thirteenth through nineteenth centuries, though the vast majority of dated vessels from that cemetery were produced in the thirteenth and fourteenth centuries.

Vessels in the collection are designated in two ways: by Guthe site and vessel number (e.g., C19-36—Cave 19, Object 36; comparable codes are B = Burial, G = Grave, M = Miscellaneous) and by UMMA catalogue number. In addition, vessels analyzed at the University of Missouri Research Reactor were assigned laboratory numbers CMS001 to CMS050. The designations of each analyzed sherd are reported in Table 2. As noted above, multiple analyses were conducted on the whole vessels and sherds in the Guthe Collection.[4] In the sections below, we begin with chemical characterization studies before moving on to discussions of vessel morphology and decorative treatment.

## CHARACTERIZATION STUDIES

A sample of 50 stoneware jar sherds from University of Michigan Museum of Anthropology Collections was submitted to the University of Missouri Research Reactor in 1995 (designated CMS001-050).[5] Forty-six sherds derive from the Guthe Collection; two are kiln wasters from the Sankampaeng kilns in Thailand

Table 2. Dragon Jar Identifications and Compositional and Decorative Groups

| UMMA CAT # | MURR NUMBER | UMMA COLL. | FIELD # | SITE | ISLAND | LOCALE | MAP ID | NAA GROUP | LA-ICP-MS GROUP | DECORATIVE GROUP |
|---|---|---|---|---|---|---|---|---|---|---|
| 19659 | CMS006 | Guthe | C1-106 | Cave 1 | Lagunit Island, Samar | Chapel Cave | 19 | **1** | **1** | **1** |
| 35265 | CMS007 | Guthe | G10-a | Grave 10 | Camiguan | Mambajo | 7 | **1** | **n.a.** | **n.a.** |
| 35523 | CMS010 | Guthe | G88-1 | Grave 88 | Siquijor | Sition Kanbonga | 8 | **1** | **n.a.** | **n.a.** |
| 34558 | CMS012 | Guthe | C28-03 | Cave 28 | Mindanao | Port Talaguilong | 10 | **1** | **1** | **1** |
| 34019 | CMS018 | Guthe | C11-334 | Cave 11 | Southern Bohol | Sucgan cave | 3 | **1** | **1** | **n.a.** |
| 34554 | CMS023 | Guthe | C28-1 | Cave 28 | Mindanao | Port Taliguilong | 10 | **1** | **1** | **1** |
| 34554 | CMS026 | Guthe | C28-1 | Cave 28 | Mindanao | Port Taliguilong | 10 | **1** | **1** | **n.a.** |
| 35539 | CMS029 | Guthe | G91-1 | Grave 91 | Northern Masbate | Barrio Colorado | 2 | **1** | **unassigned** | **n.a.** |
| 35030 | CMS032 | Guthe | C69-10 | Cave 69 | Palawan | Bacuit Bay | 14 | **1** | **1** | **1** |
| 35222 | CMS046 | Guthe | C94-1 | Cave 94 | Bohol | Barrio Peyajan | 16 | **1** | **unassigned** | **n.a.** |
| 34850 | CMS001 | Guthe | C64-60 | Cave 64 | Penon de Coron, Calamianes | Banuangdan | 1 | **2** | **2/3** | **2** |
| 34196 | CMS002 | Guthe | C16-43 | Cave 16 | Samar | Majaras Cave | 5 | **2** | **n.a.** | **n.a.** |
| 35996 | CMS003 | Guthe | M2-21 | Misc. 2 | Northern Masbate | Schwab's Gold Mine | 2 | **2** | **n.a.** | **2** |
| 34341 | CMS005 | Guthe | C19-36 | Cave 19 | Daram, Samar | Tigauan Cavbe | 6 | **2** | **2/3** | **2** |
| 34191 | CMS009 | Guthe | C16-38 | Cave 16 | Samar | Majaras Cave | 5 | **2** | **2/3** | **2** |
| 18191 | CMS014 | Guthe | B4-174 | Burial 4 | Koulan | | 4 | **2** | **2/3** | **n.a.** |
| 18189 | CMS015 | Guthe | B4-172 | Burial 4 | Koulan | | 4 | **2** | **n.a.** | **n.a.** |
| 18205 | CMS019 | Guthe | B4-188 | Burial 4 | Koulan | | 4 | **2** | **2/3** | **2** |
| 18204 | CMS024 | Guthe | B4-187 | Burial 4 | Koulan | | 4 | **2** | **n.a.** | **n.a.** |
| 18204 | CMS025 | Guthe | B4-187 | Burial 4 | Koulan | | 4 | **2** | **2/3** | **n.a.** |
| 19080 | CMS028 | Guthe | B73-1 | Burial 73 | Cebu | Baqrrio Cinocdung | 17 | **2** | **2/3** | **2** |
| 18203 | CMS038 | Guthe | B4-186 | Burial 4 | Koulan | | 4 | **2** | **n.a.** | **2** |
| 18190 | CMS031 | Guthe | B4-173 | Burial 4 | Koulan | | 4 | **2** | **2/3** | **2** |
| 34473 | CMS035 | Guthe | C23-62 | Cave 23 | Suluan Island | Maidamanoc | 12 | **2** | **n.a.** | **2** |
| 34195 | CMS037 | Guthe | C16-42 | Cave 16 | Samar | Majaras Cave | 5 | **2** | **2/3** | **2** |
| 34194 | CMS041 | Guthe | C16-41 | Cave 16 | Samar | Majaras Cave | 5 | **2** | **n.a.** | **n.a.** |
| 19924 | CMS042 | Guthe | C7-44 | Cave 7 | Oacan Island | | 19 | **2** | **n.a.** | **2** |
| 18048 | CMS043 | Guthe | B4-31 | Burial 4 | Koulan | | 4 | **2** | **2/3** | **2** |
| 34627 | CMS044 | Guthe | C42-9 | Cave 42 | Southern Cebu | Barrio Tubud | 15 | **2** | **2/3** | **2** |
| 34189 | CMS045 | Guthe | C16-36 | Cave 16 | Samar | Majaras Cave | 5 | **2** | **n.a.** | **2** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 34026 | CMS004 | Guthe | C11-342 | Cave 11 | Bohol | Sucgan Cave | 3 | **3** | **2/3** | **n.a.** |
| 34650 | CMS008 | Guthe | C47-5 | Cave 47 | Northern Masbate | Malibun, Barrio Mataba | 2 | **3** | **2/3** | **n.a.** |
| 17955 | CMS011 | Guthe | B1-107 | Burial 1 | Eastern Negros | Tabon | 9 | **3** | **2/3** | **3** |
| 35148 | CMS013 | Guthe | C81-12 | Cave 81 | Northeast Tablas | Barrio Majaban Baybay | 11 | **3** | **2/3** | **n.a.** |
| 34475 | CMS017 | Guthe | C23-64 | Cave 23 | Suluan Island | Maidamanoc | 12 | **3** | **2/3** | **n.a.** |
| 34562 | CMS021 | Guthe | C28-9 | Cave 28 | Mindanao | Port Taliguilong | 10 | **3** | **2/3** | **n.a.** |
| 34563 | CMS022 | Guthe | C28-10 | Cave 28 | Mindanao | Port Taliguilong | 10 | **3** | **2/3** | **n.a.** |
| Loan | CMS030 | Verin (loan) | | | Kingany | Madagascar | 21 | **3** | **2/3** | **n.a.** |
| 34472 | CMS016 | Guthe | C23-61 | Cave 23 | Suluan Island | Maidamanoc | 12 | **4** | **4** | **4** |
| 18181 | CMS020 | Guthe | B4-164 | Burial 4 | Koulan | | 4 | **4** | **4** | **4** |
| 18184 | CMS039 | Guthe | B4-167 | Burial 4 | Koulan | | 4 | **4** | **4** | **n.a.** |
| 18053 | CMS040 | Guthe | B4-36 | Burial 4 | Koulan | | 4 | **4** | **4** | **4** |
| 18047 | CMS047 | Guthe | B4-30 | Burial 4 | Koulan | | 4 | **4** | **4** | **n.a.** |
| 19081 | CMS027 | Guthe | B74-1 | Burial 74 | Sta Cruz (Mindanao) | Zamboanga | 13 | **unassigned** | **unassigned** | **n.a.** |
| 84041 | CMS036 | Wright | | | N'tsoha | Anjuan, Comoro | 22 | **unassigned** | **n.a.** | **n.a.** |
| 34031 | CMS034 | Guthe | C11-347 | Cave 11 | Southern Bohol | Sucgan Cave | 3 | **unassigned** | **unassigned** | **unassigned** |
| 18216 | CMS033 | Guthe | B4-199 | Burial 4 | Koulan | | 4 | **unassigned** | **n.a.** | **unassigned** |
| 35579 | CMS048 | Guthe | G103-1 | Grave 103 | Cebu | Barrio Ibado | 18 | **unassigned** | **unassigned** | **n.a.** |
| 47935 | CMS049 | Pope | | | Thailand | Sangampaeng | 20 | **unassigned** | **unassigned** | **n.a.** |
| 47935 | CMS050 | Pope | | | Thailand | Sangampeng | 20 | **unassigned** | **unassigned** | **n.a.** |

also in UMMA collections, and one each derives from museum research in Madagascar and the Comoro Islands (see Table 2). Two analyses have been performed at MURR on these samples: neutron activation analysis (NAA) in 1995 on ceramic fabrics and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) in 2004 on glazes. These are discussed separately below.

### *Neutron Activation Analysis*

The primary goal of the neutron activation analysis was to identify compositional subgroups of the jars that pertain to or derive from unique source or production areas. In chemistry-based sourcing studies, chemically homogenous subgroups are assumed, based on the provenience postulate (Weigand et al. 1977), to derive from localized sources or source zones (see also Bishop et al. 1992; Steponaitis et al. 1996). Thus, a homogenous group of unknown provenience can be "sourced" if sampled raw materials or kiln wasters can be shown to fall within the chemical variation of that group. In this study, the two kiln wasters from Thailand provide the only basis for evaluating provenience in this way, though they ultimately proved not to be relevant to materials in the Guthe Collection. Although we lack samples from additional relevant kiln sites, the homogenous groups that emerged from this analysis point to distinct production locales, and the results can be compared to samples from known production locales that may be analyzed in the future.

Pottery specimens were prepared and analyzed using standard MURR procedures (see Glascock 1992; Neff 1992). The analyses produced elemental concentration values for 33 elements (see appendix 1). Nickel and strontium were below detection in 39 and 25 analyses, respectively, and they were omitted from quantitative analysis of the compositional data.

Because the jars in this analysis were imported to the sites where they were found archaeologically, archaeological context cannot be assumed to provide any indication of compositional affiliation. As a result, pattern recognition techniques—hierarchical cluster analysis and principal components analysis (Baxter 1992; Neff 1994)—were used to recognize the initial groups. Often multivariate statistics based on Mahalanobis distance are necessary to evaluate and refine such hypothetical groups (Bieber et al. 1976; Bishop and Neff 1989; Harbottle 1976; Sayre 1975). In this analysis, however, compositional patterning is so clear that such tests are neither necessary nor appropriate. Below, we describe these groups; in subsequent sections of this paper, the compositional groups are compared to groupings defined by noncompositional attributes, including decorative style and morphology.

*INAA Results: Compositional Groups* — Hierarchical cluster analysis and PCA both suggested the existence of four distinct groups in the dragon jar data; 43 of the 50 analyzed samples could be attributed to one of these four groups, while 7 samples were unassigned. The four groups are clearly differentiated on principal components 1 and 2 (Fig. 3a). Based on the configuration of element coordinates, Group 1 is distinguished by high Cs and Sb; Group 2 is distinguished by low Cr; and Group 4 is distinguished by high Fe. Group 3 occupies an intermediate position on the PCA plots. These relations are illustrated on bivariate plots (Figs. 3b and 3c), and the data are presented in appendix 1. Plots of numerous other element

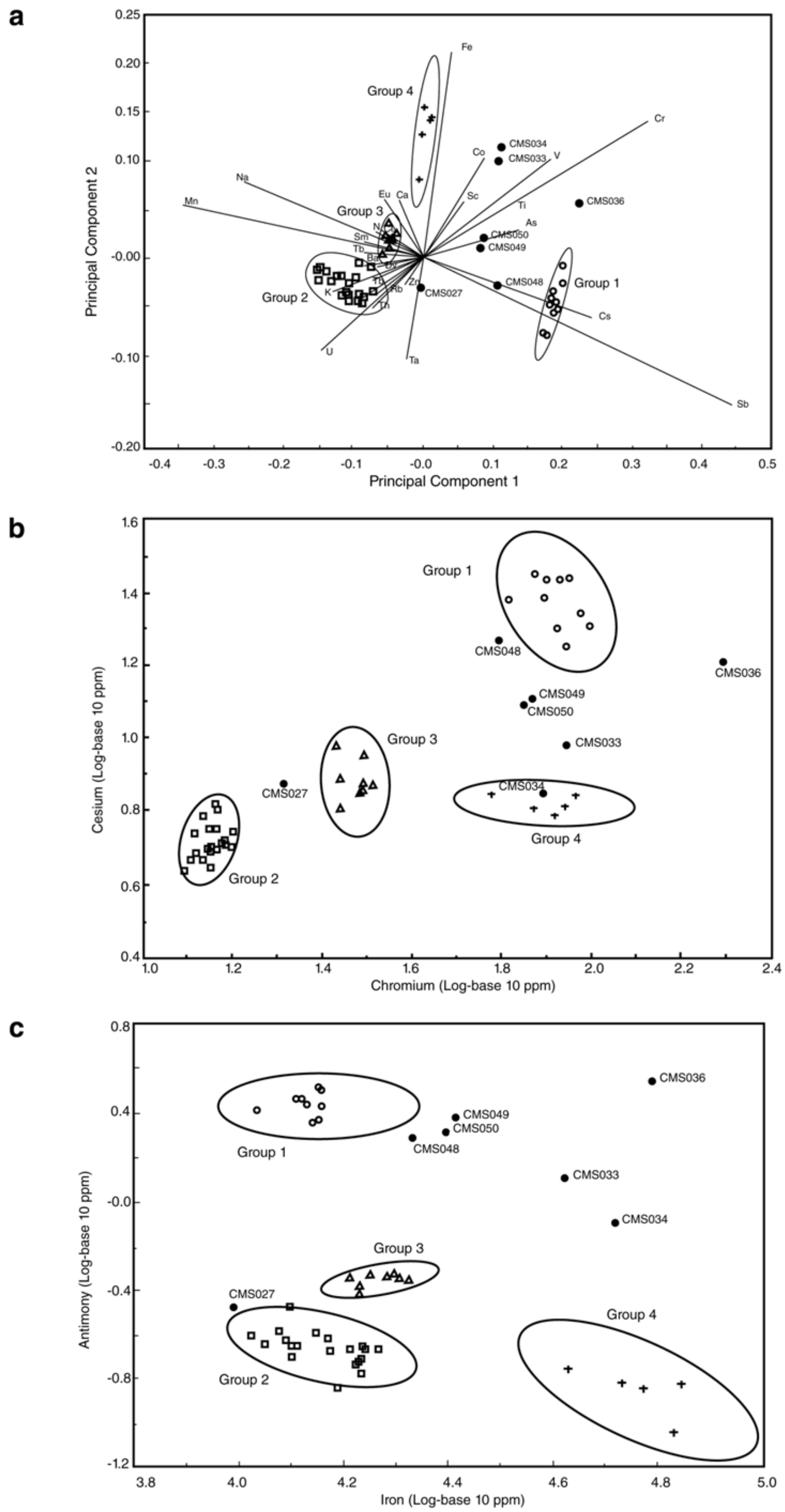



Fig. 3. Neutron activation analysis: a: principal components distributions; b: bivariate plot of cesium and chromium; c: bivariate plot of antimony and iron.

pairs also illustrate the distinctiveness of two or more of these groups. The remarkably clear chemical distinctions revealed in this sample are rare if not unique in ceramic provenience studies.

Although Groups 2 and 3 are easily differentiable from one another on several elements, both the PCA plot and bivariate plot suggest that they are chemically closer to one another than either is to the other groups. The chemical similarity of these two groups may indicate derivation from separate production centers within the same region, a topic we return to below.

*INAA Results: Unassigned Specimens* — The seven unassigned specimens are labeled in the plots illustrated in Figure 3 (see also appendix 1). CMS027 is chemically close to Groups 2 and 3 and may come from a minor production center close to the centers that produced jars of those groups. Similarly, CMS048, CMS049, and CMS050 fall within or close to Group 1 on several dimensions that tend to separate the groups, leaving open the possibility that they come from related production centers. The other unassigned specimens may pertain to compositional groups that are represented by only one or two analyses in the present sample. CMS033 and CMS034 are close to one another on many elements, and it is possible that they represent a single group. CMS036 seems to be a distinctive composition distinguished by enrichment of transition metal elements (e.g., Cr, V, Ti, Fe).

*Conclusions from INAA Results* — Based on this pilot study, a significant proportion of the dragon jars from throughout the Philippines apparently come from just four production centers or regions. Moreover, products from one of these centers (represented by Group 3) were also distributed as far away as Madagascar (CMS030, see Table 2). On the other hand, a single sample (CMS036) from another non-Philippines locale (Comoro Islands) apparently did not originate in a production center linked to the Guthe Collection.

This small sample provides some basis for discussing differential external exchange relations among the various Philippine sites from which it derives. Guthe site Burial 4 on Koulan Island in the far south of the Philippine archipelago (Fig. 1, Site 4) has only Group 2 and Group 4 jars (and one unassigned), and Group 4 appears almost exclusively at this site (with one example from Cave 23 on Suluan Island in the northeast of the study area) (Fig. 1, Site 12). Site Cave 28 on Mindanao (No. 10 in Fig. 1) received only Group 1 and Group 3 vessels. Less restricted access is exemplified by Cave 23, which received vessels of Groups 2, 3, and 4.

The exceptionally clear composition distinctions present in the Philippine data suggest that unequivocal source identification would be possible for these vessels if potential production centers were sampled intensively enough. Clearly, much more extensive sampling of wasters from the kilns in Viet Nam, China, and Thailand is warranted.

### *Laser Ablation Inductively Coupled Plasma Mass Spectrometry*

During the last several years, researchers have begun to use LA-ICP-MS with increasing frequency to address archaeological questions (e.g., Devos et al. 2000; Gratuze 1999; Gratuze et al. 2001; Junk 2001; Neff 2003; Pollard and Heron 1996; Speakman and Neff 2002, 2005; Speakman et al. 2002; Watling 1998).

LA-ICP-MS offers several advantages over other microprobe and surface analytical techniques, including rapid analytic time, low cost per sample, high sample throughput, and low detection limits. In addition, LA-ICP-MS is minimally destructive to the artifact. One of the more exciting applications of LA-ICP-MS is the ability to conduct in situ analyses of pigments and glazes used to decorate pottery (e.g., Gratuze 1997; Neff 2003; Rodriguez 2003; Speakman and Neff 2002).

LA-ICP-MS can be used to generate data for almost any element in the periodic table (oxygen and nitrogen are two notable exceptions). The technique can also be used to determine elements that are present in the low parts-per-million (ppm) to parts-per-trillion (ppt) range. In contrast, other microprobe and surface techniques are limited by the number of elements detectable, and in general they have higher detection limits than ICP-MS. The laser can be targeted on spots as small as 5 μm in diameter. The small spot size and the high sensitivity of magnetic-sector ICP-MS to a wide range of major, minor, and trace elements make LA-ICP-MS a very powerful microprobe. Moreover, laser ablation is virtually nondestructive to most samples, considering that the ablated areas are often indistinguishable with the naked eye.

The instrument used in the study reported here is a Thermo Elemental Axiom magnetic-sector inductively coupled plasma mass spectrometer capable of resolving atomic masses as close as 0.001 atomic mass units apart, thus eliminating many interferences caused by molecular ions that pose problems for quadrupole and time-of-flight ICP-MS instruments. The ICP-MS is coupled to a Merchantek Nd:YAG 213-nanometer wavelength laser ablation unit. Prior to data acquisition, samples were preablated using the laser to remove possible surface contamination. Power settings were adjusted to prevent the laser from burning through the glaze during analysis, ensuring that the material introduced to the ICP-MS was actually glaze and not the underlying clay matrix. Table 3 lists the laser ablation and ICP-MS operating parameters. NIST SRM 610 and 612 (glass wafers spiked with ~60 elements), Ohio red clay fired to 1200 °C, and Glass Buttes obsidian were used as standards to calibrate data. Blank-subtracted counts were calibrated using what we refer to as the Gratuze Method (Gratuze 1999; Gratuze et al. 2001; Neff 2003) to produce oxide concentrations for the elements analyzed in each sample. The basic assumption of the Gratuze approach is that the measured elements represent essentially all of the material, other than oxygen, that is ablated from the sample. Oxygen is then taken into consideration by converting the elemental signals to their appropriate oxides and constraining the sum of all oxides to 100 percent. Some error may be introduced at this point for elements that occur in more than one oxidation state—particularly iron, which may be present as FeO as well as $Fe_2O_3$. Additionally, any water in the material is unaccounted for in the summation to 100 percent, as are some elements such as chlorine, carbon, and sulfur, which may be present but were not measured. These missing measurements may contribute to a slight overestimation of the various measured oxides.

*LA-ICP-MS Results* — Glazes are coatings of glass fused on ceramic surfaces. They are an integral part of the dragon jar production process and can contribute independent information on their manufacturing technology. In order to investi-

Table 3. Operating Parameters Used for the Laser Ablation System and ICP-MS

| | |
|---|---|
| Preablation parameters | |
| Laser frequency | 200 microns |
| Laser beam diameter | 70 microns/second |
| Laser speed | 20 Hz |
| Laser beam energy | ~2 mJ (90% power) |
| Number of passes | 4 |
| Ablation pattern | line (~500 microns long) |
| Ablation parameters | |
| Laser frequency | 5 Hz |
| Laser beam diameter | 100 microns |
| Laser speed | 10 microns/second |
| Laser beam energy | ~2 mJ |
| Ablation pattern | line (~600 microns) |
| ICP-MS settings | |
| Cool gas | 13.0 liters/min |
| Nebulizer gas | 1.35 liters/min |
| Aux. gas flow thru cell | 1.3 liters/min |
| RF Power | 1400 W |
| Analytical time per run | 1 min |
| Number of runs per sample | 3 |
| Dwell time | 10 ms per point |
| Mass settling time | 3 sec |
| Analytical mode | Full peak scanning mode |
| Resolution ($m/\Delta m$) | 4000 |

Isotopes measured

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Li-7 | Na-23 | Mg-24 | Al-27 | Si-30 | P-31 | K-39 | Ca-44 |
| Sc-45 | Ti-47 | V-51 | Cr-52 | Fe-54 | Mn-55 | Co-59 | Ni-60 |
| Cu-63 | Zn-66 | As-75 | Rb-85 | Y-89 | Zr-90 | Ag-107 | Cd-114 |
| In-115 | Sn-120 | Sb-121 | Sn-124 | Cs-133 | Ba-138 | La-139 | Ce-140 |
| Sm-152 | Eu-153 | Ta-181 | Pb-208 | Th-232 | U-238 | | |

gate the relationships between bulk-paste composition and the glazes, LA-ICP-MS was used to analyze a subset of the 50 samples analyzed by INAA.[6]

As expected, compositional analysis of the dragon jar glazes by LA-ICP-MS produced results similar to the INAA study of the pastes (see above) and the study of decorative attributes (discussed below). However, unlike the INAA characterization of the pastes, three groups were identified rather than four (see Table 2, Fig. 4 and appendix 2). Glaze Groups 1 (n = 6) and 4 (n = 5) correspond directly to INAA paste Groups 1 and 4; Glaze Group 2/3 (n = 20) comprises specimens assigned to the INAA paste Groups 2 and 3. The compositional patterning in the glazes is illustrated by the bivariate plots of the cobalt and barium oxides (Fig. 4a) and of principal components 1 and 2 (Fig. 4b). Group 1 dragon jar glazes are enriched in Cr, Cs, Li, and Sb; Group 2/3 jar glazes are enriched in Ba, Eu, La, Mg, Sm, Sr, and Th; Group 4 dragon jar glazes are enriched in Ag, Co, Cd, and Pb. Groups 2 and 3 were found to resemble one another more than the other groups in the composition of their pastes. The fact that that glazes found on Group 2 and Group 3 pastes are chemically indistinguishable suggests that similar raw materials and recipes were used by potters producing these ceramics. Seven specimens are unassigned. The pastes from two of the unassigned glazes are

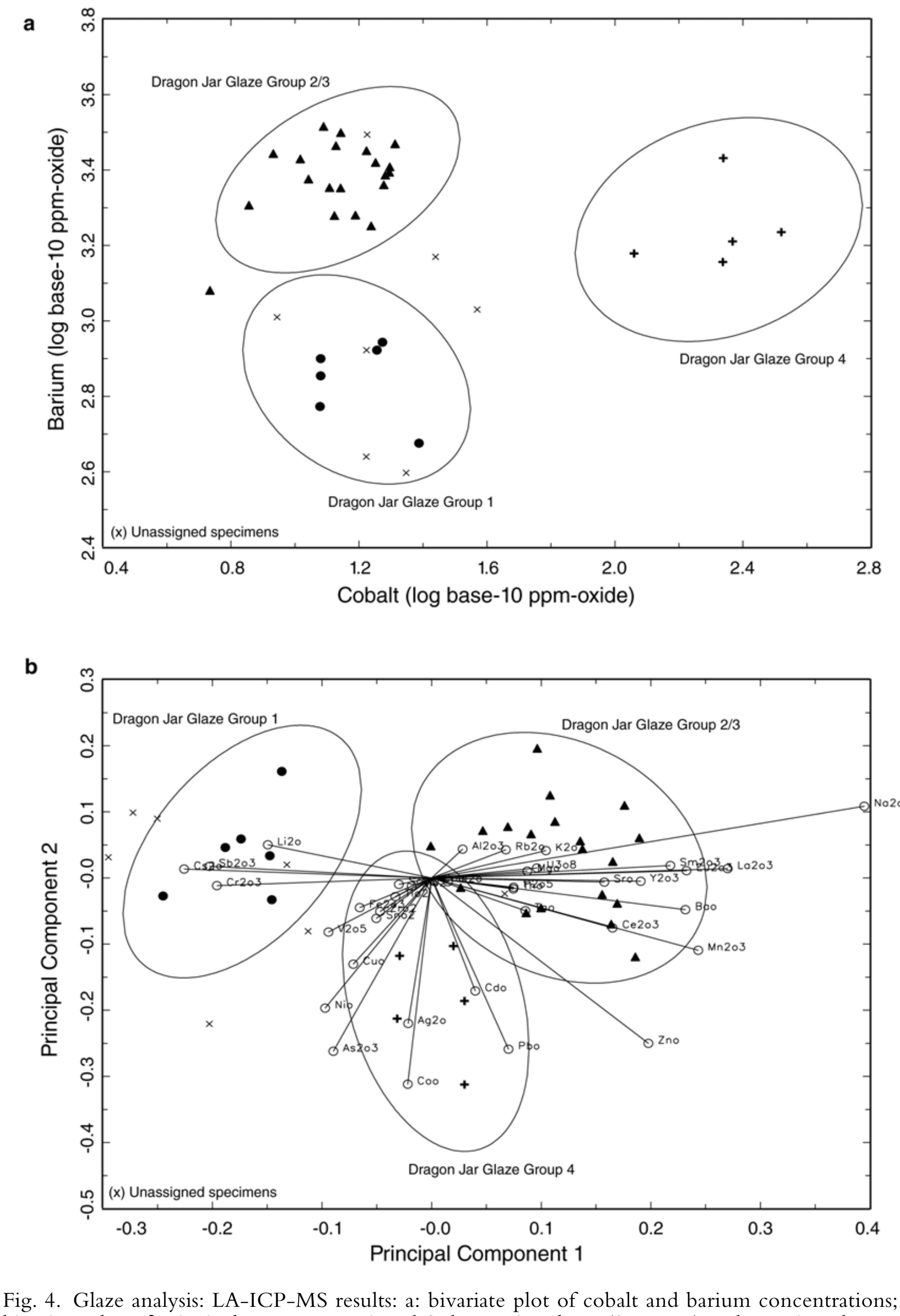



Fig. 4. Glaze analysis: LA-ICP-MS results: a: bivariate plot of cobalt and barium concentrations; b: bivariate plot of principal components 1 and 2 dragon jar glazes (3 groups) and unassigned samples along with elemental vectors. Ellipses represent 90 percent confidence level for group membership.

assigned to INAA Group 1 (CMS029 and CMS046), but the glaze composition differs from other samples in glaze Group 1. The remaining unassigned samples in the glaze study were classified as unassigned in the paste study.

## ANALYSES OF VESSEL MORPHOLOGY AND DECORATION

Characterization techniques such as NAA or LA-ICP-MS discussed above permit classification of vessel pastes and glazes based on their chemical constituents. In this section, we turn to consideration of the visible attributes of the vessels: decorative elements and the techniques by which they were produced, glaze and paste color, rim form, and wall thickness. While sample sizes are small for many of these variables, each yielded robust evidence of discrete typological groups that closely matched those identified by the compositional studies. In the following discussion, we first consider decorative elements independently, then in relation to compositional groups, and finally we add in consideration of ware, rim form, and wall thickness.

### *Decoration: Dragon Motifs and Handles*

The analysis of dragon jar decoration, conducted by Stephen Dueppen,[7] focused on the subset of decorated vessels and sherds (n = 68) large enough to permit an assessment of overall design treatment; this amounted to approximately 70 percent of the total sample of decorated sherds (the remainder were either too fragmentary or were unique or rare designs that could not be studied systematically). The analysis focused on the *techniques* by which designs were constructed and the *operational chains* that defined the sequence of their construction. This approach is influenced by the writings of French archaeologist André Leroi-Gourhan (1943), who advised scholars to consider the choices artisans make in the production of material goods, and by ethnologist and material culture theorist Pierre Lemonnier (1993), who advocated a focus on gestures and physical actions of production, conceived as a linear sequence of production steps or an "operational chain." Knowledge of desired artifact form and gestures are learned, and diverse options always potentially exist. It is therefore expected that artisans working in a single artistic tradition will share both cultural values concerning appropriate forms for the products they manufacture and knowledge of technological actions—including the proper tools, hand motions, and techniques to use to shape and decorate objects. The examination of both visual form and productive technologies can thus provide complementary evidence for the study of the production and consumption of material culture.

At the simplest level, the operational chain for the production of dragon jars can be envisioned as comprising six stages, each of which can be divided into subchains:

Stage 1: Procurement of clay, temper, and other necessary raw materials
Stage 2: Production of paste
Stage 3: Vessel formation
Stage 4: Decoration of vessels
Stage 5: Firing of vessels
Stage 6: Distribution of vessels

It is important to note that different operational sequences can in some cases yield visually similar products and that similar operational sequences can produce visually distinctive products. Detailed study of traces of production sequences and of the final forms of objects can allow identification of discrete production traditions, which may in turn be linked to diverse cultural factors (e.g., production groups or regions, temporal change, technological innovation, stylistic borrowing, etc.).

Our research has generated data relevant to addressing all stages of the general operational sequence presented above. In the present paper, compositional analyses address raw materials (Stage 1), paste analysis and vessel form will address paste preparation and vessel formation (Stages 2 and 3, respectively), data from kilns and postulated production locales will contribute to understanding distribution (Stage 6). The stylistic analysis presented below focuses on Stage 4 of the production sequence—the decoration of vessels—through examination of major decorative motifs (typically dragons) and handles. Analysis focused on identifying the diverse techniques and sequence of steps used in the production of these elements. For example, dragon motifs could be incised on the walls of vessels (before or after glazing); formed of hand-built coils that were attached to vessels and then incised; impressed on vessel walls with molds or stamps; or formed as separate elements in molds and then attached to vessels (Table 4). Similarly, handles could be shaped in molds or of hand-formed coils and were attached and decorated in a variety of ways (Table 5).

The analysis resulted in the identification of five major groups for the production of dragon elements and five major groups for the production of handles. Membership in each grouping is identical (thus, Group 1 dragons = Group 1 handles; Group 2 dragons = Group 2 handles, etc.), providing strong support for at least five distinct production traditions. Other less common motifs and handle forms were identified, but sample sizes were too small to identify clear groupings; these are not discussed in detail here.

*Dragon Motifs* — Table 4 and Figure 5 summarize the operational chains and motif forms for the dragon decorative elements in the Guthe Collection. Each operational sequence is described as a series of steps that were performed sequentially in the production of the motifs. Motifs in Groups 1, 2, and 4 began with the preparation of a negative mold. In some production groups (Groups 1 and 4), the mold was impressed against the walls of the vessel shortly after throwing, when the paste was still soft enough to be modified. In others (Groups 2 and 4), soft clay was pressed into the mold to form a decorative element that was subsequently attached to the vessel. The Group 3 dragons were formed of small coils that were shaped by hand and then attached to the vessel, while Group 5 motifs were incised into the vessel wall after it was glazed.

Of these five groups, Group 2 is the largest numerically. While production sequences in this group were consistent, visual motif form varies considerably. A similar pattern is found in Group 4. This is quite different from dragon motifs of Groups 1, 3, and 5, which are each internally homogenous. The greater variability in Groups 2 and 4 may result from multiple production locales in a region employing similar technologies, a longer temporal range being represented in these groups, or it may be a function of sample size. Whichever the case, it pro-

Table 4. Operational Sequence for the Production of Dragon Motifs

| GROUP | SEQUENCE | MOTIF FORM |
|---|---|---|
| 1 (n = 10) | 1. mold is produced, negative of dragon is ornate containing all decorations (horns, whiskers, scales, claws)<br>2. negative mold is impressed into shoulder of vessel.<br>3. glaze is applied over dragon | Thin dragon, head has horns and crest behind the face, characteristic scale pattern resembling separate cells. Dragon has four legs, each leg has 3 claws. Inside of vessel shows negative of dragon |
| 2 (n = 36) | 1. mold is produced, negative of dragon is not ornate, consists of general shape of dragon body and appendages.<br>2. clay is impressed into mold and then removed and applied by hand to shoulder or body of vessels.<br>3. decoration stage 1: incised whiskers, fins and facial and foot features; decoration stage 2 impressed semi-circular scales and eyes<br>4. glaze is applied over dragon | Motifs vary in shape, but are generally applied from shoulder to belly of vessel. Dragons do not have horns; eyes are impressed circles. All have scales of semi-circular impressions, have four appendages, and feet with toes rather than claws. |
| 3 (n = 7) | 1. thin coils are produced<br>2. coils are applied on vessel shoulder to create dragon, with separate coils for body, legs, head, horns, claws.<br>3. parallel 45-dregree incision/gouges are made on dragon bodies.<br>4. glaze is applied over dragon | Motifs are simple, producing a thin worm-like dragon. Claws have root-like appearance, head is bulbous. Dragons have no whiskers. Scales are produced by a series of parallel incisions that run the length of the body. Located on vessel shoulders between handles |
| 4 (n = 9) | 1. mold is produced; negative of dragon and other designs is ornate, including all decorations.<br>2. two alternatives are used to apply design to vessel: 1. The negative mold of design is impressed into the shoulder/body of the vessel; or 2. Clay is impressed into mold, then is removed and applied by hand to shoulder or body of vessel.<br>3. glaze is applied over design | Dragons are large and placed on body of vessel. Dragon heads have whiskers and horns, scales are cellular in appearance, dragons have four legs, with claws rather than feet. |
| 5 (n = 4) | 1. glaze is applied over vessels<br>2. dragons, bands and other designs, are incised through glaze onto vessel | Large dragons are formed through incisions into glaze. Dragon heads have horns and whiskers. Dragons have three claws on each foot. Dragon tongue extends away from dragon toward a flaming pearl motif. All motifs are placed within incised bands of horizontal wavy lines that delineate design field. |

vides an interesting example of a stable technological tradition being used to produce formally and stylistically diverse elements.

*Handle Production* — Of the five groups of dragon motifs described above, each has a distinct production method. Forms and operational sequences of handles are

TABLE 5. OPERATIONAL SEQUENCES FOR THE PRODUCTION OF HANDLES

| GROUP | SEQUENCE | MOTIF FORM |
|---|---|---|
| 1 | 1. Mold production (negative of dragon/devil face)<br>2. Clay strip production<br>3. Mold impressed into clay strip and vertical lines incised above and below it.<br>4. Handle applied vertically to shoulder/neck of vessel<br>5. Glaze applied over handle | Handles are vertically placed below neck at top of shoulder. An impressed face is in the center of handle, with vertical lines above and below. Finger marks visible at base of handle where it was pushed onto vessel wall. |
| 2 | 1. Mold production (variety of motifs, including dragon)<br>2. Clay strips produced<br>3. Vertical incisions made into clay strip<br>4. Clay strip attached vertically<br>5. Clay impressed into mold and then taken out and applied by hand, usually to base of strip<br>6. Decoration of handles (for dragon type) incisions and semicircular impressions<br>7. Glaze applied over handle | Handles are diverse in size, shape, and type of creature represented. Some handles are produced entirely in molds, others have separate clay strips above mold-formed applied figure. Handles connect the shoulder to the neck. Tools used to decorate handles after application. |
| 3 | 1. Clay strips produced.<br>2. Linear incisions made into strips<br>3. Clay strip attached vertically<br>4. Glaze applied over vessel | Plain vertical handles located on vessel shoulder. |
| 4 | 1. Clay strips produced<br>2. Linear incisions made into strips<br>3. Handles attached horizontally<br>4. Glaze applied over vessel | Simple horizontal handles decorated with incisions. |
| 5 | 1. Mold-produced, negative of elaborate round face<br>2. Clay impressed into mold and then taken out and applied to vessel<br>3. Horizontal hole bored through handle<br>4. Glaze applied over vessel | Handles are round faces of lions/dragon, produced by a mold. Handle holes are bored under the mouth. |

also distinctive and can be divided into five groups with identical membership to the dragon motif groups (Table 5, Fig. 6). Handle forms vary from simple horizontal (Group 4) or vertical (Group 3) coils attached by hand and decorated with incised lines to more elaborate decorative forms that entail the use of molds (Groups 1, 2, and 5). Of the latter, Group 5 is entirely mold made, and the round handle is the large face of an animal with a hole bored through its chin. Group 1 is a vertical strip handle, with the mold or stamp of a face impressed into it. As with the dragon motifs, Group 2 handles are the most diverse, with a wide variety of plastic motifs placed on vertical handles (a small number [n = 3] in this group have vertical handles identical to those in Group 3).

## COMPARING DECORATIVE AND COMPOSITIONAL GROUPS

Thus far, we have presented two quite different approaches to characterizing the Guthe dragon jars—the first based on chemical composition and the second based

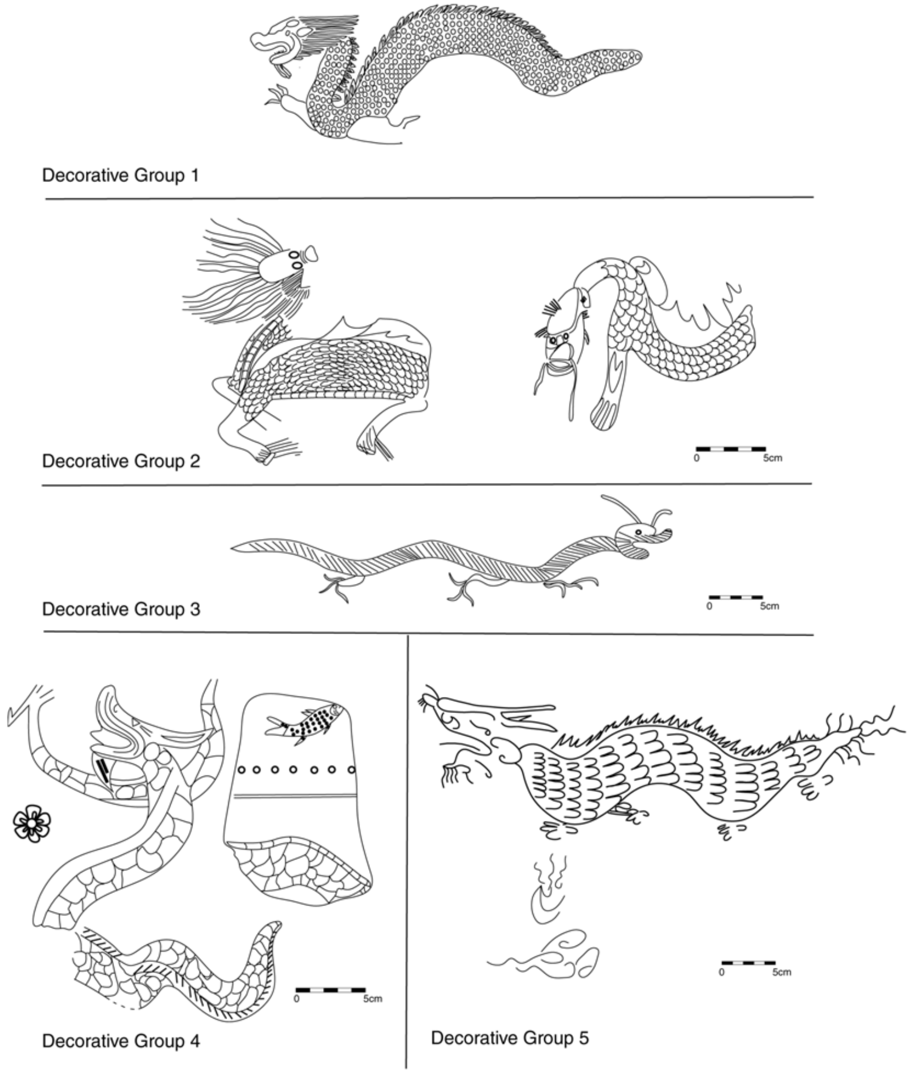



Fig. 5. Dragon motif forms: Groups 1–5.

on the production of decorative elements. For each, we have argued an internal logic linked to production locales and cultural choices of production strategies that yielded clearly marked, discrete vessel groupings. For the compositional analysis, we suggest that ceramics with similar paste and glaze compositions likely were produced in the same production center or geographic locale. In the decorative analysis, we argue that sequences of production are also likely to be similarly constrained to potters working in the same tradition of pottery manufacture, with shared knowledge of appropriate decoration and its technology of production. In this section, we consider how these two typologies match up.

As summarized above, the neutron activation analysis isolated four chemically

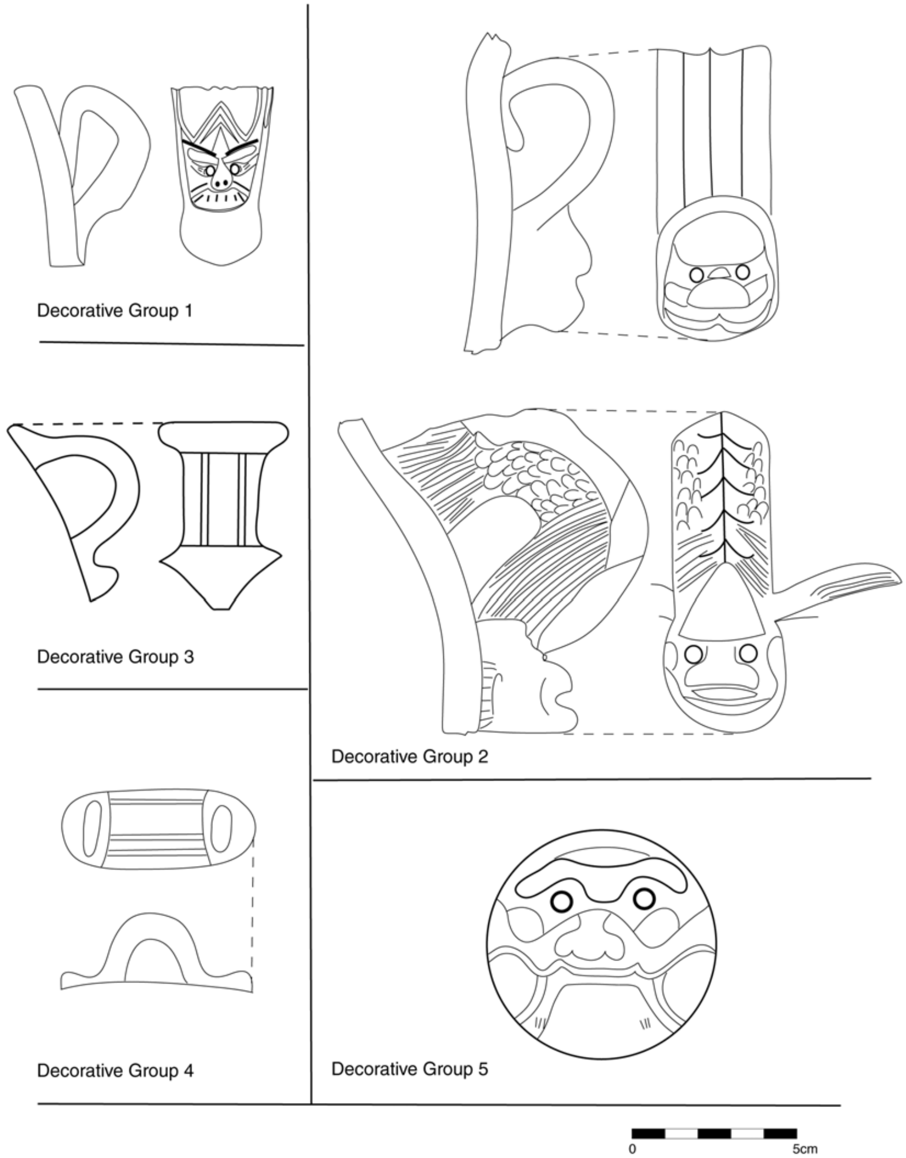



Fig. 6. Handle motif forms: Groups 1–5.

homogenous subgroups. Based upon the provenience postulate, we have suggested that each subgroup was produced in a specific area. Twenty-four of the 50 vessels subject to compositional analysis can be compared with the decorative groups (Table 2). Of the remaining vessels, 15 were either undecorated or lacked large enough decorative fields for analysis and 7 were unassigned to groups, as they were compositionally unique.

As illustrated in Table 5, the decoration-based Groups 1–4 compare well with these data on clay sources. All sherds of Decorative Group 1 belong to NAA

Group 1; all sherds of Decorative Group 2 belong to NAA Group 2, and so on. The one exception to the pattern is the vessel from excavations in Kingany, Madagascar (CMS 30), which resembles a classic Group 1 dragon motif and handle but clusters with Group 3 in composition. Unfortunately, none of the vessels assigned to Decorative Group 5 were selected for compositional analysis. Nonetheless, the consistent relationship between these two sets of results strengthens the suggestion above that both decorative and compositional groups constitute evidence for specific and geographically distinct production groups.

## OTHER VESSEL CHARACTERISTICS: PASTE AND MORPHOLOGY

Not all brown-glazed stoneware jars were decorated, nor do all sherds from decorated vessels contain sufficient decorative fields for analyses of the kinds discussed above. In this section, we consider how our compositional and decorative groups relate to other vessel attributes, particularly those that can be straightforwardly assessed on even the smallest sherds. We first consider paste color, inclusion characteristics, and density—all variables that can typically be assessed by eye or at low magnification on the vast majority of sherds. Next we turn to rim morphology, a feature that is commonly recorded by archaeologists and often argued to have temporal, geographic, or cultural significance. Our goal is to construct a "thick description" of the Guthe dragon jars based on a broad and diverse range of variables. Not all variables will necessarily be recordable on any individual archaeological fragment; however, the strength and redundancies of the patterning along diverse dimensions of ceramic variability permit the classification of most samples into discrete and meaningful categories.

### *Visual Paste Assessment*

Harrison's typology presented above considers the visual paste characteristics of color, porosity, inclusion size, and distribution to distinguish among her categories. Like Harrison, our analysis of paste characteristics focused on paste color, the size and percentage of vacua (density), and the size, color, and percentage of inclusions visible from thin sections of the 50 sherds used in chemical analyses or fresh breaks made on the remainder of the sample. The paste classification resulted in the identification of significant variability in paste color and in visible inclusions (e.g., gray paste with low, medium, or high densities of inclusions; dark red paste with few inclusions; red to dark gray paste with large black inclusions; and dark gray paste with few inclusions or vacua).

When compared against the data from decoration and compositional analysis, the addition of data on paste color and inclusions provides further details on dragon jar production groups. In Decorative and Compositional Groups 1–4, the color of the paste is consistent within each proposed production center. Groups 1, 2, and 3 all have gray paste; Group 4 has red paste. However, information on density (porosity) is more variable, suggesting that in preparing the paste, potters in some production areas varied considerably in their use of similar raw materials.

Thus, Decorative/Compositional Group 1 has a very consistent paste; all samples have a dense gray paste with few inclusions. In contrast, Decorative/

Compositional Group 2 is very diverse, a pattern that parallels the decorative classification. Although all sherds have gray paste, some are dense with small inclusions while others are porous with larger inclusions. The inclusions used vary widely in this group and include grog, chaff, and various mineral inclusions. The variation in tempers and density in vessels made with the same clay source perhaps show more specific levels of choice during the first raw material procurement and paste preparation—possibly at the level of individual production group. Since all of these vessels were successful, it does not appear that functional considerations influenced decisions on kinds or combinations of tempers. Decorative/Compositional Group 3 also shows homogeneity in paste color (gray) but diversity in inclusions, mirroring the patterning in Group 2. Finally, sherds classed in Decorative/Compositional Group 4 are homogenous in paste color but vary in density and inclusions.

In sum, patterns in Decorative/Compositional Groups 2, 3, and 4 suggest that potters working in a single technological tradition likely procured their clay from the same general region. Within each of these traditions, however, individual workshops or other subgroups varied in how they prepared their paste, either by making different choices concerning the quantities and types of inclusions they added to the raw clay or over time. These data indicate that, for this group of vessels, while broad visual paste attributes may be valuable to assessing production locales or traditions, finer variations in paste treatment may not be an appropriate means on which to base a typology.

### *Rim Morphology*

Both the decorative and compositional analysis examined mainly sherds rather than complete vessels; the latter were either unique vessels or sufficiently different from the groups examined here. And in most cases, especially for decorative studies, we focused on sherds from the shoulder and bodies of vessels, where decorative fields and handles were preserved. As a result of these sampling biases, the number of vessels for which we have evidence on decoration, composition, *and* rim form is very small. Indeed, rim data on the analyzed sample were obtainable on only 15 vessels. Nonetheless, when rim data are compared with the established groups, there is at least suggestive evidence that rim morphology also patterns at the level of production group (Fig. 7). Rim forms from Group 1 are everted, with rounded lips; rims from Group 2 are everted, with triangular and pointed lips; and rims from Group 4 are everted with rectangular-shaped lips. The one rim recorded from Group 3 is a flared rim with an overturning lip.

### *Glaze Color*

Detailed discussion of glaze composition is presented above. Here we consider only the visual characteristics of glaze to see if they too pattern with our compositional/decorative groups. Glaze color exhibits weak patterning with the four major groups, although each exhibits intragroup variability. Groups 1–3 are mainly olive to olive brown. Group 4 is darker, with more dark yellow brown and dark browns.

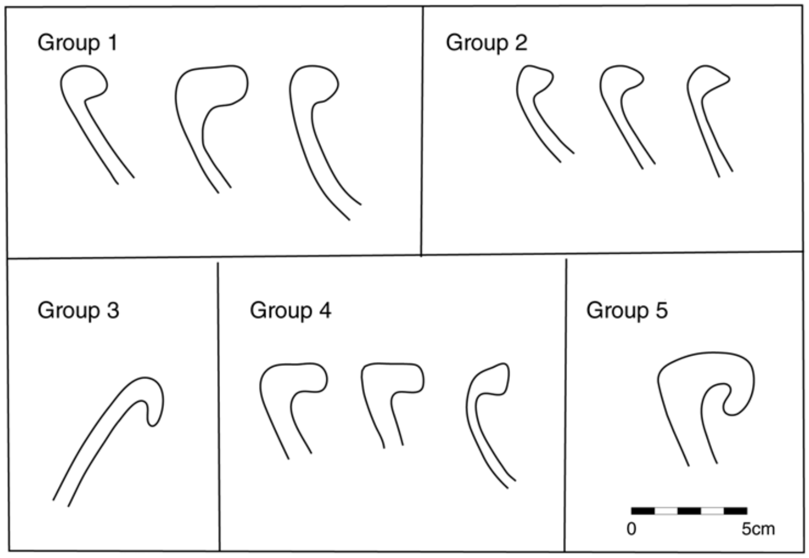



Fig. 7. Rim forms by compositional/decorative group.

### *Wall Thickness*

In contrast to glaze color, significant intergroup differences exist in vessel wall thickness (thickness values used are the mean of three measurements taken on the vessel wall below the shoulder). Vessels in Group 1 are very thin, with an average wall thickness of 5.5 mm and a relatively narrow range from 4 to 7.5 mm. Wall thickness for vessels in Group 2 is more variable and is in general thicker, with a range of 6–11 mm and a mean of 8.1 mm. Group 3 is also thin, averaging 5.6 mm. Group 4 has a mean thickness of 6.7 mm and a range of 6–8 mm. These differences are statistically significant at the .01 level.

## SUMMARY OF RESULTS

The analyses presented above defined several quite clear groupings of the Guthe large glazed stoneware jars based on compositional and decorative characteristics and confirmed by attributes of vessel thickness, rim form, and broad paste categories. Both approaches yielded evidence for multiple production locales, with four compositional groups defined for the Guthe sherds selected for compositional study (n = 46) and five major decorative production groupings identified from the study of handle and motif production (n = 68). In both studies, a portion of the vessels did not fall into any of the major production categories, indicating that there were more production locales than can presently be clearly distinguished, and evidence from Group 3 vessel CMS 30 demonstrates that multiple types of jars were made in specific production locales. This is not surprising, given both the broad temporal range over which dragon jars were produced and the enormous numbers produced and traded throughout Asia and beyond throughout the second millennium A.D.

The groups we report on in this study are not unknown to scholars of stoneware vessels; indeed they can be correlated with many of Harrison's (1986) groups discussed above and also with information presented by historical sources, archaeological excavations of kilns and other features, and the emerging results of shipwreck archaeology in Southeast Asia. We summarize the results of our research below and integrate them with published information from elsewhere in Southeast and East Asia.

Compositional/Decorative Group 1 (n = 10) is redundantly identified by discrete elemental distributions (high Cs and Sb) and glaze composition (high Cr, Cs, Li, and Sb); by the form of its mold-impressed dragon (thin, with horns and crest, four legs, with three-clawed feet); by the use of simple vertical strap handles with finger impressions; by characteristic dense gray paste with few inclusions; by round-lip everted rims; and by olive brown glaze color. The vessels have thin walls and rounded rims. Valdes et al. (1992:102–109, plates 16–19, 26–29) illustrate several similar vessels and attribute them to southern Chinese kilns near Quanzhou port, dating to the thirteenth and fourteenth centuries (see also Harrison 1986). Group 1 jars recovered from Malaysia are dated to the end of the thirteenth century to the fourteenth and fifteenth centuries; in addition, Group 1 handles have been found in a context dating to the Song/Yuan period (Lam et al. 1985:111–112, plates 230–234, 236).

Compositional/Decorative Group 2 (n = 36) is distinguished by discrete elemental composition (low chromium), though its glaze composition could not be distinguished from that of Group 3. The glaze is typically olive brown in color. The decorative motifs in dragon and handle elements in this group exhibited the greatest formal diversity of any of the groups but shared a consistent production technique. For the dragon elements, this involved the forming of components in a mold, followed by their subsequent appliqué to the vessel wall and impression of motif details (semicircular scales, eyes, etc.); for handles it involved a similar pattern of appliqué and subsequent decoration. Thus, despite visual diversity, vessels in this group were produced of consistent materials and using a consistent set of techniques. Vessel walls are generally thick, averaging .81 cm, and rims are everted with pointed triangular lips. According to Valdes et al. (1992), these pots probably derive from the Guangdong region in China and date to the sixteenth century (Harrison [1986] dates them to the fifteenth–sixteenth centuries and to Viet Nam). Similarly, John Guy attributes Group 2 dragon jars to the Go Sanh kilns between the fifteenth and sixteenth centuries (1986:111, plate 105). Brown also suggests that Group 2 jars are from the Go Sanh kilns (1988: plate 22). Several rim profiles from the emerging research literature on the kiln sites of central Viet Nam resemble Group 2 in rim shape and shoulder angles (Morimoto and Ohashi 2002: fig. 5, no. 16; Yamamoto et al. 1993:176, figs. 1, 3, 4).

The chronological assignment is confirmed by recent shipwreck excavations; in particular, all of the dragon jar vessels reported from the *San Diego* shipwreck (Desroches et al. 1998; Valdes and Alba 1993) off of Luzon in 1600 belong to our Group 2 category. Group 2 jars were also recovered from a fifteenth-century shipwreck off of Marinduque; however, here they are attributed to Swatow (Zhangzhou), the southeast Chinese port (Quimpo 1982:33–48, plates from pages 35, 46, and 47). Another shipwreck off of Pandanan Island dates to the fourteenth–fifteenth centuries and also contains dragon jars with Group 2 primary motifs (Loviny 1996:39, 54).

The *San Diego* data also provide some insights into the significance of decorated stoneware jars within Philippine mortuary ritual. Of the 621 storage jars aboard the *San Diego,* only 5.3 percent are dragon jars (Valdes and Alba 1993 : 43). In contrast, more than 50 percent of the Guthe Collection glazed stoneware jars are dragon jars. This suggests that decorated jars were incorporated into mortuary contexts at far higher frequencies than undecorated stoneware jars, perhaps pointing to their higher cultural value to indigenous Philippine consumers.

Compositional/Decorative Group 3 (n = 7), while chemically unique, falls close to Compositional/Decorative Group 2 in the neutron activation results (see Fig. 3). Their similarity is even more evident in the glazes, where the two groups could not be distinguished. In decoration, Group 3 was quite distinct. With the exception of the Madagascar sample, molds were not employed in the production of these elements; both dragon motifs and handles were formed of applied coils, which were simply decorated with incisions. Glaze color is predominately olive and olive brown, and vessel walls are thin, averaging .6 cm. Rims are flared and out-turning. These coil-decorated vessels appear to be the earliest in the Guthe assemblage, with similar forms attributed to Chinese kilns and dated by Valdes et al. (1992 : 104, 108) to the twelfth through fourteenth centuries. Similarly, Group 3 vessels are attributed by Lam et al. to the twelfth-to-fourteenth-century Quanzhou kiln complex in China (1985 : 110, nos. 229a and b). In addition, simple vertical handles were produced in the kilns of central Viet Nam (Koezuka et al. 1996 : 24–25, figs. 12, 14). However, it is important to note that early forms were later reproduced, and we cannot at present determine whether ours are early or later reproductions. Two of the seven Group 3 vessels in the Guthe Collection are whole pots and were not included in the INAA study. Whatever their date, Compositional/Decorative Group 3 is internally cohesive, and its similarity in paste and glaze composition to Group 2 suggests that these vessels were produced relatively near to each other, separated by time and decorative traditions more than by geography.

Compositional/Decorative Group 4 (n = 9) is distinguished by elemental composition (high iron) and distinctive glaze composition (high Ag, Co, Cd, and Pb). Dragon elements were mold formed and applied to vessel walls or mold impressed into walls, creating distinctive dragon elements that are large, with clawed feet and cellular scales. The vessels have undecorated horizontal strap handles decorated with linear incisions. Glaze color is predominantly dark yellow brown, and the vessels have an average wall thickness of .67 cm. Similar vessels have been attributed by Valdes et al. (1992 : 141) to South China and by Harrison (1986: plates 108–112) to Viet Nam. Both date them to the seventeenth and eighteenth centuries. The Pandanan Island shipwreck noted above also contained vessels from Group 4, dating to the fourteenth–fifteenth centuries and attributed to central Viet Nam (Loviny 1996 : 50, 100–101, figs. 7, 8). Vessels resembling Group 4 jars have been recovered from the central Vietnamese kiln sites and other Champa sites investigated by Japanese researchers. These jars have similar profiles and necks, red paste, and similar motifs, dating to around the fifteenth–sixteenth centuries (Aoyagi 2002: fig. 4, no. 20; Koezuka et al. 1996 : 24, 27, figs. 4, 5, 50; Yamamoto et al. 1993 : 176, figs. 6, 12, 15, 16, 1995 : 50, 85, 100, figs. 7, 8).

No samples from Decorative Group 5 (n = 4) were submitted for chemical analysis, so this grouping is defined solely on the basis of decorative production.

All vessels in this group were whole and vessel decoration is quite distinctive. Dragon motifs were formed through incision into glaze rather than through any plastic technique; handles are round faces of lions or dragons, with holes bored through below the mouth. Rims are thick and everted, with down-curling lips. The glaze color was olive brown (n = 2) and dark yellow brown (n = 2). Vessels with decorations made by incision into glaze have been attributed to central Viet Nam during the fourteenth and fifteenth centuries and possibly throughout the Champa period (Brown 1988: plate 15b and c; Koezuka et al. 1996:24, fig. 3). Jars with handles resembling our sample are placed later and may be chronologically the latest dragon jar vessels in the Guthe Collection, attributed by Valdes et al. (1992:149–151) to the nineteenth and twentieth centuries.

## CONCLUSIONS

The analyses presented in this paper report on the intensive study of a small assemblage of Asian trade wares recovered from mortuary contexts in the Philippines. Ongoing work on larger samples—and particularly on kiln and shipwreck sites—will no doubt considerably refine the results presented here. Nonetheless, despite the small samples, we have documented remarkably robust patterns that have enabled us to redundantly identify coherent groups of vessels through diverse analytical approaches. Because of the fragmentary nature of the collection, we have been unable to devote as much attention to vessel morphology as we would like, and the study would certainly benefit from larger samples of measurable rims, bases, and attributes sensitive to assessing vessel proportions. Perhaps most distinctive of the analyses presented here is Dueppen's use of the operational sequences perspective to characterize vessel motifs and dragon forms. His analysis pointed both to long-standing technological traditions of vessel production and to the kind of diverse visual forms that could emerge from a single production tradition—or conversely, that multiple techniques may have been practiced within a single production locale. Dragon jar production can be characterized as a dynamic phenomenon requiring further study.

Finally, this article has been addressed primarily at characterizing these ceramics, rather than answering specific anthropological or historical questions about Asian maritime trade or Philippine social practices. It is, of course, these larger questions that are ultimately of interest, and to that extent this paper is merely a step along the way, which we hope will provide useful information to scholars working on similar materials elsewhere in Asia.

## ACKNOWLEDGMENTS

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# Appendix 1. INAA Data Organized by Assigned Compositional Group

| SAMPLE # | GROUP | AS | LA | LU | ND | SM | U | YB | CE | CO | CR | CS | EU | FE | HF | NI | RB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS006 | 1 | 4.0166 | 53.1596 | 0.5957 | 37.1284 | 7.4959 | 8.0521 | 3.4317 | 96.7921 | 9.4482 | 94.062 | 22.139 | 1.2052 | 13057.2 | 9.6204 | 35.8 | 144.93 |
| CMS007 | 1 | 4.815 | 49.3962 | 0.5577 | 35.693 | 6.5395 | 8.9556 | 3.2215 | 87.0468 | 6.3997 | 79.042 | 27.281 | 0.9603 | 14203.1 | 10.8123 | 0 | 169.55 |
| CMS010 | 1 | 5.5778 | 39.3251 | 0.4909 | 26.8501 | 5.3444 | 6.2292 | 3.117 | 68.7917 | 7.524 | 87.048 | 17.98 | 0.8555 | 13680 | 9.663 | 0 | 133.64 |
| CMS012 | 1 | 4.8496 | 59.4014 | 0.5928 | 41.1166 | 7.461 | 9.7089 | 3.2404 | 104.936 | 3.4459 | 74.642 | 28.42 | 1.0673 | 12740.8 | 9.7588 | 0 | 202.6 |
| CMS018 | 1 | 5.0333 | 39.7721 | 0.5264 | 29.1994 | 5.505 | 6.8979 | 2.9791 | 74.1903 | 7.4364 | 98.435 | 20.459 | 0.9353 | 20668.8 | 9.4023 | 0 | 145.2 |
| CMS023 | 1 | 6.6935 | 51.6818 | 0.5611 | 43.5485 | 6.6808 | 9.7725 | 3.4322 | 85.6742 | 7.8758 | 85.039 | 27.177 | 0.9573 | 14092.3 | 9.9091 | 38.7 | 159.38 |
| CMS026 | 1 | 7.35 | 53.2265 | 0.5851 | 40.7527 | 6.9962 | 9.708 | 3.5663 | 90.034 | 8.0743 | 88.584 | 27.679 | 0.9901 | 14237.9 | 10.3989 | 0 | 159.65 |
| CMS029 | 1 | 0 | 46.2386 | 0.5691 | 28.9042 | 6.3894 | 9.611 | 3.506 | 79.0982 | 5.7143 | 65.18 | 24.208 | 0.8487 | 10748.4 | 12.2725 | 0 | 166.57 |
| CMS032 | 1 | 5.3526 | 47.1895 | 0.541 | 31.5177 | 6.1868 | 7.3242 | 3.4638 | 80.9953 | 5.8375 | 83.413 | 20.075 | 0.9371 | 13473.5 | 11.3606 | 0 | 122.69 |
| CMS046 | 1 | 13.096 | 55.3211 | 0.4756 | 37.0238 | 7.5215 | 8.6568 | 3.5472 | 99.6142 | 4.519 | 78.094 | 24.389 | 1.1335 | 14014.3 | 9.8557 | 0 | 160.63 |
| **Mean** | **1** | **5.6784** | **49.47119** | **0.5495** | **35.17344** | **6.6121** | **8.49162** | **3.3505** | **86.7172** | **6.6275** | **83.354** | **23.981** | **0.989** | **14091.6** | **10.3054** | **7.45** | **156.48** |
| **Median** | **1** | **5.193** | **50.539** | **0.5594** | **36.3584** | **6.6102** | **8.8062** | **3.432** | **86.3605** | **6.9181** | **84.226** | **24.299** | **0.9588** | **13847.2** | **9.8824** | **0** | **159.52** |
| CMS001 | 2 | 1.0346 | 64.1543 | 0.8241 | 44.6691 | 9.4965 | 14.4654 | 4.6935 | 111.799 | 3.3049 | 15.209 | 5.267 | 1.2321 | 12323.5 | 8.6522 | 0 | 209.17 |
| CMS002 | 2 | 0 | 64.7939 | 0.9053 | 40.923 | 9.8679 | 15.2438 | 4.7139 | 116.146 | 3.2149 | 14.209 | 5.031 | 1.276 | 11233.8 | 9.8265 | 0 | 212.84 |
| CMS003 | 2 | 2.8229 | 62.0521 | 0.795 | 46.5741 | 9.2614 | 13.0902 | 4.3358 | 118.054 | 4.4526 | 13.675 | 4.6561 | 1.144 | 12492.1 | 9.9967 | 0 | 206.25 |
| CMS005 | 2 | 0 | 78.1562 | 0.9797 | 57.1023 | 11.956 | 16.5417 | 5.4454 | 129.695 | 3.5179 | 14.545 | 5.6254 | 1.5468 | 11915.5 | 8.7081 | 29 | 219.57 |
| CMS009 | 2 | 0 | 73.6842 | 1.1345 | 53.665 | 11.877 | 23.4872 | 5.8355 | 123.863 | 4.5541 | 14.674 | 4.9824 | 1.5046 | 17510 | 7.8424 | 0 | 217.73 |
| CMS014 | 2 | 0 | 78.2664 | 0.7742 | 65.2765 | 10.743 | 12.339 | 4.1983 | 125.779 | 4.3867 | 13.066 | 5.4733 | 1.6535 | 18433.2 | 10.1808 | 0 | 204.35 |
| CMS015 | 2 | 0 | 71.1595 | 1.1979 | 59.4964 | 12.427 | 26.7973 | 6.1983 | 130.901 | 4.9837 | 15.813 | 5.0024 | 1.4803 | 17059.9 | 8.2267 | 0 | 236.2 |
| CMS019 | 2 | 0 | 79.9102 | 1.3138 | 64.978 | 13.642 | 24.3003 | 7.0444 | 153.113 | 5.479 | 13.972 | 4.947 | 1.6546 | 16992.2 | 9.6466 | 20.9 | 225.34 |
| CMS024 | 2 | 0 | 91.0314 | 1.111 | 69.7747 | 14.272 | 20.3622 | 6.2087 | 147.925 | 3.9415 | 14.589 | 5.6437 | 1.9589 | 12596.6 | 8.0287 | 0 | 214.88 |
| CMS025 | 2 | 0 | 77.0131 | 1.3448 | 65.2442 | 13.58 | 27.493 | 6.9698 | 134.896 | 4.4655 | 15.151 | 5.1321 | 1.6254 | 16907.8 | 8.6069 | 0 | 219.75 |
| CMS028 | 2 | 0 | 86.0552 | 0.9233 | 62.737 | 12.771 | 16.1893 | 5.0362 | 138.213 | 3.7121 | 14.48 | 6.6045 | 1.8913 | 14006.1 | 6.5365 | 0 | 224.4 |
| CMS031 | 2 | 0 | 76.7188 | 1.179 | 54.6586 | 12.667 | 23.2331 | 6.594 | 129.857 | 4.5058 | 14.238 | 4.4163 | 1.5032 | 15452.6 | 10.2366 | 0 | 229.53 |
| CMS035 | 2 | 0 | 60.206 | 0.704 | 44.4122 | 8.455 | 13.2645 | 4.0676 | 110.699 | 3.0757 | 12.825 | 4.6486 | 0.9706 | 12899.2 | 9.6997 | 0 | 216.9 |
| CMS037 | 2 | 0 | 78.1431 | 0.9206 | 56.0109 | 12.397 | 18.3686 | 5.4683 | 134.828 | 4.6008 | 14.08 | 5.625 | 1.7026 | 14955.1 | 8.1488 | 0 | 213.69 |
| CMS038 | 2 | 0 | 64.2302 | 0.7967 | 47.7203 | 9.7045 | 15.0914 | 4.682 | 117.006 | 3.5713 | 12.471 | 4.344 | 1.2285 | 10620 | 10.9597 | 0 | 210.8 |
| CMS041 | 2 | 0 | 83.6182 | 0.8236 | 68.3658 | 12.615 | 15.6931 | 5.0782 | 132.322 | 4.4852 | 14.671 | 6.3185 | 1.7958 | 16373.4 | 7.6096 | 0 | 217.32 |
| CMS042 | 2 | 0 | 72.0683 | 1.0885 | 58.6366 | 12.081 | 23.577 | 5.7658 | 120.375 | 3.167 | 13.2 | 4.8325 | 1.44 | 12648.2 | 7.556 | 0 | 217.24 |
| CMS043 | 2 | 0 | 70.8538 | 0.9851 | 50.2219 | 11.48 | 21.4538 | 5.5845 | 119.896 | 4.8547 | 14.107 | 4.9163 | 1.3894 | 17228.6 | 8.6317 | 0 | 220.61 |
| CMS044 | 2 | 0 | 79.062 | 1.0677 | 58.6651 | 12.874 | 17.7256 | 6.4964 | 132.017 | 4.1215 | 15.901 | 5.5138 | 1.7224 | 14848.5 | 9.9163 | 0 | 220.69 |
| CMS045 | 2 | 0 | 81.0679 | 0.8043 | 58.6852 | 12.136 | 15.5001 | 4.9219 | 128.895 | 4.7549 | 13.646 | 6.0757 | 1.7196 | 16807.5 | 7.21 | 0 | 215.9 |
| **Mean** | **2** | **0.1929** | **74.61224** | **0.9837** | **56.39085** | **11.715** | **18.7108** | **5.4669** | **127.814** | **4.1575** | **14.226** | **5.2528** | **1.522** | **14665.2** | **8.81103** | **2.495** | **217.66** |
| **Median** | **2** | **0** | **76.86595** | **0.9515** | **57.86945** | **12.108** | **17.1337** | **5.4569** | **129.295** | **4.4197** | **14.224** | **5.0816** | **1.5257** | **14901.8** | **8.64195** | **0** | **217.28** |
| CMS004 | 3 | 2.9557 | 63.8007 | 0.7233 | 44.2985 | 9.1964 | 8.935 | 4.422 | 115.123 | 6.523 | 27.637 | 7.7 | 1.633 | 16898.8 | 6.0058 | 23.5 | 179.32 |
| CMS008 | 3 | 3.058 | 65.6261 | 0.6361 | 50.0284 | 9.6833 | 8.1233 | 4.0642 | 116.889 | 7.5542 | 31.09 | 8.9539 | 1.8285 | 16894.8 | 4.244 | 0 | 154.83 |
| CMS011 | 3 | 3.8636 | 60.4588 | 0.6269 | 44.5799 | 8.8704 | 8.2146 | 4.073 | 109.083 | 6.9037 | 32.442 | 7.3785 | 1.5427 | 19081.2 | 6.2183 | 0 | 172.75 |
| CMS013 | 3 | 3.1005 | 54.3143 | 0.6346 | 39.8364 | 8.386 | 9.1625 | 4.0158 | 102.436 | 6.6816 | 27.61 | 6.3794 | 1.4151 | 19681.8 | 6.7623 | 0 | 177.21 |
| CMS017 | 3 | 3.1499 | 65.1017 | 0.6436 | 44.6368 | 9.2413 | 7.7978 | 4.1107 | 122.446 | 8.1609 | 30.94 | 7.1503 | 1.6632 | 21027.5 | 6.3967 | 21.8 | 163.19 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS021 | 3 | 2.3212 | 77.0151 | 0.6667 | 50.577 | 10.602 | 9.6527 | 4.3148 | 131.87 | 7.763 | 26.917 | 9.476 | 1.9153 | 17661.8 | 4.9704 | 0 | 164.37 |
| CMS022 | 3 | 2.4237 | 65.2038 | 0.7048 | 51.9764 | 10.11 | 9.1101 | 4.4267 | 118.999 | 7.3622 | 31.044 | 7.4711 | 1.7405 | 16228 | 4.9566 | 0 | 161.75 |
| CMS030 | 3 | 2.8344 | 64.0209 | 0.6645 | 46.169 | 9.6426 | 9.029 | 4.56 | 116.807 | 7.9796 | 30.401 | 7.049 | 1.6291 | 20186.7 | 6.7446 | 0 | 181.7 |
| **Mean** | **3** | **2.9634** | **64.44268** | **0.6626** | **46.5128** | **9.4664** | **8.75313** | **4.2484** | **116.707** | **7.366** | **29.76** | **7.6948** | **1.6709** | **18457.6** | **5.78734** | **5.663** | **169.39** |
| **Median** | **3** | **3.0069** | **64.5613** | **0.6541** | **45.4029** | **9.442** | **8.982** | **4.2128** | **116.848** | **7.4582** | **30.67** | **7.4248** | **1.6481** | **18371.5** | **6.11205** | **0** | **168.56** |
| CMS016 | 4 | 2.6022 | 65.5652 | 0.7213 | 55.4917 | 10.802 | 10.3947 | 4.5659 | 137.908 | 6.9239 | 59.778 | 6.9829 | 1.5684 | 42344.3 | 19.3211 | 0 | 154.51 |
| CMS020 | 4 | 0 | 67.8966 | 0.5538 | 51.7757 | 10.366 | 7.5027 | 3.0983 | 132.553 | 8.9646 | 87.327 | 6.495 | 1.854 | 67699.7 | 12.6219 | 0 | 163.37 |
| CMS039 | 4 | 0 | 76.6717 | 0.52 | 67.7216 | 11.528 | 8.313 | 3.3283 | 156.654 | 8.9705 | 82.805 | 6.1381 | 1.967 | 59038.7 | 15.772 | 0 | 160.25 |
| CMS040 | 4 | 3.8164 | 76.7849 | 0.5472 | 74.0716 | 11.935 | 8.0422 | 3.5625 | 172.135 | 9.8748 | 91.99 | 6.9562 | 2.0706 | 69584 | 13.2277 | 0 | 186.1 |
| CMS047 | 4 | 2.4967 | 78.9007 | 0.4593 | 62.4337 | 11.874 | 7.6119 | 4.2193 | 159.16 | 7.6678 | 74.257 | 6.4062 | 1.9689 | 53949.8 | 15.6092 | 0 | 162.81 |
| **Mean** | **4** | **1.7831** | **73.16382** | **0.5603** | **62.29886** | **11.301** | **8.3729** | **3.7549** | **151.682** | **8.4803** | **79.232** | **6.5957** | **1.8858** | **58523.3** | **15.3104** | **0** | **165.41** |
| **Median** | **4** | **2.4967** | **76.6717** | **0.5472** | **62.4337** | **11.528** | **8.0422** | **3.5625** | **156.654** | **8.9646** | **82.805** | **6.495** | **1.967** | **59038.7** | **15.6092** | **0** | **162.81** |
| CMS027 | Unassigned | 3.6121 | 67.8135 | 0.6429 | 48.0699 | 9.8861 | 7.1567 | 4.2886 | 153.572 | 3.7292 | 20.696 | 7.4794 | 1.6866 | 9833 | 9.4355 | 30.7 | 130.09 |
| CMS033 | Unassigned | 9.7355 | 38.1414 | 0.4582 | 34.0216 | 6.6335 | 3.6179 | 3.3657 | 76.6315 | 14.693 | 87.057 | 9.5616 | 1.383 | 41615.4 | 6.6856 | 65.2 | 108.51 |
| CMS034 | Unassigned | 16.117 | 41.5012 | 0.4249 | 37.5754 | 7.3736 | 3.3602 | 2.973 | 81.9684 | 8.2776 | 77.634 | 7.0346 | 1.5165 | 51739.3 | 5.8929 | 0 | 102.29 |
| CMS036 | Unassigned | 29.617 | 58.8083 | 0.6872 | 45.3249 | 8.4506 | 8.0016 | 4.723 | 107.791 | 8.3375 | 196.36 | 16.334 | 1.5307 | 60939.7 | 11.3509 | 39.2 | 120.89 |
| CMS048 | Unassigned | 10.042 | 81.6297 | 0.7632 | 57.3065 | 12.849 | 13.7768 | 5.5335 | 166.723 | 10.178 | 61.923 | 18.646 | 1.5572 | 21171.4 | 10.0961 | 52.5 | 211.82 |
| CMS049 | Unassigned | 1.8354 | 64.7523 | 0.5281 | 53.6851 | 11.186 | 9.2494 | 4.7615 | 127.89 | 10.294 | 73.412 | 12.814 | 1.916 | 25736.3 | 9.015 | 32.6 | 220.72 |
| CMS050 | Unassigned | 8.2093 | 76.9337 | 0.5792 | 62.6877 | 13.481 | 9.5347 | 5.3285 | 159.096 | 11.801 | 70.419 | 12.413 | 2.211 | 24674.1 | 9.1773 | 0 | 216.14 |

## Appendix 1 *(Continued)*

| SAMPLE # | GROUP | SB | SC | SR | TA | TB | TH | ZN | ZR | AL | BA | CA | DY | K | MN | NA | TI | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS006 | 1 | 2.9358 | 15.19 | 0 | 2.546 | 0.9661 | 29.995 | 104.66 | 211.59 | 117143 | 338.3 | 1502.6 | 5.9018 | 19695 | 80.48 | 917.7 | 6360 | 128.2 |
| CMS007 | 1 | 2.7171 | 13.29 | 0 | 3.317 | 0.9108 | 30.893 | 95.81 | 276.7 | 113734 | 340.7 | 3305.2 | 5.1292 | 18979 | 83.57 | 818.2 | 5855 | 105.12 |
| CMS010 | 1 | 2.2866 | 13.71 | 0 | 2.296 | 0.6691 | 21.456 | 62.18 | 232.58 | 98464 | 313.9 | 1263.3 | 4.8685 | 16250 | 67.12 | 921.5 | 7082 | 120.74 |
| CMS012 | 1 | 2.9212 | 13.59 | 0 | 3.392 | 0.9013 | 36.154 | 75.36 | 246.61 | 110886 | 376.1 | 942.5 | 5.7812 | 21682 | 78.05 | 906.3 | 5436 | 99.36 |
| CMS018 | 1 | 2.5043 | 16.35 | 0 | 2.301 | 0.7355 | 26.603 | 75.69 | 208.03 | 105848 | 326.3 | 2254.3 | 4.8184 | 17386 | 71.65 | 1028.3 | 6647 | 140.91 |
| CMS023 | 1 | 3.2511 | 13.37 | 0 | 3.693 | 0.9187 | 27.471 | 119.25 | 224.78 | 122449 | 369.7 | 880.9 | 5.3191 | 21256 | 88.39 | 1056.6 | 6123 | 110.93 |
| CMS026 | 1 | 3.2171 | 13.56 | 0 | 3.838 | 0.924 | 28.353 | 110.22 | 250.34 | 122375 | 297 | 876.3 | 5.8896 | 19739 | 85.73 | 1028 | 6212 | 121.29 |
| CMS029 | 1 | 2.5766 | 10.92 | 0 | 3.469 | 0.898 | 27.687 | 82.58 | 251.09 | 104999 | 298.4 | 884 | 5.2283 | 16418 | 85.12 | 745.7 | 5469 | 84.45 |
| CMS032 | 1 | 2.7338 | 12.88 | 0 | 3.05 | 0.9787 | 26.699 | 80.9 | 239.91 | 101840 | 307.1 | 1461 | 5.4423 | 17173 | 104.8 | 855 | 6593 | 116.98 |
| CMS046 | 1 | 2.3312 | 12.95 | 0 | 2.979 | 0.9404 | 27.4 | 46.49 | 310.15 | 100167 | 276.4 | 1246 | 5.4651 | 17718 | 68.68 | 817.9 | 5624 | 100 |
| **Mean** | **1** | **2.7475** | **13.58** | **0** | **3.088** | **0.8843** | **28.271** | **85.314** | **245.18** | **109790** | **324.39** | **1461.6** | **5.3844** | **18630** | **81.35** | **909.52** | **6140** | **112.8** |
| **Median** | **1** | **2.7255** | **13.46** | **0** | **3.184** | **0.9148** | **27.579** | **81.74** | **243.26** | **108367** | **320.1** | **1254.7** | **5.3807** | **18349** | **82.03** | **912** | **6167** | **113.96** |
| CMS001 | 2 | 0.2396 | 10.74 | 89.12 | 2.931 | 1.1969 | 40.503 | 83.81 | 216.15 | 125958 | 497 | 1357.4 | 6.8202 | 36134 | 311.7 | 3381.6 | 3107 | 41.97 |
| CMS002 | 2 | 0.2282 | 9.952 | 43.85 | 3.082 | 1.2482 | 40.236 | 82.98 | 246.48 | 120520 | 525.4 | 1688.1 | 7.477 | 39252 | 363.5 | 3651 | 3047 | 44.94 |
| CMS003 | 2 | 0.3371 | 8.859 | 0 | 2.879 | 1.1842 | 35.403 | 73.46 | 233.88 | 108682 | 443.8 | 1626.5 | 7.0248 | 40637 | 783.9 | 3274.3 | 2811 | 38.37 |
| CMS005 | 2 | 0.2602 | 10.35 | 53.97 | 3.069 | 1.5244 | 41.59 | 88.76 | 232.5 | 126874 | 559.3 | 1105.7 | 9.2974 | 40202 | 516 | 4214 | 2978 | 39.51 |
| CMS009 | 2 | 0.2139 | 10.96 | 0 | 3.591 | 1.7478 | 43.778 | 114.43 | 229.62 | 130779 | 476.1 | 1552.9 | 9.191 | 41462 | 983.3 | 4436.7 | 2647 | 40.15 |
| CMS014 | 2 | 0.2154 | 8.957 | 66.15 | 2.582 | 1.2969 | 36.06 | 47.02 | 244.78 | 115041 | 670.3 | 1230.2 | 7.1878 | 38458 | 381 | 2588.7 | 3966 | 57.98 |
| CMS015 | 2 | 0.1678 | 11.43 | 45.77 | 3.853 | 1.6636 | 46.612 | 109.71 | 286.4 | 132563 | 493.7 | 2538.9 | 8.5425 | 41537 | 1124 | 5453 | 3015 | 45.23 |
| CMS019 | 2 | 0.1932 | 10.89 | 0 | 3.715 | 1.784 | 46.541 | 100.93 | 286.2 | 131972 | 529.9 | 2733.7 | 10.49 | 44601 | 1269 | 5471.2 | 2886 | 31.28 |
| CMS024 | 2 | 0.2291 | 10.96 | 73.93 | 3.11 | 1.8214 | 42.646 | 95.63 | 262.69 | 130475 | 508 | 1085.7 | 10.208 | 34959 | 485.3 | 4063 | 2943 | 44.9 |
| CMS025 | 2 | 0.1901 | 11.85 | 41.14 | 3.801 | 1.8199 | 48.531 | 108.57 | 278.59 | 138301 | 440.3 | 2651.3 | 10.742 | 42031 | 954.9 | 5317.2 | 2972 | 44.43 |
| CMS028 | 2 | 0.2532 | 11.51 | 0 | 3.018 | 1.5621 | 42.245 | 91.94 | 176.41 | 135671 | 628 | 1216.4 | 9.0237 | 36882 | 311.3 | 2808.3 | 3883 | 50.8 |
| CMS031 | 2 | 0.1444 | 10.37 | 90.57 | 3.768 | 1.5893 | 46.183 | 67.51 | 296.85 | 128348 | 483.8 | 952.4 | 9.7712 | 43948 | 848.3 | 5391.1 | 3374 | 34.75 |
| CMS035 | 2 | 0.2191 | 9.052 | 36.52 | 3.032 | 1.0198 | 38.195 | 76.52 | 251.14 | 113107 | 439.3 | 1506 | 5.573 | 37930 | 343.3 | 3634 | 2981 | 44.24 |
| CMS037 | 2 | 0.2138 | 10.68 | 41.02 | 3.069 | 1.56 | 42.077 | 70.77 | 251.97 | 128224 | 495.3 | 1817 | 8.7282 | 35781 | 832.3 | 3938.9 | 3168 | 40.49 |
| CMS038 | 2 | 0.2468 | 8.556 | 81.74 | 3.102 | 1.245 | 37.122 | 52.99 | 257.75 | 108476 | 447 | 1911 | 6.9091 | 39104 | 719.9 | 3648.9 | 3089 | 38.75 |
| CMS041 | 2 | 0.216 | 11.08 | 79.32 | 2.839 | 1.5751 | 40.404 | 92.07 | 202.74 | 127773 | 541.7 | 1567 | 8.3112 | 34164 | 475.1 | 3006.2 | 2807 | 48.58 |
| CMS042 | 2 | 0.1984 | 10.45 | 41.78 | 3.762 | 1.5392 | 44.227 | 89.2 | 239.84 | 119760 | 388 | 2048.7 | 8.4684 | 35870 | 496.2 | 5138.3 | 2785 | 39.09 |
| CMS043 | 2 | 0.2227 | 11.11 | 0 | 3.624 | 1.4573 | 45.653 | 75.72 | 245.58 | 125746 | 441.9 | 2117.4 | 7.4713 | 36442 | 934.2 | 4410.2 | 2673 | 42.26 |
| CMS044 | 2 | 0.2446 | 10.92 | 0 | 3.526 | 1.7781 | 44.305 | 64.41 | 266.71 | 125693 | 480.5 | 1576 | 9.2766 | 38712 | 512.3 | 4569.1 | 3209 | 41.56 |
| CMS045 | 2 | 0.1838 | 10.66 | 61.18 | 2.735 | 1.6308 | 39.401 | 64.86 | 210.73 | 121502 | 501.4 | 1823 | 7.9835 | 35122 | 540.6 | 3215.9 | 3221 | 52.11 |
| **Mean** | **2** | **0.2209** | **10.47** | **42.3** | **3.254** | **1.5122** | **42.086** | **82.565** | **245.85** | **124773** | **499.54** | **1705.3** | **8.4249** | **38661** | **659.3** | **4080.6** | **3078** | **43.07** |
| **Median** | **2** | **0.2176** | **10.71** | **42.82** | **3.092** | **1.5611** | **42.161** | **83.395** | **246.03** | **126416** | **494.5** | **1601.3** | **8.5055** | **38585** | **528.3** | **4001** | **2998** | **42.115** |
| CMS004 | 3 | 0.3818 | 10.08 | 46.77 | 1.74 | 1.1808 | 24.913 | 107.29 | 173.06 | 107246 | 709.9 | 1191.8 | 7.0105 | 34815 | 609.4 | 4484.5 | 2898 | 61.15 |
| CMS008 | 3 | 0.4183 | 11.12 | 65.65 | 1.56 | 1.3123 | 23.939 | 103.25 | 154.91 | 109778 | 722.7 | 2909.8 | 7.3911 | 28394 | 797.7 | 3045.1 | 3048 | 61.17 |
| CMS011 | 3 | 0.4609 | 10.01 | 52.81 | 1.708 | 1.1825 | 23.524 | 93.72 | 161.64 | 97166 | 732.9 | 1438.7 | 6.7623 | 32230 | 774.4 | 5177.2 | 2810 | 47.08 |
| CMS013 | 3 | 0.4739 | 9.5 | 45.95 | 1.632 | 1.1152 | 25.216 | 79.8 | 181.57 | 98978 | 791.6 | 1888.8 | 6.7124 | 33376 | 665.4 | 6259.4 | 3154 | 48.44 |
| CMS017 | 3 | 0.4451 | 10.32 | 65.48 | 1.862 | 1.2655 | 25.089 | 71.21 | 187.68 | 101785 | 657.8 | 0 | 7.5445 | 30713 | 1039 | 4894.9 | 3055 | 65.04 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS021 | 3 | 0.4686 | 10.84 | 41.86 | 1.436 | 1.4112 | 25.961 | 135.71 | 142.79 | 111131 | 767.3 | 987.5 | 7.1118 | 28449 | 1170 | 2979.6 | 2165 | 46.74 |
| CMS022 | 3 | 0.4537 | 10.9 | 77.96 | 1.697 | 1.3281 | 25.826 | 116.27 | 146.07 | 108520 | 583.8 | 2086.5 | 7.9348 | 25599 | 816.4 | 3735.4 | 2732 | 69.67 |
| CMS030 | 3 | 0.4486 | 10.35 | 77.69 | 1.943 | 1.2262 | 26.539 | 103.58 | 182.69 | 97008 | 643.9 | 1849.6 | 6.9763 | 32427 | 922.5 | 4598 | 3578 | 49.8 |
| **Mean** | **3** | **0.4439** | **10.39** | **59.27** | **1.697** | **1.2527** | **25.126** | **101.35** | **166.3** | **103951** | **701.24** | **1544.1** | **7.1805** | **30750** | **849.3** | **4396.8** | **2930** | **56.136** |
| **Median** | **3** | **0.4512** | **10.34** | **59.15** | **1.702** | **1.2459** | **25.152** | **103.42** | **167.35** | **104515** | **716.3** | **1644.2** | **7.0612** | **31471** | **807** | **4541.3** | **2973** | **55.475** |
| CMS016 | 4 | 0.1754 | 14.05 | 55.71 | 2.878 | 1.3686 | 31.458 | 67.25 | 445.18 | 103425 | 392.9 | 2098.1 | 7.9119 | 20365 | 253.7 | 2717.5 | 6038 | 92.07 |
| CMS020 | 4 | 0.0892 | 19.17 | 0 | 1.815 | 1.2856 | 29.4 | 69.6 | 273.89 | 118623 | 339.5 | 2234.9 | 6.2021 | 23147 | 271.7 | 3151.4 | 7344 | 147.43 |
| CMS039 | 4 | 0 | 18.62 | 0 | 1.75 | 1.2919 | 32.868 | 59.12 | 351.87 | 114222 | 356.5 | 2014.3 | 5.7996 | 22115 | 211.5 | 4097.1 | 7185 | 138.17 |
| CMS040 | 4 | 0.1503 | 20.84 | 0 | 1.928 | 1.2274 | 32.103 | 113.31 | 310.66 | 122217 | 359 | 1547 | 6.8853 | 21986 | 247.5 | 3848.4 | 7882 | 159.46 |
| CMS047 | 4 | 0.1516 | 17.89 | 64.2 | 1.767 | 1.4162 | 30.069 | 72.43 | 437.21 | 106866 | 445.9 | 1855 | 6.8297 | 22168 | 217.4 | 4020.3 | 6805 | 121.01 |
| **Mean** | **4** | **0.1133** | **18.12** | **23.98** | **2.027** | **1.3179** | **31.179** | **76.342** | **363.76** | **113070** | **378.76** | **1949.9** | **6.7257** | **21956** | **240.4** | **3566.9** | **7051** | **131.63** |
| **Median** | **4** | **0.1503** | **18.62** | **0** | **1.815** | **1.2919** | **31.458** | **69.6** | **351.87** | **114222** | **359** | **2014.3** | **6.8297** | **22115** | **247.5** | **3848.4** | **7185** | **138.17** |
| CMS027 | Unassigned | 0.3364 | 11.38 | 43.63 | 1.559 | 1.3709 | 23.371 | 64.8 | 213.81 | 94329 | 532.2 | 986.3 | 8.168 | 16567 | 187.2 | 1214.7 | 2620 | 41.88 |
| CMS033 | Unassigned | 1.2697 | 15.09 | 0 | 1.108 | 0.9644 | 13.909 | 60.83 | 141.33 | 83662 | 259.8 | 1913.8 | 5.238 | 17183 | 778.6 | 1905.1 | 4570 | 117.76 |
| CMS034 | Unassigned | 0.8117 | 16.21 | 0 | 0.825 | 0.8823 | 14.486 | 46.26 | 138.96 | 86353 | 297.3 | 2257 | 4.746 | 16145 | 273.7 | 2020.3 | 3900 | 122.87 |
| CMS036 | Unassigned | 3.4791 | 19.77 | 0 | 2.401 | 1.1246 | 29.373 | 41.12 | 258.17 | 128900 | 308.2 | 0 | 7.4762 | 16816 | 82.93 | 1330.8 | 7146 | 203.04 |
| CMS048 | Unassigned | 1.9408 | 13.91 | 0 | 3.719 | 1.5738 | 44.494 | 89.58 | 293.91 | 113332 | 299.6 | 965.3 | 9.342 | 21017 | 186.8 | 1320.2 | 4640 | 84.08 |
| CMS049 | Unassigned | 2.3999 | 13.26 | 0 | 1.892 | 1.2648 | 27.891 | 62.41 | 306.17 | 83373 | 414.1 | 2122 | 7.7268 | 21052 | 539.9 | 1171.3 | 4387 | 79.3 |
| CMS050 | Unassigned | 2.0594 | 12.91 | 0 | 2.2 | 1.3957 | 28.331 | 60.18 | 285.23 | 84111 | 484 | 2271 | 9.3818 | 23395 | 309.1 | 1949.8 | 4050 | 87.02 |

# Appendix 2. LA-ICP-MS Data Organized by Compositional Group

| Sample # | LA Chem | $Li_2O$ | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | $K_2O$ | CaO | $Sc_2O_3$ | $TiO_2$ | $V_2O_5$ | $Cr_2O_3$ | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS006 | Glaze-1 | 613.24 | 2123.83 | 40758.94 | 148904.46 | 507232.12 | 8342.93 | 24306.22 | 200401.07 | 14.25 | 5184.60 | 102.51 | 45.82 | 54688.54 |
| CMS012 | Glaze-1 | 325.55 | 3868.89 | 20546.30 | 139652.92 | 599060.44 | 19777.45 | 48639.02 | 111818.07 | 13.30 | 4463.70 | 105.62 | 49.99 | 46477.12 |
| CMS018 | Glaze-1 | 520.89 | 1478.01 | 33748.59 | 154723.03 | 575725.32 | 14527.25 | 23123.67 | 109975.47 | 23.63 | 6488.25 | 136.51 | 54.53 | 72928.50 |
| CMS023 | Glaze-1 | 939.18 | 278.99 | 31144.81 | 152905.09 | 489889.29 | 17950.72 | 25188.09 | 168442.29 | 19.53 | 5138.61 | 137.75 | 57.58 | 100701.93 |
| CMS026 | Glaze-1 | 911.85 | 1424.05 | 31990.84 | 127423.85 | 524261.49 | 18941.65 | 27855.14 | 163153.74 | 14.30 | 5033.19 | 132.63 | 51.87 | 92154.94 |
| CMS032 | Glaze-1 | 571.66 | 0.00 | 35608.08 | 143217.40 | 512992.72 | 13350.90 | 19831.98 | 190566.56 | 13.70 | 5873.74 | 110.55 | 55.95 | 70378.91 |
| **Mean** | **Glaze-1** | **647.06** | **1528.96** | **32299.59** | **144471.12** | **534860.23** | **15481.82** | **28157.35** | **157392.87** | **16.45** | **5363.68** | **120.93** | **52.62** | **72888.32** |
| **Median** | **Glaze-1** | **592.45** | **1451.03** | **32869.71** | **146060.93** | **518627.10** | **16238.98** | **24747.15** | **165798.01** | **14.28** | **5161.61** | **121.59** | **53.20** | **71653.70** |
| CMS016 | Glaze-4 | 143.13 | 3037.25 | 22772.13 | 122334.27 | 550614.84 | 9338.59 | 19433.50 | 170924.00 | 12.98 | 5004.39 | 160.55 | 26.80 | 79760.84 |
| CMS020 | Glaze-4 | 156.64 | 3525.05 | 22883.06 | 108966.74 | 554534.40 | 10896.76 | 19371.63 | 168890.45 | 10.19 | 5009.23 | 213.39 | 29.17 | 81623.99 |
| CMS039 | Glaze-4 | 117.44 | 3701.79 | 16694.29 | 138658.90 | 596151.05 | 5669.42 | 27850.37 | 117070.66 | 16.58 | 5746.29 | 144.97 | 19.71 | 75134.04 |
| CMS040 | Glaze-4 | 153.12 | 5349.13 | 15208.40 | 119901.85 | 614938.31 | 6468.66 | 35019.87 | 111879.69 | 9.24 | 5917.31 | 116.37 | 36.36 | 65895.72 |
| CMS047 | Glaze-4 | 104.02 | 1572.80 | 20530.00 | 120128.68 | 599974.58 | 5384.90 | 25135.76 | 145300.15 | 13.54 | 3806.37 | 141.73 | 20.61 | 60514.02 |
| **Mean** | **Glaze-4** | **134.87** | **3437.20** | **19617.58** | **121998.09** | **583242.64** | **7551.67** | **25362.23** | **142812.99** | **12.50** | **5096.72** | **155.40** | **26.53** | **72585.72** |
| **Median** | **Glaze-4** | **143.13** | **3525.05** | **20530.00** | **120128.68** | **596151.05** | **6468.66** | **25135.76** | **145300.15** | **12.98** | **5009.23** | **144.97** | **26.80** | **75134.04** |
| CMS001 | Glaze-2/3 | 184.07 | 7400.55 | 39555.93 | 165373.43 | 533121.01 | 14978.79 | 43549.06 | 125305.76 | 14.49 | 4664.87 | 85.65 | 16.81 | 45588.20 |
| CMS004 | Glaze-2/3 | 245.61 | 10406.99 | 38640.05 | 186549.56 | 524871.94 | 10360.54 | 54322.89 | 98405.57 | 13.45 | 4817.96 | 108.03 | 25.00 | 61219.84 |
| CMS005 | Glaze-2/3 | 137.72 | 7857.64 | 43627.98 | 169877.64 | 464597.47 | 11029.43 | 34595.42 | 172777.68 | 13.91 | 4604.95 | 78.04 | 25.98 | 66034.92 |
| CMS008 | Glaze-2/3 | 350.80 | 8971.75 | 31546.47 | 180675.06 | 518619.44 | 13904.28 | 39178.71 | 153791.49 | 10.48 | 3537.42 | 57.66 | 26.43 | 29503.10 |
| CMS009 | Glaze-2/3 | 213.02 | 10248.50 | 41171.71 | 161101.48 | 459140.10 | 24373.53 | 33670.18 | 182107.71 | 16.01 | 3694.48 | 59.80 | 21.39 | 62163.19 |
| CMS011 | Glaze-2/3 | 248.00 | 10799.86 | 37148.91 | 172340.58 | 482276.91 | 15511.39 | 38831.92 | 163946.94 | 18.90 | 4788.26 | 98.46 | 34.73 | 56857.71 |
| CMS013 | Glaze-2/3 | 322.76 | 16900.13 | 48684.91 | 159600.36 | 456126.38 | 15590.96 | 35490.30 | 206122.24 | 8.71 | 3281.92 | 72.71 | 17.31 | 38104.70 |
| CMS014 | Glaze-2/3 | 108.27 | 9634.37 | 20198.41 | 199432.22 | 544376.55 | 7145.08 | 67316.46 | 93235.01 | 9.65 | 8714.59 | 69.36 | 19.31 | 40751.25 |
| CMS017 | Glaze-2/3 | 314.50 | 13969.70 | 44922.02 | 159822.21 | 488631.53 | 24860.38 | 31679.12 | 182843.21 | 14.53 | 3254.97 | 59.03 | 25.51 | 33666.62 |
| CMS019 | Glaze-2/3 | 198.30 | 9709.31 | 40493.56 | 162874.88 | 499801.17 | 15046.29 | 42680.82 | 155225.12 | 9.93 | 4213.27 | 44.42 | 10.51 | 48851.09 |
| CMS021 | Glaze-2/3 | 248.33 | 4004.81 | 38071.06 | 160010.00 | 504352.98 | 14855.57 | 27011.11 | 192822.61 | 17.03 | 3823.89 | 70.47 | 22.03 | 37301.04 |
| CMS022 | Glaze-2/3 | 261.80 | 9079.24 | 38993.95 | 154564.24 | 496460.77 | 20823.72 | 37285.89 | 170906.23 | 12.54 | 3275.89 | 88.32 | 29.44 | 43438.52 |
| CMS025 | Glaze-2/3 | 164.74 | 8528.03 | 34454.95 | 171956.32 | 526614.01 | 14271.10 | 37423.14 | 126921.73 | 12.63 | 3878.52 | 50.09 | 19.48 | 56615.35 |
| CMS028 | Glaze-2/3 | 171.87 | 5744.61 | 40009.75 | 197943.64 | 497508.15 | 13153.71 | 45518.83 | 137062.36 | 12.07 | 4573.02 | 60.26 | 6.61 | 36237.83 |
| CMS030 | Glaze-2/3 | 199.33 | 7680.81 | 47813.10 | 146563.44 | 483639.85 | 18439.19 | 44064.64 | 186745.53 | 13.38 | 3458.55 | 73.30 | 16.45 | 36897.34 |
| CMS031 | Glaze-2/3 | 144.12 | 7933.33 | 38180.60 | 159221.91 | 516015.06 | 13626.68 | 37828.26 | 137016.99 | 14.61 | 4335.45 | 63.07 | 19.60 | 63697.82 |
| CMS037 | Glaze-2/3 | 178.22 | 7352.14 | 43981.56 | 176677.60 | 501460.14 | 11509.98 | 50286.90 | 113693.38 | 13.10 | 4736.82 | 71.86 | 15.20 | 69215.37 |
| CMS043 | Glaze-2/3 | 207.67 | 7999.63 | 36176.12 | 171171.61 | 523728.93 | 14596.09 | 46934.06 | 108839.25 | 11.64 | 3999.16 | 62.04 | 14.31 | 68604.29 |
| CMS044 | Glaze-2/3 | 210.67 | 6883.07 | 40308.39 | 210327.73 | 460014.59 | 10189.86 | 41934.38 | 142502.14 | 16.51 | 5393.01 | 84.36 | 42.42 | 62539.06 |
| **Mean** | **Glaze-2/3** | **216.31** | **9005.50** | **39156.81** | **171899.15** | **499018.79** | **14961.40** | **41558.00** | **150014.26** | **13.35** | **4370.89** | **71.42** | **21.50** | **50383.54** |
| **Median** | **Glaze-2/3** | **207.67** | **8528.03** | **39555.93** | **169877.64** | **499801.17** | **14596.09** | **39178.71** | **153791.49** | **13.38** | **4213.27** | **70.47** | **19.60** | **48851.09** |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS027 | Unassigned | 318.08 | 2199.79 | 36159.34 | 152811.15 | 550464.94 | 10352.42 | 29885.51 | 166044.15 | 15.04 | 3647.14 | 72.19 | 13.98 | 31533.69 |
| CMS029 | Unassigned | 366.41 | 1368.72 | 11143.55 | 193201.90 | 620700.40 | 4449.02 | 24816.54 | 88718.09 | 11.33 | 4553.13 | 85.81 | 43.90 | 46695.74 |
| CMS034 | Unassigned | 479.58 | 721.37 | 16078.15 | 111780.38 | 593112.10 | 5202.45 | 9506.11 | 172736.33 | 14.17 | 4293.95 | 140.92 | 56.59 | 81825.35 |
| CMS046 | Unassigned | 586.35 | 353.81 | 42365.22 | 137270.07 | 570497.01 | 11251.70 | 27842.21 | 133902.00 | 15.02 | 6379.45 | 129.92 | 76.17 | 49705.50 |
| CMS048 | Unassigned | 273.96 | 1229.36 | 35853.80 | 222619.32 | 511821.49 | 21806.88 | 30395.09 | 88410.79 | 23.16 | 7758.17 | 136.75 | 28.54 | 65193.08 |
| CMS049 | Unassigned | 188.95 | 0.00 | 30471.36 | 152010.85 | 481773.59 | 9422.73 | 26742.33 | 203667.72 | 12.51 | 4155.79 | 95.31 | 60.27 | 85731.70 |
| CMS050 | Unassigned | 228.56 | 346.20 | 13139.75 | 113841.97 | 562291.40 | 4337.23 | 22972.36 | 193436.65 | 11.10 | 4274.55 | 71.12 | 45.97 | 80910.01 |

## Appendix 2 *(Continued)*

| SAMPLE # | LA CHEM | $MN_2O_3$ | COO | NIO | CUO | ZNO | $AS_2O_3$ | $RB_2O$ | SRO | $Y_2O_3$ | $ZRO_2$ | $AG_2O$ | CDO | $IN_2O$ | $SNO_2$ | $SB_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS006 | Glaze-1 | 4802.49 | 11.97 | 4.69 | 261.65 | 48.73 | 1.32 | 128.27 | 871.69 | 47.47 | 246.00 | 0.13 | 0.54 | 1.53 | 5.66 | 0.75 |
| CMS012 | Glaze-1 | 2883.93 | 12.03 | 24.64 | 125.34 | 290.06 | 3.18 | 162.18 | 333.07 | 34.20 | 132.38 | 0.31 | 0.39 | 0.47 | 9.84 | 1.28 |
| CMS018 | Glaze-1 | 4580.03 | 24.39 | 60.64 | 137.41 | 60.77 | 1.31 | 122.53 | 507.73 | 53.40 | 212.70 | 0.93 | 0.42 | 0.69 | 5.73 | 1.01 |
| CMS023 | Glaze-1 | 4783.18 | 18.77 | 62.09 | 192.74 | 64.05 | 2.59 | 143.87 | 510.35 | 36.00 | 191.63 | 0.00 | 0.91 | 0.56 | 11.75 | 0.52 |
| CMS026 | Glaze-1 | 4289.33 | 18.03 | 43.72 | 171.22 | 118.12 | 1.49 | 151.59 | 493.61 | 50.27 | 154.64 | 0.12 | 0.47 | 0.54 | 12.80 | 1.51 |
| CMS032 | Glaze-1 | 5062.48 | 12.03 | 32.74 | 163.31 | 149.90 | 16.33 | 96.52 | 580.93 | 40.77 | 219.97 | 0.38 | 1.69 | 0.55 | 12.43 | 1.33 |
| **Mean** | **Glaze-1** | **4400.24** | **16.20** | **38.09** | **175.28** | **121.94** | **4.37** | **134.16** | **549.56** | **43.69** | **192.89** | **0.31** | **0.74** | **0.72** | **9.70** | **1.07** |
| **Median** | **Glaze-1** | **4681.61** | **15.03** | **38.23** | **167.27** | **91.08** | **2.04** | **136.07** | **509.04** | **44.12** | **202.17** | **0.22** | **0.51** | **0.55** | **10.80** | **1.15** |
| CMS016 | Glaze-4 | 12485.73 | 217.32 | 37.62 | 163.50 | 207.33 | 2.25 | 90.04 | 1032.30 | 57.92 | 240.48 | 0.11 | 1.02 | 0.67 | 5.60 | 0.06 |
| CMS020 | Glaze-4 | 19426.01 | 330.85 | 45.26 | 230.19 | 243.13 | 1.07 | 91.18 | 952.66 | 45.67 | 262.64 | 5.37 | 0.44 | 0.90 | 4.74 | 0.06 |
| CMS039 | Glaze-4 | 9500.73 | 114.67 | 50.93 | 161.00 | 235.51 | 5.37 | 115.81 | 529.83 | 59.42 | 207.38 | 0.22 | 0.77 | 0.79 | 3.70 | 0.83 |
| CMS040 | Glaze-4 | 12856.77 | 217.88 | 83.11 | 195.81 | 820.80 | 11.04 | 179.81 | 841.38 | 98.72 | 276.00 | 2.24 | 3.51 | 1.17 | 9.93 | 0.47 |
| CMS047 | Glaze-4 | 12960.28 | 232.99 | 50.18 | 157.43 | 347.91 | 4.50 | 127.76 | 1016.07 | 74.68 | 272.95 | 1.41 | 1.89 | 1.01 | 7.65 | 0.72 |
| **Mean** | **Glaze-4** | **13445.90** | **222.74** | **53.42** | **181.58** | **370.94** | **4.85** | **120.92** | **874.45** | **67.28** | **251.89** | **1.87** | **1.53** | **0.91** | **6.33** | **0.43** |
| **Median** | **Glaze-4** | **12856.77** | **217.88** | **50.18** | **163.50** | **243.13** | **4.50** | **115.81** | **952.66** | **59.42** | **262.64** | **1.41** | **1.02** | **0.90** | **5.60** | **0.47** |
| CMS001 | Glaze-2/3 | 15120.49 | 18.96 | 46.75 | 56.13 | 425.54 | 1.94 | 166.44 | 908.73 | 125.46 | 167.79 | 0.37 | 1.34 | 0.93 | 3.21 | 0.31 |
| CMS004 | Glaze-2/3 | 6071.59 | 13.29 | 0.87 | 72.36 | 295.58 | 5.39 | 212.24 | 987.11 | 46.02 | 89.49 | 0.47 | 1.39 | 0.55 | 34.70 | 1.29 |
| CMS005 | Glaze-2/3 | 18968.01 | 13.42 | 16.62 | 124.98 | 101.04 | 3.59 | 166.94 | 1557.30 | 125.82 | 242.38 | 0.11 | 0.77 | 0.55 | 5.01 | 0.69 |
| CMS008 | Glaze-2/3 | 14891.74 | 19.77 | 15.25 | 48.87 | 33.50 | 1.08 | 145.47 | 1278.74 | 104.43 | 161.47 | 0.16 | 0.31 | 1.87 | 2.60 | 0.27 |
| CMS009 | Glaze-2/3 | 16222.43 | 19.71 | 24.41 | 89.76 | 688.14 | 6.82 | 155.30 | 1415.05 | 121.01 | 162.60 | 0.17 | 1.29 | 0.60 | 3.94 | 0.12 |
| CMS011 | Glaze-2/3 | 12175.29 | 19.15 | 27.92 | 62.64 | 339.91 | 0.28 | 148.69 | 1216.83 | 61.78 | 315.88 | 0.24 | 0.84 | 0.47 | 7.62 | 0.12 |
| CMS013 | Glaze-2/3 | 13148.99 | 12.28 | 12.62 | 88.02 | 179.39 | 1.77 | 135.09 | 1574.63 | 126.40 | 187.59 | 0.19 | 0.32 | 0.61 | 28.85 | 0.57 |
| CMS014 | Glaze-2/3 | 4336.47 | 7.18 | 12.80 | 39.95 | 327.19 | 4.30 | 310.77 | 964.15 | 109.47 | 90.03 | 0.31 | 0.59 | 0.51 | 4.62 | 0.20 |
| CMS017 | Glaze-2/3 | 10170.33 | 10.39 | 20.48 | 71.13 | 452.28 | 11.97 | 117.02 | 1385.02 | 67.88 | 414.91 | 0.42 | 1.26 | 0.76 | 19.01 | 1.31 |
| CMS019 | Glaze-2/3 | 14662.19 | 16.73 | 25.88 | 87.74 | 700.19 | 6.98 | 183.15 | 1380.18 | 118.13 | 119.88 | 0.47 | 0.76 | 0.94 | 12.98 | 0.38 |
| CMS021 | Glaze-2/3 | 11729.74 | 8.55 | 45.64 | 100.83 | 320.49 | 6.26 | 109.22 | 1737.52 | 62.22 | 163.24 | 0.31 | 1.56 | 1.33 | 3.74 | 0.72 |
| CMS022 | Glaze-2/3 | 19204.78 | 17.85 | 42.35 | 98.60 | 520.32 | 7.71 | 145.64 | 1331.86 | 97.10 | 156.08 | 0.33 | 0.42 | 0.55 | 7.20 | 0.65 |
| CMS025 | Glaze-2/3 | 15109.77 | 15.46 | 40.92 | 48.12 | 44.26 | 0.55 | 145.28 | 809.87 | 136.15 | 194.03 | 0.18 | 1.11 | 0.93 | 3.57 | 0.32 |
| CMS028 | Glaze-2/3 | 16898.23 | 11.02 | 17.79 | 79.79 | 453.01 | 1.14 | 199.43 | 1108.24 | 97.56 | 204.64 | 1.05 | 0.62 | 0.80 | 6.85 | 0.07 |
| CMS030 | Glaze-2/3 | 17958.48 | 13.91 | 30.33 | 56.67 | 276.08 | 1.50 | 153.04 | 1556.04 | 130.92 | 171.60 | 0.35 | 1.11 | 1.12 | 17.33 | 1.43 |
| CMS031 | Glaze-2/3 | 15329.11 | 20.55 | 41.41 | 67.79 | 734.46 | 9.75 | 185.47 | 1248.44 | 198.04 | 125.47 | 0.46 | 2.04 | 0.49 | 5.32 | 0.21 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS037 | Glaze-2/3 | 16132.76 | 17.30 | 22.78 | 122.25 | 162.15 | 1.13 | 245.10 | 886.16 | 183.83 | 182.83 | 0.41 | 0.73 | 0.95 | 2.15 | 0.00 |
| CMS043 | Glaze-2/3 | 12883.13 | 12.83 | 42.32 | 45.72 | 72.58 | 1.88 | 191.57 | 958.51 | 127.05 | 348.89 | 0.22 | 0.00 | 0.51 | 4.24 | 0.00 |
| CMS044 | Glaze-2/3 | 15163.53 | 13.88 | 18.28 | 66.55 | 79.73 | 2.29 | 178.38 | 1116.77 | 108.93 | 201.24 | 0.30 | 1.11 | 0.60 | 4.68 | 0.37 |
| **Mean** | **Glaze-2/3** | **14009.32** | **14.85** | **26.60** | **75.15** | **326.62** | **4.02** | **173.38** | **1232.69** | **113.06** | **194.74** | **0.34** | **0.92** | **0.79** | **9.35** | **0.47** |
| **Median** | **Glaze-2/3** | **15109.77** | **13.91** | **24.41** | **71.13** | **320.49** | **2.29** | **166.44** | **1248.44** | **118.13** | **171.60** | **0.31** | **0.84** | **0.61** | **5.01** | **0.32** |
| CMS027 | Unassigned | 10222.94 | 16.80 | 33.01 | 115.71 | 447.13 | 6.23 | 147.18 | 1385.27 | 109.37 | 142.02 | 0.14 | 0.56 | 0.66 | 4.87 | 0.67 |
| CMS029 | Unassigned | 2428.93 | 16.70 | 53.78 | 21.37 | 112.86 | 1.72 | 187.44 | 282.32 | 29.75 | 100.01 | 0.33 | 0.29 | 0.39 | 10.10 | 0.67 |
| CMS034 | Unassigned | 2307.23 | 22.27 | 83.77 | 183.81 | 22.52 | 0.00 | 39.34 | 496.74 | 32.97 | 309.90 | 0.50 | 0.00 | 1.49 | 1.76 | 0.23 |
| CMS046 | Unassigned | 16119.06 | 27.49 | 75.30 | 233.35 | 337.14 | 73.55 | 133.35 | 534.01 | 72.18 | 186.29 | 0.77 | 2.32 | 0.38 | 24.95 | 2.00 |
| CMS048 | Unassigned | 11435.73 | 37.13 | 72.98 | 47.57 | 215.50 | 2.44 | 164.55 | 381.20 | 52.06 | 280.81 | 0.16 | 0.63 | 1.03 | 22.37 | 1.95 |
| CMS049 | Unassigned | 2648.72 | 16.74 | 35.34 | 59.58 | 82.84 | 11.44 | 159.28 | 891.20 | 50.34 | 590.64 | 0.49 | 0.75 | 0.60 | 7.93 | 0.78 |
| CMS050 | Unassigned | 1176.91 | 8.79 | 26.05 | 61.42 | 87.83 | 3.68 | 112.29 | 741.24 | 44.67 | 570.04 | 0.16 | 0.43 | 0.86 | 5.68 | 2.01 |

## Appendix 2 *(Continued)*

| SAMPLE # | LA CHEM | $CS_2O$ | BAO | $LA_2O_3$ | $CE_2O_3$ | $SM_2O_3$ | $EU_2O_3$ | TAO | PBO | THO | $U_3O_8$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS006 | Glaze-1 | 6.86 | 593.13 | 85.20 | 110.62 | 12.72 | 2.35 | 1.90 | 15.27 | 16.62 | 3.89 |
| CMS012 | Glaze-1 | 23.69 | 793.86 | 70.28 | 207.11 | 8.35 | 1.06 | 2.97 | 43.87 | 30.51 | 6.62 |
| CMS018 | Glaze-1 | 10.15 | 473.80 | 75.51 | 157.54 | 13.99 | 2.30 | 1.27 | 14.28 | 22.84 | 4.96 |
| CMS023 | Glaze-1 | 7.71 | 878.16 | 75.04 | 154.87 | 7.12 | 1.43 | 1.40 | 37.03 | 19.82 | 4.56 |
| CMS026 | Glaze-1 | 10.22 | 836.58 | 67.28 | 154.56 | 13.85 | 2.87 | 1.12 | 34.95 | 17.03 | 4.54 |
| CMS032 | Glaze-1 | 7.56 | 714.87 | 94.42 | 148.91 | 12.89 | 2.62 | 1.42 | 30.88 | 17.40 | 5.55 |
| **Mean** | **Glaze-1** | **11.03** | **715.07** | **77.96** | **155.60** | **11.49** | **2.10** | **1.68** | **29.38** | **20.70** | **5.02** |
| **Median** | **Glaze-1** | **8.93** | **754.36** | **75.28** | **154.72** | **12.80** | **2.33** | **1.41** | **32.92** | **18.61** | **4.76** |
| CMS016 | Glaze-4 | 2.61 | 1431.64 | 86.12 | 250.87 | 14.89 | 3.55 | 2.50 | 74.43 | 22.80 | 5.39 |
| CMS020 | Glaze-4 | 1.62 | 1717.62 | 93.30 | 323.25 | 11.60 | 2.93 | 2.47 | 64.66 | 25.31 | 6.32 |
| CMS039 | Glaze-4 | 2.73 | 1509.30 | 80.79 | 291.32 | 12.85 | 2.37 | 2.58 | 97.39 | 29.81 | 8.41 |
| CMS040 | Glaze-4 | 4.68 | 2698.37 | 105.16 | 357.02 | 18.26 | 2.23 | 3.04 | 278.71 | 32.16 | 7.69 |
| CMS047 | Glaze-4 | 4.91 | 1623.95 | 99.41 | 245.16 | 16.41 | 2.94 | 2.21 | 87.57 | 24.81 | 8.05 |
| **Mean** | **Glaze-4** | **3.31** | **1796.18** | **92.96** | **293.52** | **14.80** | **2.80** | **2.56** | **120.55** | **26.98** | **7.17** |
| **Median** | **Glaze-4** | **2.73** | **1623.95** | **93.30** | **291.32** | **14.89** | **2.93** | **2.50** | **87.57** | **25.31** | **7.69** |
| CMS001 | Glaze-2/3 | 2.91 | 2283.79 | 265.78 | 439.15 | 27.49 | 6.80 | 8.07 | 46.08 | 28.04 | 8.85 |
| CMS004 | Glaze-2/3 | 5.06 | 1894.20 | 71.11 | 93.37 | 9.72 | 2.57 | 1.25 | 78.62 | 18.55 | 5.79 |
| CMS005 | Glaze-2/3 | 3.40 | 2903.05 | 192.16 | 196.76 | 26.67 | 4.42 | 2.23 | 28.14 | 48.91 | 8.27 |
| CMS008 | Glaze-2/3 | 1.74 | 2550.95 | 241.24 | 259.21 | 24.78 | 4.81 | 1.28 | 6.19 | 22.65 | 8.52 |
| CMS009 | Glaze-2/3 | 2.27 | 2467.39 | 252.18 | 262.13 | 27.99 | 4.39 | 2.50 | 47.00 | 30.88 | 10.81 |
| CMS011 | Glaze-2/3 | 3.73 | 2424.31 | 101.00 | 108.70 | 11.67 | 2.71 | 1.11 | 32.49 | 26.38 | 7.66 |
| CMS013 | Glaze-2/3 | 1.28 | 3264.73 | 367.83 | 442.23 | 47.69 | 8.12 | 1.26 | 16.64 | 18.98 | 10.53 |
| CMS014 | Glaze-2/3 | 2.46 | 2017.33 | 294.68 | 323.40 | 26.47 | 5.72 | 1.69 | 80.87 | 21.56 | 6.76 |
| CMS017 | Glaze-2/3 | 1.45 | 2677.09 | 175.72 | 163.05 | 19.96 | 3.28 | 1.53 | 115.19 | 24.50 | 10.73 |
| CMS019 | Glaze-2/3 | 2.72 | 2815.67 | 237.79 | 288.49 | 26.67 | 5.08 | 4.19 | 101.80 | 33.48 | 8.84 |
| CMS021 | Glaze-2/3 | 1.46 | 2765.92 | 116.29 | 134.72 | 11.45 | 2.81 | 1.16 | 37.98 | 18.08 | 7.85 |
| CMS022 | Glaze-2/3 | 1.84 | 2617.47 | 180.71 | 219.71 | 22.23 | 3.97 | 1.21 | 58.86 | 30.90 | 11.11 |
| CMS025 | Glaze-2/3 | 3.02 | 1900.12 | 242.82 | 285.43 | 33.33 | 4.83 | 1.57 | 25.90 | 32.68 | 9.68 |
| CMS028 | Glaze-2/3 | 2.79 | 2366.53 | 210.51 | 229.62 | 21.59 | 4.32 | 2.75 | 28.49 | 39.19 | 11.27 |
| CMS030 | Glaze-2/3 | 2.13 | 3142.54 | 383.55 | 411.39 | 36.31 | 5.82 | 1.50 | 15.66 | 20.69 | 5.60 |
| CMS031 | Glaze-2/3 | 3.24 | 2934.56 | 358.01 | 415.75 | 41.51 | 7.69 | 2.43 | 133.29 | 28.43 | 8.59 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CMS037 | Glaze-2/3 | 2.00 | 1777.93 | 478.95 | 459.95 | 49.14 | 8.94 | 3.08 | 19.47 | 37.03 | 10.70 |
| CMS043 | Glaze-2/3 | 1.75 | 2248.49 | 262.68 | 339.75 | 33.37 | 5.22 | 2.58 | 23.01 | 32.51 | 16.39 |
| CMS044 | Glaze-2/3 | 3.29 | 2240.20 | 136.30 | 133.62 | 17.49 | 3.78 | 1.96 | 26.53 | 23.99 | 10.02 |
| **Mean** | **Glaze-2/3** | **2.56** | **2489.07** | **240.49** | **274.02** | **27.13** | **5.02** | **2.28** | **48.54** | **28.29** | **9.37** |
| **Median** | **Glaze-2/3** | **2.46** | **2467.39** | **241.24** | **262.13** | **26.67** | **4.81** | **1.69** | **32.49** | **28.04** | **8.85** |
| CMS027 | Unassigned | 2.53 | 3117.26 | 264.09 | 351.73 | 23.44 | 5.10 | 1.49 | 58.71 | 20.04 | 5.65 |
| CMS029 | Unassigned | 16.21 | 436.73 | 32.40 | 67.58 | 4.51 | 0.78 | 0.74 | 25.59 | 11.29 | 3.00 |
| CMS034 | Unassigned | 1.73 | 395.63 | 31.21 | 89.50 | 8.80 | 0.71 | 0.87 | 6.69 | 11.41 | 3.46 |
| CMS046 | Unassigned | 8.58 | 1478.82 | 79.39 | 137.08 | 6.65 | 2.23 | 1.42 | 61.96 | 21.34 | 6.01 |
| CMS048 | Unassigned | 17.61 | 1072.18 | 95.39 | 191.92 | 11.02 | 1.87 | 3.13 | 291.26 | 37.77 | 11.38 |
| CMS049 | Unassigned | 9.00 | 836.34 | 56.43 | 119.52 | 15.54 | 2.26 | 3.00 | 15.46 | 34.45 | 18.20 |
| CMS050 | Unassigned | 5.42 | 1023.59 | 59.59 | 98.92 | 7.00 | 1.41 | 1.46 | 22.30 | 21.74 | 9.65 |

## NOTES

1. We have, however, no way of documenting specific collection procedures, so we cannot say what proportion of materials were collected or how these collections were made.
2. Because many of the vessels consist of multiple sherds that cannot be joined, it is not possible to determine a precise vessel count; this is our best current estimate of the total number of vessels.
3. Guthe M2-21 (CMS003) was collected from an ancient gold mine site.
4. This discussion does not include ongoing studies by Michael Maccheroni of Australia National University, who has sampled the Guthe Collection.
5. Support for this analysis was provided by the Office of the Vice President for Research, University of Michigan, to whom we extend our gratitude. MURR research is also supported by grants from the National Science Foundation (DBS-9102016).
6. The number of samples analyzed by LA-ICP-MS is smaller than the number of samples analyzed by INAA because several of the dragon jar specimens (n = 13) in the MURR archival collection did not have intact glazes.
7. This discussion of decorative production is a summary presentation of Stephen Dueppen's more extensive analysis presented in an unpublished predoctoral research paper (Dueppen 2004) on file in the Museum of Anthropology, University of Michigan, and it will be presented in greater detail in a manuscript currently being prepared for publication.

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## ABSTRACT

This paper presents a multifaceted study of a collection of stoneware ceramic vessels in the Guthe Collection of the Museum of Anthropology, University of Michigan. These vessels, recovered in the Philippines but manufactured in multiple production sites across East and Southeast Asia, provide insights into premodern economic interactions and maritime trade. Our study of this collection drew on multiple approaches to identify coherent groupings of vessels associated with locations and traditions of production. These include instrumental neutron activation analysis (INAA) of pastes; laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) of glazes; stylistic analysis of decorative motifs and their execution; and study of morphological attributes. Results of our analyses point to at least four production areas for these ubiquitous trade wares and lay the groundwork for future research on Southeast Asian maritime trade from the twelfth through nineteenth centuries A.D. Keywords: Southeast Asia, ceramic classification, trade wares, dragon jars.