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Ceramic Technology and Social Boundaries: Cultural Practices in Kalinga Clay Selection and Use

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This study examines cultural sources of variation in ceramic compositional patterning in two pottery-making villages of the highland Philippines. In Dalupa, many potters are part-time specialists whereas in Dangtalan, women make pottery less frequently. Previous studies show that both pottery form and decoration correspond well with Kalinga social boundaries, but how do morphological and decorative patterning relate to compositional variability? Although researchers have made substantial advances in our understanding of natural and postdepositional sources of compositional variability, little is known about behavioral factors that affect chemical and mineralogical compositional patterning. This study examines cultural practices of clay selection and use in an ethnographic setting, and undertakes technical analyses to assess the relationship between behavior and material culture patterning. Our study identified paste differences between the clays and fired ceramics from Dangtalan and those from Dalupa. Findings from our compositional research thus parallel earlier morphological and stylistic studies, and illustrate multivariate differences in ceramics from these two Kalinga communities. This ethnoarchaeological and analytical project contributes, therefore, to understanding objective parameters within a behavioral context. It also provides an example of how a combined characterization approach, using chemical and petrographic techniques, can yield insights on intraregional variation at a finer scale of resolution than is often attempted.

KEY WORDS: ceramic composition; quantitative petrography; ethnoarchaeology; social boundaries.

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INTRODUCTION

Studying social boundaries through ceramic analysis has a hallowed tradition in archaeological research, and stylistic approaches have dominated research on social boundaries for more than 20 years (e.g., Carr and Neitzel, 1995; Hegmon, 1992, 1998; Rice, 1996a, pp. 148–153; Stark, 1998a). As the use of ceramic compositional analyses increases among archaeologists, more work is required to refine our understanding of different techniques and their applications to archaeological questions (e.g., Bishop *et al.*, 1982; Bishop and Neff, 1989; DeAtley and Bishop, 1991; Druc and Gwyn, 1998; Neff, 1992; Neff *et al.*, 1988a,b; Rice, 1996b). One fruitful, if underexplored, application lies in the analysis of compositional data to study technical and social boundaries. Interest in these two domains—that is, studies of social boundaries and compositional approaches—offers opportunities to ceramic ethnoarchaeologists, who can study both behavior and material culture patterning that potters and consumers create in various settings. Ethnoarchaeological research allows us to apply compositional techniques to a data set with a known provenance to test the validity of our techniques.

This study combines ethnoarchaeological and analytical approaches to study cultural practices of clay selection (as the decision-making processes governing which sources the potters choose) and clay use (as the processes involved in transforming raw clays into finished ceramics) in one area of the northern Philippines (Fig. 1). Using this approach enables us to examine sources of variation in the composition of Kalinga ceramics. Data derive from the Kalinga Ethnoarchaeological Project, specifically from the two Kalinga villages in the Pasil river valley: Dalupa and Dangtalan. In this paper, we use compositional analyses to examine technological differences in the goods produced in these two pottery-making villages. These villages are closely spaced in a similar geological environment, and potters from both villages participate in a single exchange network.

We give emphasis to differences in raw materials, focusing on the material characteristics resulting from the cultural practices of Kalinga clay use. Most archaeological studies must rely on inferences about procurement and production variables, without knowledge of either raw material provenance or manufacturing technology. In combining ethnoarchaeological data on manufacturing technology and behavior with compositional analysis, this technological study is a rare opportunity to evaluate the strength of interpretations that archaeologists routinely use to explain patterning in archaeological ceramic data.

One goal of our research was to detect whether stylistic and morphological boundaries reflected at the aggregate (village) level are also manifested at the compositional level. This compositional study of Kalinga raw materials and pottery was able to link together regional clays (raw materials) and the finished products. Further, chemical and mineralogical distinctions between the two groups of clay sources were identified that represent discrete pottery-making communities. Given the homogenous geological setting in which these villages are found, with villages

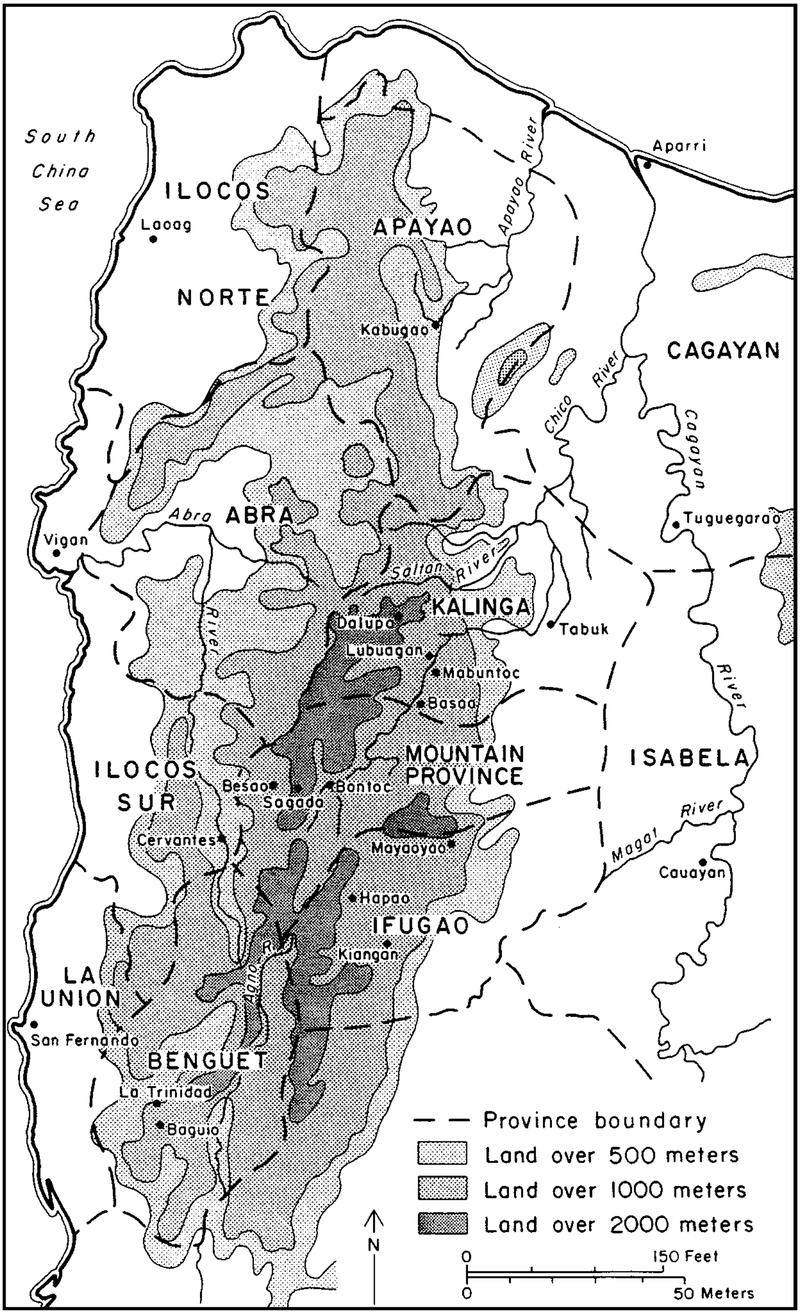

Fig. 1. The study area (Kalinga province, Philippines).

separated by only 2 km, these results demonstrate the potential of compositional approaches to provide fine-grained perspectives on ceramic production in the archaeological past. In the following section, we discuss the relationship between ceramic technology and social boundaries, and then we turn to the Kalinga case study.

CERAMIC TECHNOLOGY AND SOCIAL BOUNDARIES

Archaeologists working around the world have been interested in studying social boundaries through distributional patterning since the culture history era. A recent, revived interest in social units such as “ethnic groups” and social processes such as “migration” underscores our abiding concern with identifying social units in the archaeological record of both complex and noncomplex societies (e.g., MacEachern, 1992, 1998; Shennan, 1989). Researchers now use a variety of improved approaches to identify social boundaries in material culture patterning (e.g., Dietler and Herbich, 1998; Gosselain, 1998; Graves, 1994; Hegmon, 1998; Hosler, 1996; Stark, 1998a,b). Arnold and his colleagues (1991, p. 75) point out that, in most compositional research that focuses on archaeological ceramics, archaeologists know little about the potential variability of raw materials in terms of their location and procurement variables involved. Ethnoarchaeology provides a potentially powerful strategy for studying such variability because it allows archaeologists to investigate both the behaviors and their material results within a well-understood spatial and temporal framework (Kramer, 1985).

A growing technological emphasis in ceramic studies has increased the range of methods available for studying social boundaries based on material culture patterning. Ethnoarchaeological studies that focus on the impact of producers’ choices in raw materials selection (Aronson *et al.*, 1991; Gosselain, 1994) and on the variability inherent in raw materials sources (e.g., Arnold *et al.*, 1991; Druc and Gwyn, 1998; Rye, 1976) have been especially useful in expanding our knowledge of resource use by potters. So, too, have ethnoarchaeological studies that study the relationship between the manufacturing sequence and social boundaries among traditional potters (e.g., Dietler and Herbich, 1998; Druc and Gwyn, 1998; Gosselain, 1992, 1998). Understanding the complex and heterogenous nature of ceramic composition (which reflects both natural and cultural processes) in archaeological patterning requires extensive research using a variety of compositional approaches. To contextualize this study of technical choices in Kalinga clay use, we first provide a brief background to the study region and to the Kalinga Ethnoarchaeological Project.

Background to Kalinga Pottery Production

William A. Longacre launched the Kalinga Ethnoarchaeological Project in 1973 in the Pasil river valley (Kalinga province) of the northern Philippines (Fig. 2).

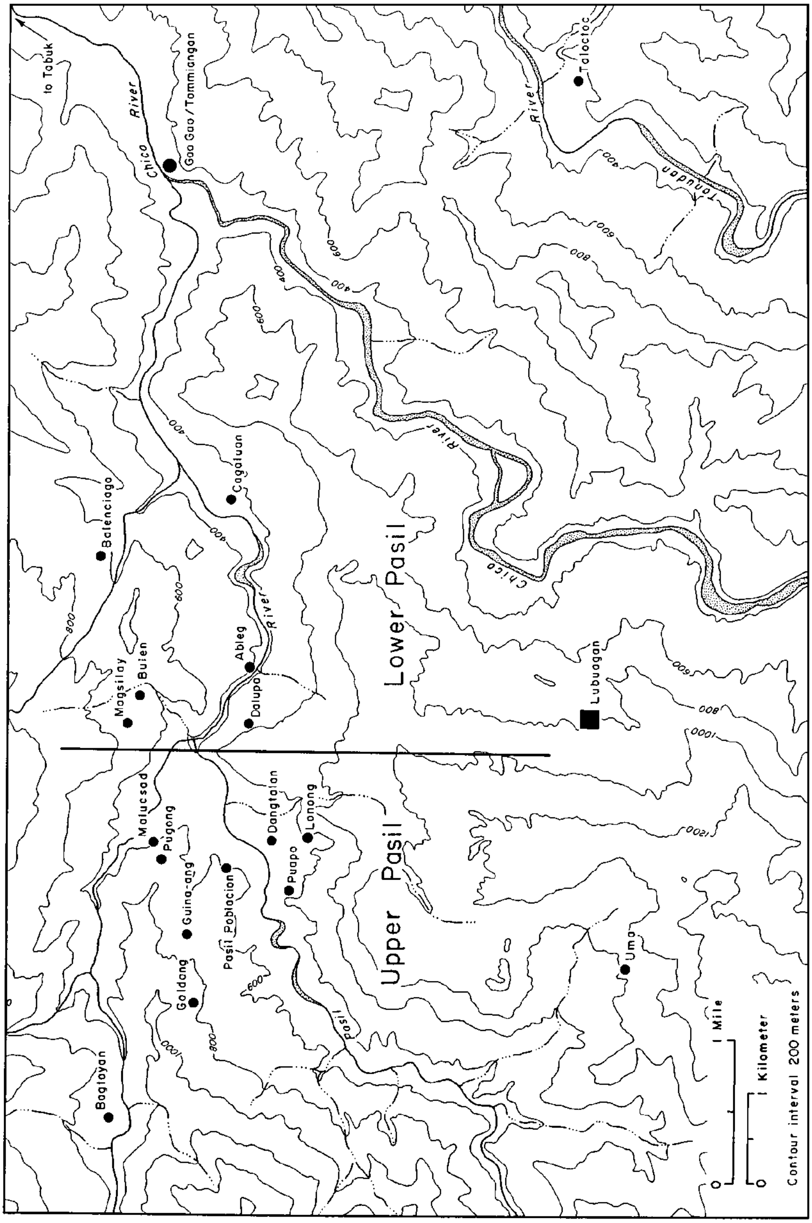

Fig. 2. Intravalley differences in the Pasil river valley.

With field seasons undertaken intermittently since then, the Kalinga Ethnoarchaeological Project is one of a handful of longitudinal ethnoarchaeological projects in the world. The time-depth involved in the project (now in its 26th year) barely begins to approximate the scale of archaeological time for sites in most areas of the world. Yet, researchers have already observed substantial changes since the project's inception that are only evident through a long-term research commitment (e.g., Stark, 1991a, 1993; Stark and Longacre, 1993).

Of the many topics studied by researchers associated with the Kalinga Ethnoarchaeological Project (see Longacre *et al.*, 1991), understanding the social contexts of ceramic production and distribution has been one of its longstanding goals (Graves, 1981, 1985, 1991, 1994; Longacre, 1974; Longacre and Stark, 1992; Stark, 1991a,b, 1993, 1994, 1999; Stark and Longacre, 1993). The earliest Kalinga research initially focused on social boundaries at the intracommunity level to test assumptions that had structured previous research in the American Southwest (Longacre, 1974, 1981). The project's commitment to studying social boundaries was made even clearer in Michael Graves' research on incised design styles (Graves, 1985, 1991, 1994) that compared Dalupa and Dangtalan. Later research made comparisons between the morphology of Kalinga pottery made in the Pasil river valley and the morphology of pottery made beyond its boundaries (Longacre, 1991; Stark, 1999).

The Pasil river valley is a tributary of the Chico river, one of the larger drainage systems in the northern Philippines. Kalinga speakers live in topographically distinct regions along both the Chico and the Pasil rivers, and their villages are linked together by peace pacts and other political alliances (Dozier, 1966; Stark, 1993; Takaki, 1977). These drainages are part of the Cordillera mountain range, which ranges in elevation from 1000 m to 2400 m (Kowal, 1966, p. 389). The Cordillera population of 1.2 million people includes many different indigenous groups, or ethnic minorities, across six provinces (National Census and Statistics Office, 1996).

Previous anthropologists have focused on the combination of tribal warfare and custom law that structures Kalinga's political organization (e.g., Bacdayan, 1967; Barton, 1949; Dozier, 1966; Lawless, 1980; Takaki, 1977; Von Fürer-Haimendorf, 1970). This uneasy fluctuation between tribal warfare and peace pacts continues today, and intercommunity tensions persist despite the recent emergence of integrating factors (Lawless, 1978). The area is too distant from major centers for full integration into a market economy, as has happened elsewhere in the Cordilleras as in Benguet province (Lewis, 1989, 1992; Russell, 1987; Wiber, 1993). Capitalist penetration into the region affects many aspects of daily life, but the Kalinga, as their Bontoc neighbors (e.g., Lawless, 1977; Voss, 1987), continue to practice their customs and traditions.

Thirteen nucleated villages are nestled on the slopes and base of the Pasil river valley, ranging in population from a few hundred to more than one thousand inhabitants each. Over the past 20 years, most Kalinga Ethnoarchaeological

Project research has concentrated on the two pottery-making villages of Dalupa and Dangtalan. Throughout the 1970s and 1980s, Dangtalan had a population of 300–350 residents, whereas Dalupa had a larger population of approximately 400 residents. Employment-related emigration is common in each village, and family members frequently work outside Kalinga during part or most of their active working lives (Stark, 1995).

Kalinga Pottery Technology

Despite the availability of ceramic substitutes such as metal, plastic, and glass, Kalingas still use earthenware pottery for culinary purposes on a daily basis in the Pasil river valley. Women potters in Dalupa and Dangtalan provide most Pasil residents with their earthenware ceramics, and many households in each village include women who are inactive or active potters. Pasil Kalinga pottery production relies on hand-building, rather than wheel-made or mold-made, construction techniques (Longacre, 1981). Earthenware jars are used to store water and for cooking meat and vegetables. Some still use earthenware rice-cooking pots, although most admit that metal cauldrons are more durable (see also Skibo, 1994). Communal events, such as weddings, funerals, or other celebrations, require many cooking pots. At such events, large earthenware pots are most visible as part of food preparation. The low cost of Pasil pots, and a traditional preference for food cooked in earthenware pottery, both contribute to the continued popularity of Kalinga pottery in daily life.

Since the 1970s, the Pasil pottery manufacturing tradition has undergone dramatic changes in its organization and scale (see Stark, 1991a, 1993; Stark and Longacre, 1993). In the 1970s, Pasil potters manufactured two types of cooking vessels (one for meat and vegetables [*oppaya*] and one for rice [*ittoyom*]), a water storage vessel (*immosso*), and occasionally, a sugarcane wine storage jar (*amuto*) (Longacre, 1974, 1981). By the mid-1980s, few potters in either village made earthenware wine storage jars, and Dalupa potters had begun a process of innovation that involved technological and stylistic changes. They modified the surface decorations of water storage jars and experimented with a variety of nontraditional ceramics (*ay-ayam*) whose forms ranged from flower pots and ashtrays to photographic plaques and animal sculptures. Pasil ceramic production is geared toward the manufacture of utilitarian ceramics, and even the locally manufactured wine storage jar lacks the status of imported stoneware jars (*gusi*) from Ilocos Norte or even (indirectly) from China.

In the Pasil river valley, pottery manufacturing is one economic strategy to meet household economic needs (Stark, 1995). For historical reasons, the scale of pottery production today is much higher in Dalupa than in Dangtalan. As more Dalupa women turned to pottery-making out of economic necessity, increasing numbers of Dangtalan women abandoned the craft as their husbands gained employment in and beyond the limits of the Pasil municipality. Market demand, environmental stress, and the entry of younger, less experienced women into Dalupa's potter workforce all contributed to these changes (Stark, 1991a; Stark and Longacre, 1993).

These technological changes in the Dalupa production system were accompanied by an expansion of the ceramic distribution system (Stark, 1993, 1994). Dalupa women developed a wider range of ceramic goods to barter or sell to customers. They sought larger and more distant markets for their wares. Traveling by foot and by truck, they reached their limits at the edges of competing pottery exchange networks and established new trade partnerships as they went (Stark, 1992). Despite these scalar changes, the Pasil system has never become a market-oriented industry like those seen in lowland areas of northern Luzon (see Scheans, 1977, for examples). The demand for traditional Pasil pottery remains steady within the river valley, and Dalupa women continue to make pots as time permits, given their other household responsibilities.

In 1987 and 1988, Dalupa potters were more active and produced more pottery than their Dangtalan neighbors did (Stark, 1993, 1995): nearly two-third ($n = 55$) of Dalupa households had active potters. In contrast, fewer than one-half (29) of Dangtalan households had active potters during the 1987–88 field season, and women from three of these households manufactured pots only during the museum collection period from April 1988 to June 1988. Research concentrated on Dalupa potters, who manufactured an average of 100 vessels a year during 1988 (Stark, 1993, pp. 125, 182–184). Potters in both Dalupa and Dangtalan make some pottery for their own use, but they have also begun to rely on pottery production for exchange to supplement their household income (Graves, 1991).

Although ceramic production activity is more intensive in Dalupa than in Dangtalan, potters in both communities are, at most, part-time specialists. Pottery manufacture for exchange is neither a lucrative nor a preferable economic activity: when interviewed, most potters expressed a strong desire to farm instead of making and exchanging pottery to feed their families (Stark, 1993, pp. 206, 207). Because Dalupa and Dangtalan potters practice varying degrees of part-time specialization, comparisons of their production scale and intensity illustrate different facets of their productive systems. One of these is raw materials selection and use. Pasil potters use a single "self-tempered" clay, and we use the term "clay procurement" to discuss raw materials selection and use.

SOCIAL BOUNDARIES AND KALINGA CERAMICS

Previous Kalinga research has identified scalar issues in social boundaries at several levels: the river valley, the region, and the village (see review in Stark, 1999). This pattern, in which social affiliation focused on the local community rather than on a larger entity like an ethnic group, was common throughout the Cordilleras until quite recently (Dozier, 1966; Hutterer, 1991, p. 21; Rood, 1991). Although Dalupa and Dangtalan are 2 km apart, they belong to two separate "regions" (following Takaki, 1977), or peace pact-holding units. Despite intermarriage and frequent interaction between the villages, Dalupa and Dangtalan have different sets of social and political alliances. Dangtalan affiliates with villages in the western half of the river valley, or Upper Pasil (Fig. 2), whereas Dalupa people align with their neighbors in villages from the eastern half of the river valley, or Lower Pasil (Aronson *et al.*, 1994). In times of tribal warfare and political campaigning, these social boundaries have been drawn clearly and can have profound implications for Kalingas' safety in work and travel (e.g., Dozier, 1966, pp. 197–238; Lawless, 1980).

Material reflections of these boundaries are evident in the pottery that Dalupa and Dangtalan women manufacture. At the broadest scale, differences are evident between vessel forms of Pasil pottery and pottery made in neighboring river valleys (Longacre, 1991; Stark, 1999). At a smaller scale, stylistic and morphological differences are evident between the two Pasil villages. Incised and painted design styles of vessels vary between the two groups of potters in subtle but measurable ways (Graves, 1985, 1991). Dangtalan potters emphasize incised decoration on all their vessels more than Dalupa potters do, and they employ different design motifs to incise their vessels (Graves, 1994, pp. 29–32). Dangtalan potters also paint the shoulder of their cooking vessels with a band of red ocher, whereas Dalupa potters do not. One innovation that Dalupa potters made in the 1980s involves the application of geometric or floral painted designs in red ocher to their water jars (Stark, 1991; Stark and Longacre, 1993). Most Dangtalan potters prefer to make their traditional style of water jars, which involves a full-body slip in ocher rather than an elaborate decoration (Longacre, 1981; Stark, 1993).

Inspection of dimensional data from Dalupa and Dangtalan suggests that each village has a unique, if subtly different, vessel shape for its meat/vegetable cooking pot (*oppaya*). Figure 3 presents box-and-whiskers plots that display the distribution of values recorded for three-dimensional attributes of 940 Dalupa and Dangtalan meat/vegetable cooking pots during the field season. Metrical morphological attributes of cooking vessels from the two villages display different ratios (Stark, 1993, pp. 267–280): Dangtalan meat/vegetables cooking pots ($n = 114$) are shorter and have wider mouths than their Dalupa counterparts ($n = 826$). A simple discriminant analysis of these raw morphological data classified the vessels to their correct village in 79% of the cases; the classification increased to 82% when we examined the vessels by their circumference/height and aperture/height ratios. Pasil consumers recognize and discuss these morphological differences by village (Aronson *et al.*, 1994, pp. 102–108; Stark, 1999).

From an archaeologist's perspective, the existence of such differences between pottery-making communities is encouraging. Cross-cultural ethnoarchaeological research (Hegmon, 1992, 1998; Sackett, 1986, 1990; Wobst, 1977), however, suggests that stylistic variation in decorative style is sensitive to temporal

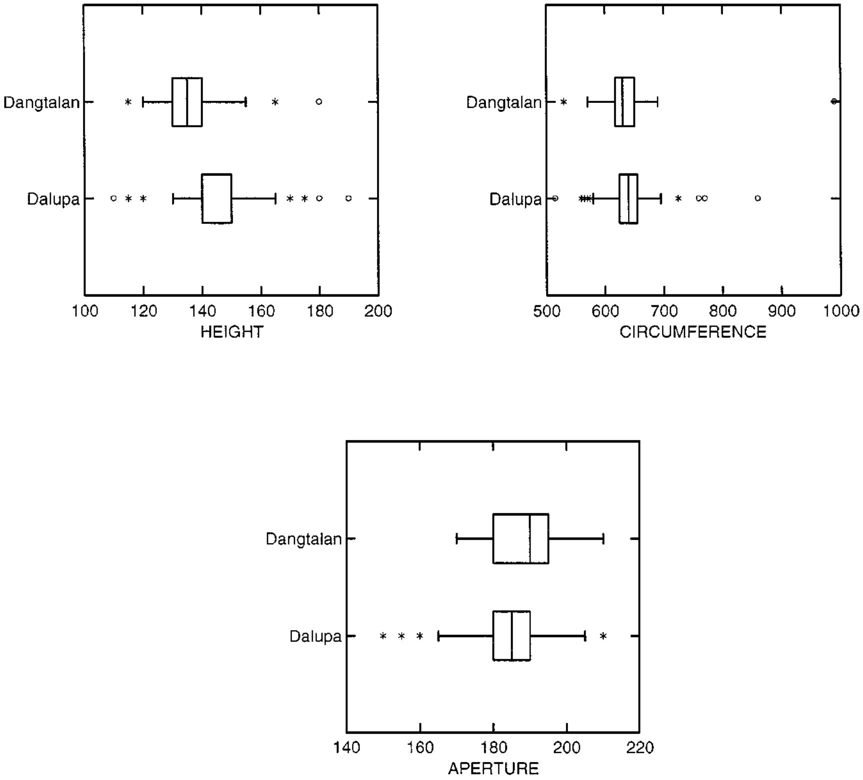

Fig. 3. Box-and-whiskers plot of dimensional attributes in Dangtalan vs. Dalupa cooking pots (Dangtalan: $n = 114$; Dalupa: $n = 826$).

changes and other social factors, and may not be the most robust indicator of long-term group affiliation. In the Kalinga case, for example, stylistic variation in the Dalupa water jars developed rapidly—over a period of 4 years—and continues to change with time. Studying various levels of Kalinga social boundaries requires us to adopt a more holistic methodology for analyzing formal variation in earthenware pottery. A technological approach (e.g., Dietler and Herbich, 1998; Gosselain, 1992, 1998; Hosler, 1996; Lechtman, 1977; Lemonnier, 1986, 1993; Stark, 1998b) allows us to study a wider range of technological variability in Pasil pottery and avoids the problematic distinction between "style" and "function" that complicate archaeological research on social boundaries.

TECHNICAL CHOICES IN PASIL POTTERY MANUFACTURE

Dalupa and Dangtalan potters generally make three kinds of pots: meat/vegetable (*oppaya*), rice cooking (*ittoyom*), and water storage jars (*immosso*).

Some Dalupa potters also make nontraditional forms or *ay-ayam* (Stark, 1991a; Stark and Longacre, 1993). Pottery-making is largely a female occupation, from the beginning to the end of the manufacturing and distribution process. Itinerant male traders visit Dalupa and Dangtalan occasionally to barter resin and ocher that they collect from upland forests. Women, however, mine and prepare the clay, and shape and fire their pottery. Non-potters (daughters, sisters, other relatives, and occasionally friends) may participate in some stages of the firing process, but few men participate in any stage in the pottery-making process.

Several production steps are involved in making Pasil pottery, from materials procurement to the application of resin immediately after firing (Longacre, 1981). Pasil potters often travel in pairs or take children along to help transport clay. Crude digging sticks or grub hoes are used to loosen clay deposits. Clay is collected in baskets or rice bags, and potters carry sufficient clay back to the village to make approximately 10 medium-sized vessels or four large-sized rice cooking pots. These sandy clays contain abundant natural nonplastics and require cleaning to remove all visible gravel during the pounding process, which takes approximately 20 min. Potters pulverize the cleaned clay, using a wooden pestle on a flat stone; they add no “temper” or nonplastic materials to the clay.

When the potter finishes cleaning and pounding her clay, she shapes a lump into a cylindrical block and begins to form a vessel. She presses her fingers into the center of the cylindrical lump, and pulls the clay away from the cylinder’s center to begin the building process. A series of coils is then added to the emergent vessel. When the vessel reaches a sufficient height, it is scraped smooth with a piece of bamboo. She then shapes the vessel’s neck and rim, using a wet cloth, and produces an everted rim. Potters let their vessels dry for a few hours and then use the paddle-and-anvil technique to expand the body into a globular form characteristic of all traditional Pasil vessels.

The initial vessel-forming sequence lasts 15–25 min, and the potter finishes shaping the pot by the end of the day. She then sets aside the vessel in a shady place to dry for 1–4 days. Drying time varies seasonally in this part of the humid tropics; the number of rainy days each month and the type and amount of rainfall affect the rhythm of Kalinga pottery production. During the hot, dry *dagon* season (March–April), a short drying time may cause cracking because of uneven drying or excessive shrinkage. When pots are inadequately dried during the wet *agilid* season (June–August), steam expands during firing and ruins pots. Because large-scale pottery drying and firing require relatively dry weather, Dalupa and Dangtalan potters make fewer pots during the rainy season than during other times of the year.

Women carry the dried vessels to a firing area—a flat, cleared location some distance from the houses—and stack the vessels for an open firing. Firing episodes often involve 15–20 vessels of different sizes and types, made by multiple potters (see also Longacre, 1974, 1981). Potters pile rice stalks, split bamboo, and (occasionally) pieces of wood on the pyramid of stacked pots, and tend the fire throughout the process. Use of a thermocouple during eight firing episodes in

Dalupa (May–June 1988) shows that a typical firing lasts an average of 48 min, and that firing temperatures rarely exceed 700°C.

The entire ceramic manufacturing process, from clay procurement and preparation to firing, takes 3–6 days. An active Pasil potter finishes between 10 and 15 vessels in a week. However, this number differs by village (because Dalupa potters are more active) and by individual (depending on household economic need and personal expertise). Across both villages, productivity also varies by season, because more potters are active during the dry season than at any other time of the year.

COMPOSITIONAL RESEARCH

This compositional study forms part of a broader research program to study sources of ceramic variability in the Pasil river valley (see also Aronson *et al.*, 1991, 1994; Graves, 1981, 1991, 1994; Stark, 1999). Three central objectives guide the examination of compositional variability in the raw materials and finished products from Dalupa and Dangtalan: (1) to explore whether detecting chemical compositional differences between two closely situated production centers in a single geological region is possible; (2) to evaluate the closeness of fit between the composition of clays from specific sources and products manufactured from these clays; and (3) to seek explanations for aspects of observed compositional variability. Answering these questions provides data to complement our extant knowledge of technological differences in Dalupa and Dangtalan pottery.

Materials Procurement and Infield Data Collection

Three strategies were used to study materials procurement and preferences: infield collection of pots, infield interviews/surveys, and postfieldwork data collection and compositional studies.[5] Part of the 1988 field season was devoted to collecting ceramics from Dalupa and Dangtalan for the National Museum of the Philippines and the Arizona State Museum (Tucson). One portion of this collection was designated for the Arizona State Museum to enlarge its extant Kalinga pottery research collection, and was used subsequently for this study. A separate portion of the collection, also housed at the Arizona State Museum, was used for use-alteration analyses by Skibo and Kobayashi (Kobayashi, 1994; Skibo, 1992, pp. 62, 63; Stark, 1993, pp. 124–130).

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[5] Data on Dalupa and Dangtalan materials selection and use were collected during Stark's fieldwork in 1987–88 for her dissertation (Stark, 1993). Compositional analyses were undertaken as part of a postdoctoral fellowship in Materials Analysis (Conservation Analytical Laboratory, Smithsonian Institution) in 1995 and 1996, in collaboration with R. Bishop. Elizabeth Miksa point-counted and characterized the mineralogical composition of Pasil clays during April and May of 1996, and undertook petrographic analysis of the INAA pottery samples in November–December 1998.

Ethnoarchaeological field research involved the collection of Kalinga pots and raw materials to fulfill the project's goal of building a comparative collection. More than 600 ceramics (pottery vessels and nontraditional forms) from Dalupa and Dangtalan were obtained during the museum collection project in 1988; most pottery vessels from this collection were sampled for the present study. Of these, most were commissioned and made during that year, and information was recorded on the producer, the month of production, and producer community in which each object was made. The museum collection project was coordinated with a series of structured interviews with potters, including a survey regarding materials procurement and use. Ethnographic interviews with potters from both production communities contain information on each potter's four most commonly used clay sources, in order of preference and frequency of usage.

The *Sources of Materials for Potters* survey was administered to a total of 104 Pasil active and inactive potters: 55 in Dalupa and 49 in Dangtalan. Generally, Dalupa potters used two clay sources during 1987–88, whereas Dangtalan potters preferred a single source. However, most potters listed between three and four sources (Dalupa mean = 3.9; Dangtalan mean = 2.3); this study used the seven most common Dalupa and Dangtalan clay sources that Pasil potters listed. In Dalupa, all sources are found in one area of terraced rice fields called Lopok, a 15-min walk west from Dalupa; the clay sources are named after their landowners (Awaga, Marcelo, Awing, Bullayao). More than 80% of the Dalupa potters use two preferred sources that are found approximately 75 m apart in another set of terraced fields. In Dangtalan, most potters reported that they used the school source, but two other locations (Lonong, Col-ang) were commonly cited as well (Aronson *et al.*, 1994; Stark, 1993, pp. 141–147). For potters in both villages, each clay source is a hole, approximately 2–3 m in diameter (depths of sources vary according to mining intensity) and may average as much as 3 m in depth.

Interviews with Dalupa and Dangtalan potters revealed preferences for clay sources based on technical and nontechnical factors that include workability of raw materials, geographic proximity, and political considerations (Aronson *et al.*, 1994, pp. 86–90, Table 1). Dalupa potters, for example, recognize two types of inclusions that cause problems in the manufacturing process: (1) white inclusions (*lanipga* or *boga*) that shrink in size but do not disappear with pounding and (2) large yellowish particles (no Kalinga name given) that potters cannot eliminate through pounding the clay and that protrude on the burnished surface of pots. Although potters believe that some clay sources are better than others, potters consider a wide latitude of clays to be usable. A series of laboratory-based tests involving workability, strength, and compositional variability corroborate this finding (Aronson *et al.*, 1991, 1994).

For Dalupa potters, social relations between potter and field owner matter as much as resource quality in selecting clay resources. Clay sources occur in the fields of individual land owners, and these fields are commonly used for irrigated rice cultivation; some are used instead for swidden agriculture. Potters use some clay sources so intensively that they cut deep tunnels into hill slopes to collect clay. This practice can—and does—exhaust clay sources in particular areas. Clay mining in rice terraces can also cause the terraces to collapse, whereas clay mining in swidden fields is less destructive. Land owners, most of whom have relatives who are potters, receive no compensation from potters for the mined clays. Some owners occasionally close fields to clay mining if they fear damage to their fields from mining activities.

Access to particular clay sources varies with time. For example, data contained in the *Sources of Materials for Potters Survey* lists the closing of 13 Dalupa clay sources since 1962, or 65% of all clay sources used. One closing occurred during October 1987, when a disgruntled land owner denied potters access to the clay source on his land and threatened to fine offenders one water buffalo, or the cost of a small house. Potters gave various explanations why he cut off access to this most popular clay source, including collusion with an envious older Dalupa potter, who wanted to damage other, more productive potters, and collaboration with wealthy Dalupa households, who wanted to recruit agricultural laborers from pottery-making households. By 1988, Dangtalan potters had steadfastly refused to abandon their most popular clay source below the village elementary school, where they had already tunneled some distance into the mountainside.

Dalupa potters select raw materials for their workability and their performance characteristics during manufacture and use. A previous study gauged the workability of different clays by their relative plasticity and is reported elsewhere (Aronson *et al.*, 1994). Dalupa potters prefer clay sources that contained the most workable clay in terms of plasticity (Aronson *et al.*, 1994, Table 5), although these same clays have the highest potential for problems with shrinkage. Most Dangtalan potters, on the other hand, preferred clay sources that exhibited no difference in relative plasticity. Some Dalupa potters stated a preference for clay scrapings from previous pots (made with the same batch of clay) for their water storage jars. These scrapings have a finer consistency than standard, cleaned clay, and potters state that water storage jars made from these scrapings are less porous than those made with standard clay. In 1988, Dalupa potters used the same clay to make nontraditional forms (*ay-ayam*) as they did for traditional pots. This pattern contrasts with materials selection in tourist-oriented industries elsewhere; in Mexico, for example, potters use lower-quality clays (such as montmorillonites) for producing smaller tourist forms of pottery than those used for culinary vessels (Arnold, 1985, p. 31). Perhaps this Kalinga pattern will change as Dalupa potters develop and refine their technology for making nontraditional forms.

Compositional Studies of Pasil Pottery

A two-pronged approach was used for compositional analysis that incorporated chemical and mineralogical characterization of Dalupa and Dangtalan clays and pots. The analysis initially used instrumental neutron activation analysis (INAA) to investigate paste-based compositional differences because of its demonstrated high sensitivity and precision (e.g., Bishop *et al.*, 1982, p. 292; Glascock, 1992, p. 12). One-inch diameter samples were drilled from 305 Dalupa and Dangtalan pots in the Kalinga pottery collection at the Arizona State Museum (Tucson). The sampling program focused on pots obtained directly from their producers (to ensure control over provenance) that were one of two traditional types: cooking pots or water storage jars. Nontraditional forms were excluded from this analysis, because observations during the field season suggested that some potters occasionally use different paste preparation strategies to make these new forms.

Changing research interests during the Kalinga Ethnoarchaeological Project's 25-year history introduced some variability into the compositional patterning evident in our study. The 1976 Kalinga pottery collection program concentrated on Dangtalan potters (few Dalupa pots are represented in the 1976 collection), when research focused on variability in pottery design; no particular interest was paid to the clay source of particular pots. The 1988 Dangtalan pottery collection program sought to supplement the 1976 Dangtalan sample with pots by new Dangtalan potters, with a continued focus on tracking design, rather than compositional, variability. Many of Dangtalan's active potters from 1976 had died by 1988, and few vessels were collected in 1988 from older potters who had been active in 1976. The 1988 work obtained a representative collection of Dalupa ceramics, but did not focus on compositional variability. Interviews with all potters whose work was collected provide a better idea of the range of clay sources represented in the sample.

Results reported here rely on analyses of 312 pots and clay samples from Dalupa and Dangtalan 305 pots and 7 clays. The Dangtalan sample includes vessels collected in 1976 ($n = 108$); vessels collected in 1988 ($n = 53$); pots commissioned from specific clay sources in 1988, called "prep-pots" in our figures ($n = 5$); and samples from the three most frequently used clay sources (School, Lonong, Col-ang) according to the *Sources of Materials for Potters* survey. The Dalupa sample includes vessels collected in 1988 ($n = 132$), pots commissioned from specific clay sources in 1988. ($n = 7$), and samples from the four most frequently used clay sources (Marcelo, Awaga, Bullayao, Awing). Although pots were collected in 1976 with a Dalupa provenance, they were excluded from this analysis to ensure analytical control because these pots were collected in Dangtalan rather than in Dalupa (i.e., their presumed village of origin).

A small sample of pots ($n = 12$) made with clay from known sources for each of the two communities was commissioned to serve as standards for the study; the sample includes six water jars (*immosso*) and six meat/vegetable cooking pots (*oppaya*). No information was collected on clay sources for the remaining 293 pots. Samples were also prepared from cleaned and pounded clay representing the seven most frequently used clay sources in Dalupa and Dangtalan (see also Aronson *et al.*, 1994). To ensure comparability between the pottery samples and the clay samples, a part-time specialist potter in each village prepared some clay from each of the seven samples as if she was going to use it for pottery manufacture. This process removed small stones and pulverized other inclusions, and was intended to make the clay samples as comparable to the pottery samples as possible in terms of raw materials preparation.

Disagreement persists between ceramic compositional analysts regarding whether the chemical signature of clay is sensitive to firing temperature (e.g., Burton and Simon, 1993, 1996; Cogswell *et al.*, 1996; Neff *et al.*, 1996), and some previous studies have used raw, rather than fired, clays in their comparisons with finished pots (e.g., Arnold *et al.*, 1991; Neff *et al.*, 1988a). To tighten analytical control in this study, each clay sample was shaped into several briquettes and placed into a cold kiln, which was then turned on. The kiln was turned off when the temperature reached 750°C (which took an average of 28.2 min); the briquettes were removed after the kiln had cooled. One thin section was made from a clay briquette from each clay source and was used for the petrographic analysis as a means of obtaining information on the parent material and served as a basis for interpreting aspects of the chemical patterning.

These samples were prepared at the Smithsonian Center for Materials Research and Education and submitted for INAA at two facilities: the National Institute of Standards (NIST) and the Missouri Nuclear Reactor (MURR). Having characterized the chemical and mineralogical composition of the clay sources and the chemical composition of the pottery, we then sampled the pots for petrographic study. Selection of the samples to be prepared for thin sectioning was based on an initial inspection of the variation within the chemical data set. A principal components analysis was carried out using the log transformed concentrations of 23 or the 26 determined elemental abundances; concentration data for K, Dy, and V were not included because of occasional missing data. The components were extracted from the variance–covariance matrix of the 23 logged elemental concentrations.

Inspection of the sample coordinates viewed relative to the first two principal components (which encompass approximately 55% of the variation) revealed a tendency for the Dalupa pottery to diverge from the Dangtalan pottery. Further, a small number of the Dangtalan specimens appeared to be compositionally different relative to most of the other pottery from that village. Samples for petrographic analysis were randomly selected from each of these three major “clusters” observed in the plot and 23 pots were redrilled to obtain thin sections for point-counting samples to characterize the mineralogy of each cluster. A total of 30 thin sections provides data for this study: 7 clay samples (one from each major source the potters reported) and 23 pottery samples. We first describe the geological environment that the Pasil potters exploited, then the petrographic analyses.

Geology of the Region and Petrographic Analyses

The Philippine Archipelago, in the western Pacific Ocean, comprises a group of more than 7000 islands near the junction of four tectonic plates (Bureau of Mines and Geo-sciences, 1982; Durkee and Pederson, 1961; Kvale, 1983). Complex interactions among these four plates have produced many volcanic island arcs bounded by deep tectonic troughs. The island arcs are mountain ranges spawned by the intense volcanic activity that accompanies the subduction of the earth's crust along plate margins. Luzon is the large island in the Phillippines, and it grew through accretion as several island arcs—each with its own distinctive geology—were tectonically welded to one another. The subparallel mountain ranges impart a linear structure to Luzon; their intervening valleys are filled with sediments eroded from the volcanic rocks of the mountains, alternating with marine sediments deposited before the valleys were lifted above sea level.

Northern Luzon has two major mountain ranges—the Cordillera Central to the west and the Sierra Madre to the east—separated by the sediment-filled Cagayan Basin. The Kalinga Foothills are found east of the Cordillera Central, on the west side of the Cagayan Basin (Durkee and Pederson, 1961). The Pasil study area is found within the southwestern Kalinga Foothills, near the eastern Cordillera Central in an area that remains tectonically active today.

Geologically, the Cordillera Central consists of volcanic and hypabyssal rocks rich in plagioclase and quartz (Divis, 1980). Thick sequences of bedded volcanics, metasediments, and silicic tuffs have been mapped along the margins of the mountains, including the Kalinga Foothills area (Durkee and Pederson, 1961; Kvale, 1983). Unfortunately, little detailed geologic work has been undertaken in the Pasil study area. Most work has concentrated on economic mineral resources of the Cagayan valley and the Cordillera Central (Kvale, 1983; Arribas *et al.*, 1995), and the Philippine government considers most of the region as unclassified forest (National Resources Management Center, 1990).

In the steeply dissected Pasil area, the rare flat areas are covered with villages today. Rugged mountain footpaths connect villages to each other, and few roads that would ease vehicular traffic have been built or maintained. The villages of Dalupa and Dangtalan are located along the Pasil river and are approximately 2 km apart. In this area, the river cuts through the sedimentary Mabaca River group and the tuffaceous Awiden Mesa formation (Durkee and Pederson, 1961), though silicic intrusive and extrusive rocks are probably found at the headwaters of the Pasil river a few kilometers to the west (Bureau of Mines and Geo-sciences, 1982, p. 39).

In the study area, soils are thin, poorly developed, and patchy in occurrence. More than 60% of the Cordillera region suffers from moderate to severe soil erosion (National Economic and Development Authority, 1992, p. III-5, Table 3.3), which has brought the surface down to weathered parent material (Kowal, 1966,

p. 417). Pedogenic clays formed on sedimentary or volcanic parent materials are the probable sources of clay for Pasil potters. Their compositions should vary according to differences in parent material, time of formation, and degree of post-pedogenic leaching or erosion. Individual clay deposits should reflect the complex interplay of these variables and may differ on chemical and mineralogical scales. Aspects of this complexity are visible in the thin sections of the pottery clays and pottery.

A total of 30 thin sections were prepared and counted from the two villages. Dangtalan samples included three clay sources and 13 pots (six meat/vegetable cooking pots, five rice cooking pots, two water jars), and the Dalupa sample included four clay sources and 10 pots (five meat/vegetable cooking pots, two rice cooking pots, three water jars) to explore the mineralogical variability in the clay sources that Pasil potters used. Thin sections were analyzed using the Gazzi-Dickinson point-counting method (Dickinson, 1970; Dye and Dickinson, 1996; Ingersoll *et al.*, 1984), as modified for application to archaeological problems (Lombard, 1987; Miksa and Heidke, 1995, 1998). All grains sand-sized and larger were counted as one of 35 point-count parameters designed to represent as much variation as possible in the data set (Table I). Grains smaller than the size of sand (i.e., silt and clay) were counted as matrix. The number of counted points ranged from 263 to 402, with a median count of 350 nonmatrix points per sample.

Petrographic analysis shows that pottery samples from Dalupa and Dangtalan are quite similar in general paste characteristics. The mean proportion of the matrix is 55% for both villages. The paste is rich in sand-sized zoned calcium plagioclase crystals, hornblende,[6] and opaque minerals (especially iron and titanium oxides). Figures 4A and 4B illustrate the texture of clay from the most commonly used clay source from each village. Volcanic rock fragments, pyroxene, and quartz are present in lesser amounts. The sand-sized minerals and rock fragments seen in both the clay source samples and the Pasil pots resemble those reported for the Awiden Mesa formation (Kvale, 1983). The primary difference between the reported composition of the Awiden Mesa tuffaceous rock units and the Dalupa and Dangtalan clays lies in the clay mineral content. Awiden Mesa units have only minor clay mineral content as thin montmorillonite or illite alteration layers on minerals (Kvale, 1983, p. 102).

Based on petrographic observation, Dalupa and Dangtalan clays contain at least 25–35% clay minerals (i.e., at least one-half to two-third of the matrix comprises clay minerals). The chemical data show that the pastes are relatively low in calcium, iron, and potassium; the bulk of these elements must be contained within the rock fragment and mineral phases. For instance, nearly all the calcium would be needed to account for the high proportion of plagioclase and hornblende found in the sand-sized fraction of the paste. Thus, the dominant clay minerals in the

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[6] In many of the samples, hornblende has been partially or wholly altered to oxyhornblende. The degree of alteration seems to relate to firing conditions.

Table I. Point-Count Parameters Used in the Petrographic Analysis of Dalupa and Dangtalan Pottery (after Lombard, 1987)

		Fine-grained rock fragments[a]							
Single mineral grains		Volcanic		Sedimentary		Metamorphic		Other grain types	
QTZ:	Quartz	LVF:	Felsic volcanic rock	LSS:	Siltstones	LMVF:	Metamorphosed felsic volcanic rock	UNKN:	Unknown. Grains are assigned to this category if they are indeterminate, unidentified, or if they occur only rarely
KSPAR:	Potassium feldspar	LVFb:	Biotite-bearing felsic volcanic rock	LSCH:	Chert	LMA:	Metamorphic aggregates such as metasediments		
MICR:	Microcline	LVI:	Intermediate volcanic rock such as latite, andesite or quartz-andesite	LSCA:	Carbonate	LMT:	Finer grained schists and gneisses		
P:	Plagioclase feldspar	LVM:	Mafic volcanic rock such as basalt or trachyte	*LSA*:	Shales, slates, and mudstones	*LMTP*:	Phyllite		
MUSC:	Muscovite mica	LVV:	Glassy volcanic rock; pyroclastic or vitrophyric rock	*SHERD*:	Sherd temper fragments (grog)	*LMSS*:	Metamorphosed siltstone		
BIOT:	Biotite mica	LVH:	Hypabyssal (shallow igneous) rocks			*LMAMP*H:	Amphibolite		
CHLOR:	Chlorite group minerals					*LMF*:	Foliated quartz aggregates		
PX:	Augite					*LMM*:	Microgranular quartz aggregates		
AMPH:	Hornblende or oxyhornblende								
OLIV:	Olivine group minerals								
OPAQ:	Undifferentiated opaque minerals								
EPID:	Epidote								
SPHENE:	Sphene								
CACO:	Undifferentiated carbonate minerals								

Note. Each parameter represents a mineral or rock type or group of similar minerals or rock types. Parameters listed in *italics* were not encountered in this data set.

[a] Rock fragments made up of sand-sized grains (such as granite) are counted as the single minerals of which they are composed; that is, a quartz grain in a granite is counted as quartz, etc.

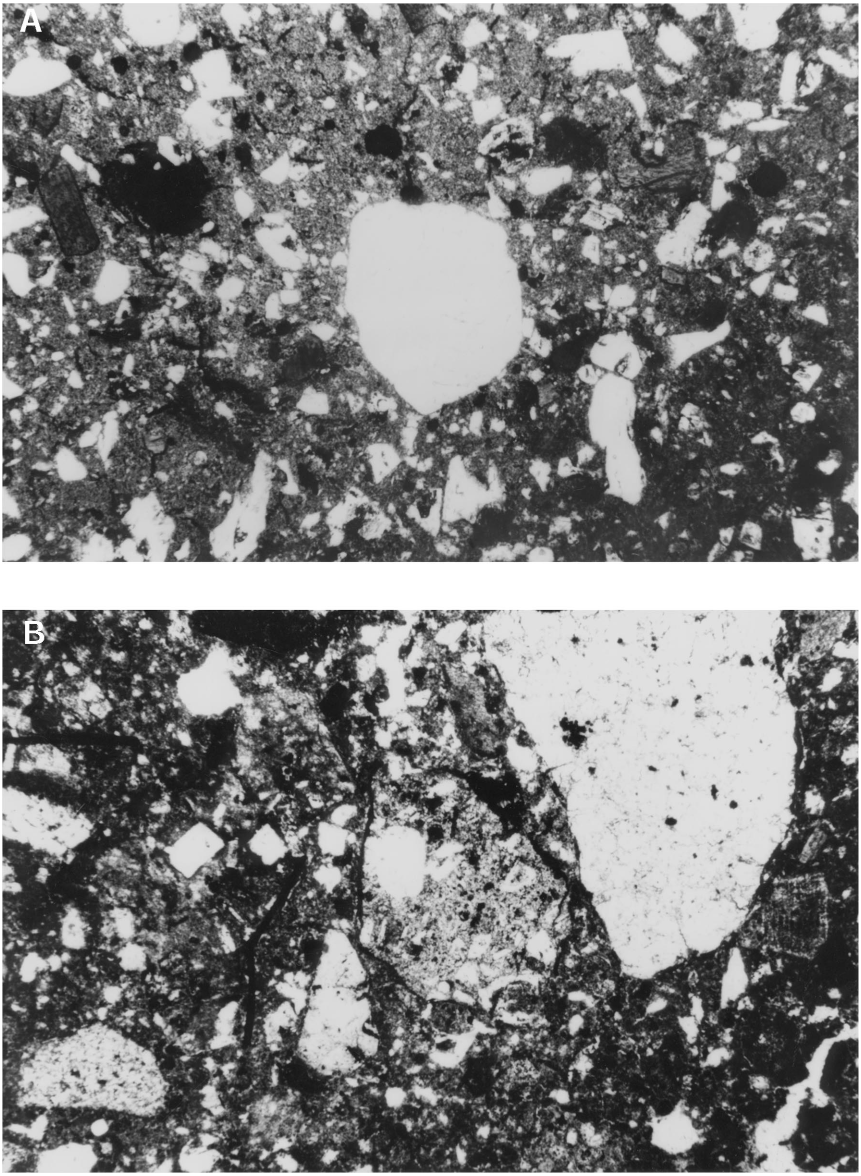

Fig. 4. Photomicrographs of samples from the most frequently used clay sources for Dalupa and Dangtalan: (A) Dalupa source (Marcelo), showing texture; (B) Dangtalan source (School), show texture. Note several volcanic grains and some plagioclase.

paste are likely to be kaolinite and halloysite, which lack cations such as calcium, iron, and potassium, and are the expected products of soil formation on volcanic parent materials under tropical climate conditions (Birkeland, 1984, pp. 178, 294).

Within this general configuration of compositional similarity, however, the detailed thin section analysis reveals small but important differences in the discrete clay sources that each village uses. These differences are visible in plots of the relative abundances of mineral grains and rock fragments (normalized in proportion to the total grains counted for each sample). Figure 5 includes a series of box-and-whiskers plots that show the percentage of plagioclase, hornblende, opaque minerals, and volcanic grains present in Dalupa and Dangtalan pots and briquettes made from clay source samples. The Dalupa samples are enriched in volcanic fragments compared with most of the samples from Dangtalan. These samples

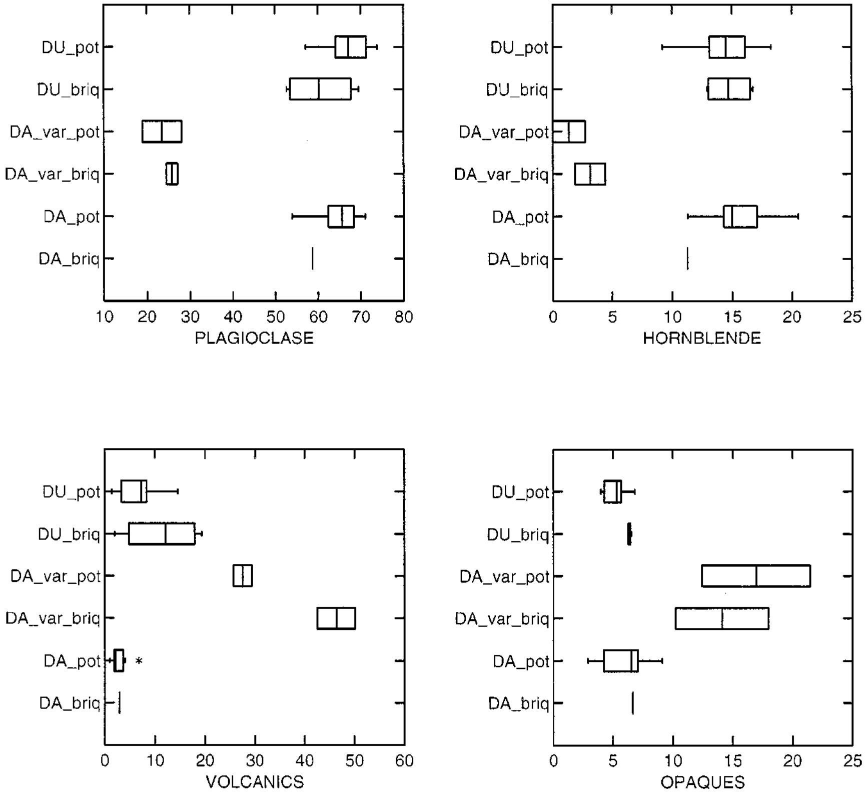

Fig. 5. Box-and-whiskers plot of relative abundances of plagioclase, amphiboles (hornblendes and oxyhornblendes), volcanic fragments, and opaque minerals in point-counted pottery samples (by village and sample type).

include a higher percentage of glassy volcanics from pyroclastic or vitrophyric rocks. Dalupa clays are otherwise quite similar to those from Dangtalan.

A minority of the Dangtalan pottery samples, and two of the Dangtalan clay samples, differ from all others. These samples, labeled as "Dangtalan Variant (DA_var)" in Fig. 5, have significantly less plagioclase and hornblende and more opaque minerals and volcanic grains than all other samples have. Interestingly, the Dangtalan Variant clay samples ("DA_var_briq" in Fig. 5) have more volcanic grains than the Dangtalan Variant pottery samples have. The volcanic grains tend to be coarse sand to granule-sized (see Fig. 4B). It may be that individual processing variation during the clay preparation stage led to removal of fewer large volcanic grains from the commissioned clay samples than from the clays subsequently used for actual ceramic manufacture.

INAA Studies

Although INAA has been a highly useful technique for differentiating among pottery prepared from different resources at an interregional level, it remains a matter of empirical demonstration to see how sensitive it is when dealing with ceramic products made from resources separated by only short distances. Distance, of course, is not the only variable being modeled: geological complexity, social organization of potting activity, production step procedures, sampling bias, and analytical error are among many factors that must be considered in compositional characterization studies. Research reported by Bishop and his colleagues (1988) demonstrated the separation of pottery produced at Hopi villages situated along Antelope Mesa at 8 km apart from each other. Hopi pottery differs from Dalupa and Dangtalan pottery because the Hopi potters manufacture their pots from a kaolin clay that is relatively free of nonplastic inclusions. Archaeological ceramics with fine pastes (and little visible temper) thus can yield clear compositional patterning (e.g., Bishop and Rands, 1982).

For a variety of reasons, technological and otherwise, ancient culinary and utilitarian ceramics were commonly made using "sand-tempered" rather than fine pastes (e.g., Rice, 1996a, pp. 138–142; Rye, 1976). In many assemblages, these "sand-tempered" ceramics are often found in higher numbers than are fine-paste ceramics. Interpreting the chemical patterning of sand-tempered ceramics is more complex than that of fine wares (Bishop, 1980, pp. 49–55; Neff *et al.*, 1988b). The "naturally tempered" nature of the clay used in Pasil pottery, with abundant volcanic lithic fragments and accessory minerals, is a potentially more difficult situation for chemical characterization. For the present paper, the focus of INAA application is the level of observable differentiation between the two Kalinga villages that are located approximately 2 km apart.

Although most of the samples consist of meat/vegetable cooking vessels, sampled Dalupa water jars commissioned from particular clay sources were also included. These water jars give us control samples to establish compositional standards against which other vessels with less well-established provenance (i.e., to the village level) can be compared. A total of 312 samples of Pasil pottery and clay sources was successfully subjected to INAA. Sample preparation, irradiation, and counting configuration generally followed procedures described by Glascock (1992, pp. 12–15). Short irradiations and counts were carried out at the MURR facility. Longer irradiations with subsequent intermediate and long counts were carried out at MURR and at the Smithsonian Center for Materials Research and Education analytical facilities at NIST. The same comparator standard, Coal Fly Ash Standard Reference Material 1633A, was used to quantify elemental concentrations at both facilities, thus requiring no interlaboratory normalization of data.

Statistical analysis of the MURR–NIST INAA data set used 23 logged elemental concentrations and suggests that chemical differences are evident at the community level in both the raw materials and the finished products. A cluster analysis, using both average and complete linkage of a matrix of Euclidean distances, revealed three clusters. Most of the Dangtalan samples separate from the Dalupa samples into two discrete clusters, as suggested by the principal components analysis. A smaller, loose cluster contains only Dangtalan samples. These samples that diverge chemically from the main body of Dangtalan samples are described as the “Dangtalan variant” group, and consist of two clay sources (School, Col-ang) and several pottery samples. The observed clusters, some intervillage overlap notwithstanding, suggest that potters from each village used clay sources that can be distinguished according to chemical parameters.

Subsequently, the nature of these initial village separations was investigated using the principal components analysis that had been the basis for selection of samples for petrographic analysis. Five components with eigenvalues greater than 1.0 had been extracted, representing 79% of the total variation. The elemental loadings for the extracted components are listed in Table II. In the bivariate principal component plots described in the next paragraph, symbols have been given to the data points to show the village where the pottery was made: Dalupa, Dangtalan, and the Dangtalan variant. No refinement of the data pattern, through removal of outliers or group reassignment, has taken place.

The plot of the data concerning the first two principal components (Fig. 6) shows the data sets by village (Dalupa [DU] vs. Dangtalan [DA]), nature of sample (fired clays vs. finished pots), and year of collection (1976 vs. 1988). Although these are not statistically refined compositional reference groups (see Bishop and Rands, 1982), 95% confidence ellipses have been calculated for the Dalupa and Dangtalan samples as a heuristic means of calling attention to the extent of village-specific separation, even in only two dimensions. The ellipse for the Dangtalan pottery is calculated for the ceramics obtained only in 1976, which occupy a relatively compact area of the plot and are distinct from the Dalupa pottery. In comparison, the pottery from Dangtalan collected in 1988 shows more heterogeneity in the plot,

Table II. Principal Component Loadings for INAA Data

	PC 1	PC2	PC3	PC4	PC5
La	0.8125	−0.2456	0.3510	0.1411	−0.1432
Lu	0.8876	0.1930	0.0168	0.2071	−0.1269
Sm	0.8874	0.0890	0.3558	0.1326	−0.0895
Yb	0.8634	0.2428	0.2861	0.0861	−0.0755
Ce	0.0649	−0.7830	0.0260	0.4205	0.1791
Co	0.1096	−0.6734	−0.5536	−0.2371	0.0221
Cr	0.8551	0.0333	0.0504	−0.3977	0.0167
Cs	0.4920	0.3933	0.0715	−0.5409	0.2026
Eu	0.8496	0.0207	0.3784	0.1532	0.0645
Fe	0.6375	−0.1221	−0.4168	−0.3051	0.2171
Hf	0.3107	−0.2657	0.1949	−0.0470	0.7427
Sb	0.8076	0.3374	−0.0355	0.1150	0.0434
Sc	0.8476	−0.3150	−0.1062	−0.2131	0.0552
Ta	0.2010	−0.8752	−0.0769	−0.0231	−0.1770
Tb	0.6333	0.0789	0.2123	0.2699	0.1665
Th	0.0145	−0.8329	−0.0332	0.4134	0.1249
Al	0.5559	0.3694	−0.6053	0.3266	−0.0318
Ba	−0.4223	−0.0548	0.0654	0.4794	0.2084
Ca	−0.3134	0.8076	−0.1554	0.1984	0.1574
K	0.4700	−0.4128	0.0221	0.0233	−0.3879
Mn	0.3662	0.3037	−0.7941	0.2151	0.0211
Na	−0.0409	0.6841	0.1786	0.2547	−0.0266
Ti	0.5943	0.0897	−0.6653	0.1896	−0.0056

Note. Percent of total variance explained: 36.1, 20.3, 11.2, 7.5, 4.5. Cumulative variance explained: 36.1, 56.4, 67.6, 75.1, 79.6.

some of it lying intermediate between the Dalupa and Dangtalan “groups,” with some samples overlapping with the composition of the Dalupa specimens. The samples designated as the Dangtalan variant diverge toward the lower right-hand corner of the plot.

The mean concentrations and standard deviations for these three clusters are given in Table III, which includes all Dalupa and Dangtalan pottery but excludes clay source samples. The tendency shown for the chemical separation of the Dalupa and the Dangtalan pottery in the plot reflects the influence of the rare earth elements (iron, scandium, titanium) on the first principal component. These are the elements whose major expression in pottery usually lies in the clay fraction of ceramic paste. The second principal component is more difficult to interpret, which is based on the chemistry alone. However, when the loadings are viewed in the perspective afforded by the petrographic analysis, the strong thorium loading, in particular, appears to reflect the more abundant volcanic-derived fragments in the Dalupa and Dangtalan variant samples and the low plagioclase abundance in the Dangtalan variant (Fig. 6). Figure 7 plots the data concerning components 1 and 3 and reveals even less intervillage overlap because fewer of the Dangtalan pots from 1988 are observed to lie within the 95% confidence ellipse drawn around the Dalupa pottery. However, again the heterogeneous nature of the 1988 Dangtalan pottery

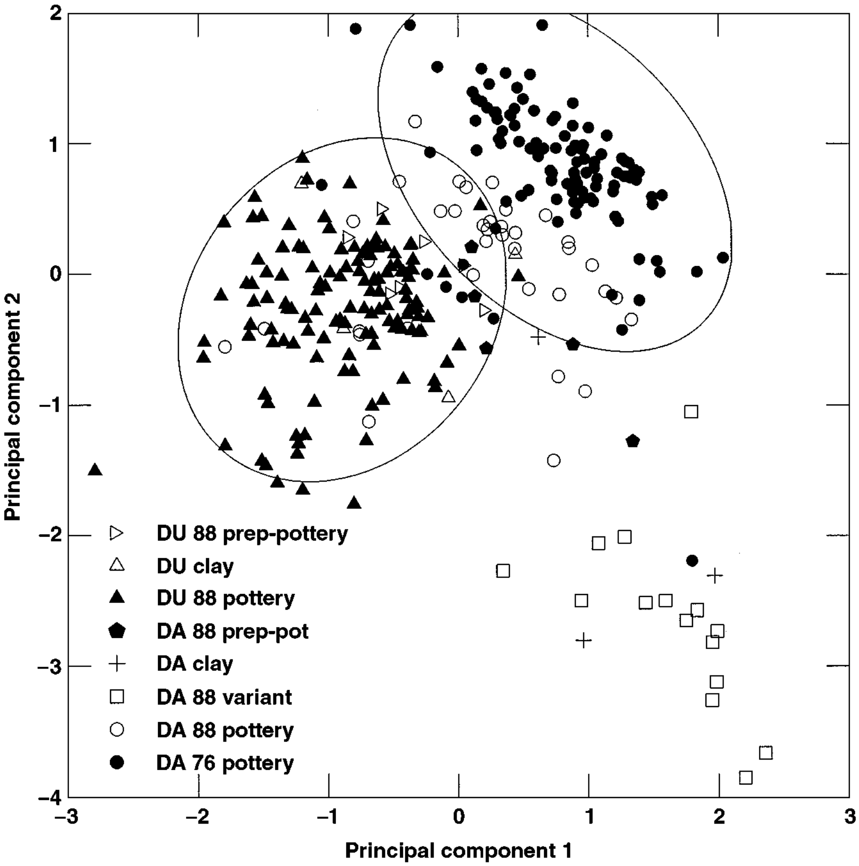

Fig. 6. Plot of principal components 1 and 2 by village, nature of sample, and year of collection.

is evident, in contrast with the clumping of the 1976 samples from the same village.

Although the principal components analysis reveals variation in a multivariate space, the strong tendency toward site-specific differentiation is also observable, especially with respect to chromium values (Fig. 8). In fact, chromium, in combination with several rare earths (scandium, thorium), separates most of the samples according to village. The bivariate plot of chromium and tantalum (Fig. 8) is used here because it also shows the divergence of the Dangtalan variant samples.

Little has been said thus far about the analyses of the fired clays. Overall, their mineralogy resembles pottery samples, but the fired clays contain more abundant clastic fragments, and thus often do not chemically covary closely with the pottery. In Fig. 8, the pattern of deviation of the Dangtalan clays from the main body

Table III. Elemental Concentration Means and Standard Deviation for Major Divisions of the Data Set ($n = 293$)

Element	Dangtalan mean concentration $n = 146$	Dangtalan variant mean concentration $n = 15$	Dalupa mean concentration $n = 132$
La	11.10 (15)	18.90 (10)	9.04 (14)
Lu	0.279 (20)	0.337 (14)	0.184 (20)
Sm	3.28 (17)	4.20 (13)	2.14 (14)
Yb	1.86 (18)	1.98 (15)	1.29 (14)
Ce	28.10 (12)	41.00 (13)	31.00 (11)
Co	15.20 (12)	20.30 (9)	16.50 (13)
Cr	15.00 (27)	17.40 (14)	5.78 (35)
Cs	1.45 (25)	0.67 (40)	0.86 (24)
Eu	1.05 (13)	1.28 (11)	0.78 (12)
Fe%	5.10 (12)	5.59 (7)	4.58 (12)
Hf	3.21 (15)	3.75 (23)	3.03 (16)
Rb	11.00 (40)	24.00 (14)	9.00 (39)
Sb	0.272 (42)	0.213 (42)	0.111 (39)
Sc	12.70 (11)	16.30 (10)	10.60 (9)
Ta	0.241 (31)	0.657 (14)	0.271 (15)
Tb	0.538 (32)	0.573 (35)	0.385 (25)
Th	2.04 (11)	3.01 (11)	2.33 (10)
Al%	11.20 (15)	10.60 (13)	9.61 (22)
Ba	238.00 (25)	222.00 (25)	324.00 (22)
Ca%	3.20 (18)	1.50 (24)	3.00 (12)
Dy	2.35 (35)	2.13 (26)	1.42 (25)
K%	0.341 (45)	0.75 (18)	0.305 (34)
Mn	1250.00 (17)	1140.00 (13)	1180.00 (23)
Na%	2.00 (14)	1.51 (18)	1.84 (15)
Ti%	0.33 (25)	0.37 (18)	0.29 (26)
V	147.00 (19)	168.00 (15)	122.00 (27)

Note. Commissioned ("prep-pot") and clay sources are excluded from this table. Village-specific compositional groups; not statistically refined or evaluated. Mean concentrations reported in parts per million except for those indicated as percent. Standard deviations (given in parentheses) expressed as a percentage of mean value.

of Dangtalan pottery samples is in the same direction as the deviation of the Dangtalan variants. The petrographic data also shed information on this problem. To the extent that the two point-counted samples from these "variant" specimens are representative, the Dangtalan clay samples can be interpreted as chemically different from the pottery because they contain more numerous volcanic lithic fragments than the pottery do.

However, the Dangtalan clay that is more similar to the Dalupa clays is also similar to the bulk of the Dangtalan pottery. In comparison, a closer correspondence exists in the chemical signatures of Dalupa clay samples and Dalupa pottery. Similarly, the mineralogical composition of Dalupa clay samples is very close to the mineralogy of the Dalupa pottery. Thus, although relatively few Dangtalan pots cluster with Dangtalan variant clay source samples, the ethnographic sample resulted in the collection and analysis of two variant clays out of the three Dangtalan clays sampled.

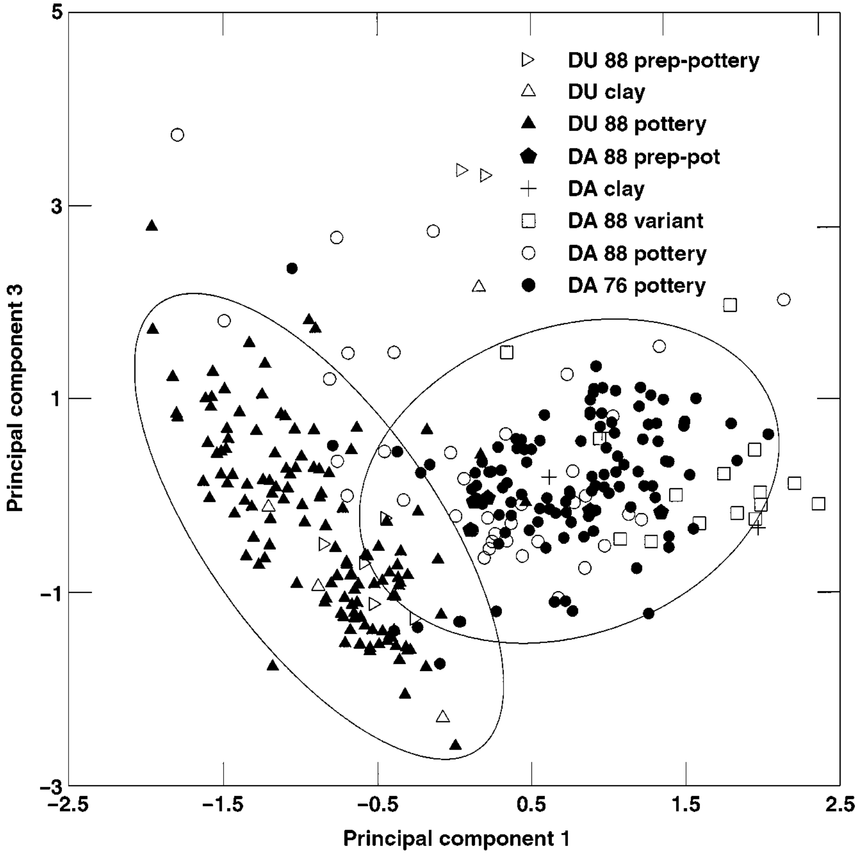

Fig. 7. Plot of principal components 1 and 3 by village, nature of sample, and year of collection.

We offer several observations through examination of the Kalinga compositional data. The first (evident in Figs. 6 and 7) concerns a correspondence in patterning between clay composition and the composition of pots made with those clays. The elemental composition of Kalinga pottery reflects the composition of its constituent clay fairly well, and particularly for the Dalupa sample. Even with the Dangtalan pottery, the differences between the pottery and clay are readily attributable to observed differences in the amount of volcanic derived fragments. In multivariate statistical space, vessels made with clay from a particular raw material source cluster with the clay source. One reason for this concordance between Kalinga clays and finished products may lie in the fact that Kalinga potters use a single self-tempered clay (rather than a manually mixed combination of discrete clays and nonplastics) to manufacture their pottery.

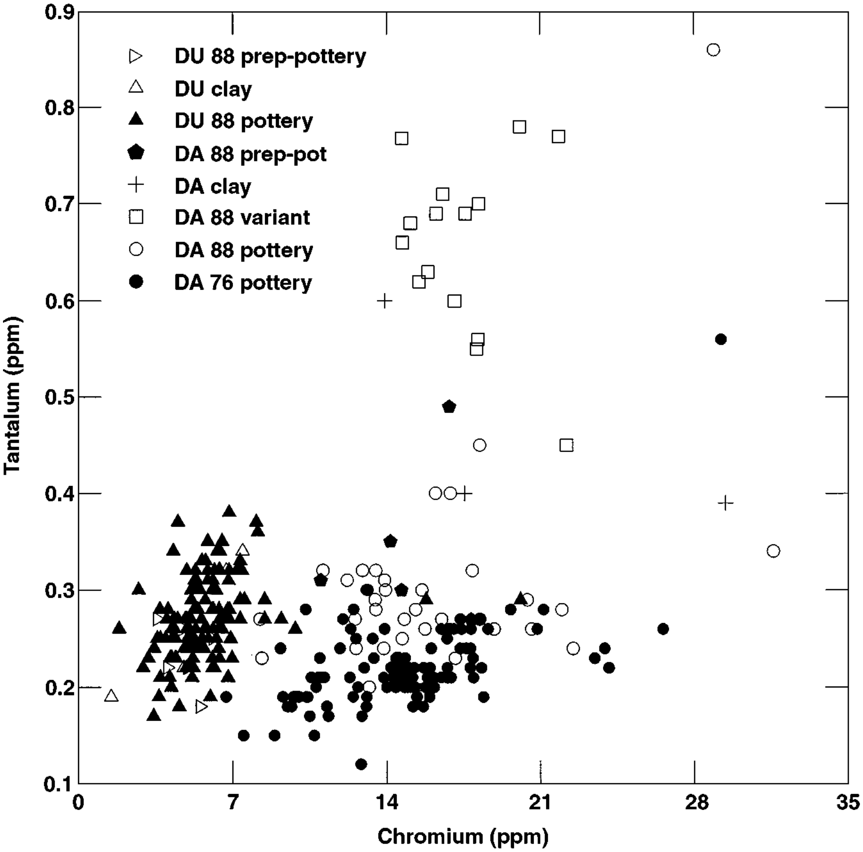

Fig. 8. Plot of chromium and tantalum elemental values by village.

As previous studies have shown (e.g., Arnold, 1992; Bishop, 1992, pp. 167–169; Neff *et al.*, 1988a, p. 339), compositional variation in a particular ceramic assemblage reflects a combination of natural processes that affect clay composition and cultural practices inherent in clay preparation. Other studies that have found less concordance between clay sources and finished products analyzed ceramics that potters manufactured by combining kaolinite paste with volcanic temper (e.g., Arnold *et al.*, 1991; Neff *et al.*, 1988a), while Kalinga potters use a self-tempered clay. Ceramics from some other pottery-making traditions pattern much better (e.g., Druc and Gwyn, 1998) for reasons that we do not yet fully understand.

A second finding from this study is that chemical compositional analysis can identify very fine differences in clay composition and facilitate studies of intraregional interaction (see also Bishop, 1980). Ethnoarchaeological research in both Dalupa and Dangtalan has documented similar steps in the manufacturing sequence that might potentially affect ceramic composition. Pasil potters procure and prepare their raw materials, using similar techniques and tools. We thus conclude that compositional patterning reflects localized geological differences in the raw materials and products of these two Kalinga villages. A few earlier studies of contemporary pottery-making communities have sought similar levels of spatial resolution in compositional analysis (e.g., Burton and Simon, 1993, pp. 53–55; Druc and Gwyn, 1998). Moreover, some previous characterization studies, using prehistoric ceramics from the American Southwest (e.g., Bishop *et al.*, 1988; Harry, 1997; Triadan, 1997; Zedeño, 1994), have identified intraregional differences in chemical composition. In the Kalinga case, compositional differences exist in the products of two pottery-making villages that are located only 2 km apart—even within a region of complex geological diversity.

The use of petrographic and chemical approaches in the Kalinga study further supports the possibility that characterization studies of archaeological ceramics can reach higher degrees of spatial resolution than archaeologists generally attempt. Logistical obstacles like cost, among other factors, have restricted most researchers to the use of either chemical or mineralogical techniques, despite a longstanding recognition that combining the approaches yields better results (e.g., Arnold, 1980, 1981; Rye, 1981, pp. 46–53; Shepard, 1965, pp. ix–xi; Tite, 1999). Ceramic studies that combine these two approaches have begun to produce more holistic understandings of compositional variability in both the New World (e.g., Bishop *et al.*, 1988; Harry, 1997; Rands and Bishop, 1980; Triadan, 1997; Zedeño, 1994) and the Old World (e.g., Adan-Bayewitz and Perlman, 1985; Wieder and Adan-Bayewitz, 1999).

As the number of archaeological ceramic characterization studies expands, so, too, does the efficacy of compositional techniques: sample sizes have grown, and more attention is paid to sampling and preparation techniques and data analysis. The increasing popularity of compositional studies in archaeological research underscores the pressing need to undertake ethnoarchaeological studies which afford the analytical control that archaeological research lacks. Ethnoarchaeological research, undertaken in a variety of geological settings and a variety of organizational contexts, is one approach that will help archaeologists to evaluate the full potential of such chemical compositional techniques. The linking of pottery to clay resources, as in the Kalinga case of clays that have the textural properties of tempered ceramics, provides a greater assurance of site-specific attribution in provenance research using archaeological ceramics.

DISCUSSION AND CONCLUSIONS

The foregoing sections have described multiple strategies for studying Kalinga social boundaries in the material culture patterning of Pasil pottery. In so doing, our study has emphasized an approach that examines variability at several stages in the ceramic manufacturing sequence. As Rice (1996b, p. 169) noted, ceramicists have begun to recognize that cultural choices are encoded in pottery, along with geochemical information. Our study identified differences in paste composition between Dalupa and Dangtalan clays and pottery. Results of our compositional analysis thus parallel previous research that has examined village-based differences in vessel morphology and decoration. Analyzing any single dimension of variability described in this study (e.g., painted or incised decoration, morphology, composition) might yield useful patterning regarding intravalley differences. Social boundaries in material culture patterning, however, are most pronounced when we use a multipronged approach. One promising result of this controlled study is that compositional groups in the Kalinga data set correlate well with social groups in the Pasil river valley: on several social and political levels, the communities of Dalupa and Dangtalan remain distinct (see also Aronson *et al.*, 1994). This study suggests that it may be possible to characterize sand-tempered archaeological ceramics to track different levels of interaction as well.

One methodological objective of our study lay in evaluating the concordance between samples of pottery and samples of raw materials. Compositional differences in the Dangtalan samples from 1976 and 1988 beg the question of whether this discrepancy reflects a relationship between paste homogeneity and changing modes of production organization. Many previous studies (see review in Kvamme *et al.*, 1996) suggest that production intensity is reflected in different forms of product standardization, or “the relative degree of homogeneity or reduction in variability in the characteristics of the pottery or [to] the process of achieving that relative homogeneity” (Rice, 1991, p. 268). Future research should test the hypothesis that the heterogeneous chemical patterning in the 1988 sample reflects a decline in Dangtalan ceramic production scale from 1976 to 1988.

Despite the burgeoning activity in ceramic compositional research in recent decades, archaeologists have devoted inadequate attention to building middle range theory that integrates human behavior into the ceramic production process (see also Rice, 1996b, p. 169). One of the most important contributions of this study is its combination of quantitative petrographic and chemical approaches to explore chemical variation as a function of both natural and cultural sources of variation. The use of quantitative petrographic techniques (e.g., Dye and Dickinson, 1996; Miksa and Heidke, 1995, 1998), rather than qualitative techniques, increases the precision of our patterning.

Ethnoarchaeological and experimental research has documented a range of factors that affect the relationship between the composition of raw materials and that of finished products (e.g., Arnold, 1985; Arnold *et al.*, 1991; Aronson *et al.*, 1991, 1994; Bishop *et al.*, 1982; Dietler and Herbich, 1998; Gosselain, 1994, 1998). Few ethnoarchaeological studies, however, have attempted to study both chemical and mineralogical sources of variation at similar degrees, in part for logistical reasons (e.g., Druc and Gwyn, 1998; Neff *et al.*, 1988a). Still fewer archaeological studies have used both approaches for the same reason. The power of this combined approach is well demonstrated in the analysis of the Pasil pottery, where the analysis of pottery samples (some of which are control samples) and fired clay briquettes provide a level of analytical control that is rarely found in such research. In the Pasil case, we benefit from using an approach that not only examines boundaries through stylistic studies, but also examines other aspects of the technological sequence of pottery manufacture. Exploring relationships between compositional variability in raw materials and goods produced using these raw materials also has important methodological implications for archaeological research.

Few ceramic studies examine compositional variability in raw materials and finished products in an ethnographic setting. We have tried to demonstrate here that ethnoarchaeological studies are particularly useful for understanding cultural sources of variation as they affect the compositional patterning that instrumental techniques identify in archaeological ceramics. Clearly, ethnoarchaeological approaches provide an analytical luxury that is not afforded to those working only with archaeological ceramics. Nevertheless, this analysis also has theoretical and methodological importance for such archaeological studies, and some methods are directly applicable to the study of archaeological assemblages (e.g., Chilton, 1998). Although demanding, the incorporation of compositional analysis, including both petrographic and chemical, allows social boundaries to become more visible and provides better comparative data for archaeologists, who benefit from combining both approaches in their analysis.

Long-term projects like the Kalinga Ethnoarchaeological Project demonstrate the value of longitudinal ethnoarchaeological research. Even the longest ethnoarchaeological studies of ceramic systems cannot equal archaeological time, but they allow archaeologists to monitor different scales of change in technological systems and to track changes in distributional networks to build better models. In the Kalinga project, investigators have embraced new analytical techniques that were previously unavailable. It is hoped that this project continues providing new avenues of study for new generations of researchers in the decades to come.

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