A PRELIMINARY GEOCHEMICAL CHARACTERIZATION OF RELIEF CERAMICS FROM THE NADIN NECROPOLIS

A Thesis

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by

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ABSTRACT

This paper analyzes a collection of Hellenistic mold-made relief vessels discovered during the 2018 season of the Nadin-Gradina Archaeological Project through non-destructive portable x-ray fluorescence (pXRF). Archaeometric analysis allows for a reconsideration of previous conclusions about the origins of these vessels and possible trade connections at the site of Nadin. The goal of this study is to determine potential source groups for these vessels through their geochemical composition. While the suitability of pXRF as an analytical tool for archaeological ceramics has been debated, the qualitative design of this research project and the physical characteristics of these vessels allow pXRF to be utilized successfully. Statistical analysis of pXRF results indicate the presence of multiple source groups represented in the samples. The attribution of most of these samples to a smaller number of potential source groups indicates a strong connection between the residents of Nadin and at least two production centers. This thesis is intended to suggest preliminary conclusions about potential sources and suggest areas of further study to better understand the trade connections that brought these vessels to Nadin and the role of Nadin in the Ravni Kotari landscape.

BIOGRAPHICAL SKETCH

Elizabeth Gaj Proctor received her BA from the University of Maine in 2017, majoring in Anthropology and minoring in Art History and Medieval and Renaissance Studies. She joined the Cornell Institute of Archaeology and Material Studies in the Fall of 2017 as an MA student. She first excavated at the site of Nadin during the 2015 field season with the University of Maine field school, and later returned in the spring of 2018. While her undergraduate research focused on the intersection of heritage, tourism, and legend with archaeology in Great Britain, her graduate work at Cornell University explores her interest in archaeometry, especially in the application of pXRF to archaeological ceramics.

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Introduction

Applications of portable X-Ray fluorescence (pXRF) to archaeometric analyses of ceramic material fall broadly into two categories: quantitative approaches focused on matching vessels directly to potential sources of raw material (e.g. Scott et al. 2018; Speakman et al. 2011), and qualitative approaches focused on creating groups of vessels with similar geochemical signatures (e.g. Emmitt et al. 2018; Ikeoka et al. 2012). This thesis undertakes a qualitative analysis of mold-made ceramics from the hillfort of Nadin, located on Croatia's Ravni Kotari coastal plain, in the heart of the ancient region of Liburnia. (Figure 1). In contrast to quantitative geochemical studies, the goal is not to quantify amounts of elements in the ceramic fabric in order to link vessels to a potential clay source, but rather to describe relationships between vessels in order to identify groups that are geochemically similar.

A pXRF study of mold-made vessels at Nadin provides an archaeometric assessment of prevailing opinions that these were produced in nearby Zadar, approximately 25 km from Nadin, or other East Adriatic production centers (Batović and Batović 2013:184). Such local production has long been assumed as a result of the discovery of a single mold in Zadar (Vrkljan, Konestra, and Ugarković 2018:1). At the same time, other artifacts at Nadin demonstrate trade connections that extended beyond the eastern Adriatic coast. Thus, it is important to consider how Nadin's role in the regional economy may have facilitated such a large collection of these vessels at the site. This thesis analyzes a large assemblage of mold-made ceramics from Grave 105 at Nadin, a sealed mortuary context that appears to have been in use during roughly the last two centuries BCE and the first century AD, in order to assess geochemical variability as an indicator of clay source groups suggesting potentially different workshops. The compositional data can give us some indication of the diversity of potential clay sources for these vessels, which has implications for the number of production sources present in the sample. The prevalence of certain source groups in the data may indicate strong trade connections and support local production, while the presence of outliers may indicate imports from greater distances.

Figure 1: Selected Liburnian sites and Adriatic Hellenistic Production centers mentioned in this thesis. Map created by Elizabeth Proctor, 2019.

Mold-made relief vessels are a particularly suitable artifact class for examining trade connections. Previously identified production centers for this style of vessel span the Mediterranean, providing a range of different geochemical signatures that may be present in the data. The focus here is on Nadin's relief pottery as potential indicators of the economic connections that developed between Nadin and other sites on the

Adriatic coast and beyond during the Late Liburnian period, from the fourth to first centuries BCE and at the beginning of the Roman period, beginning roughly in the mid-second century BCE in Dalmatia.[1] The last two centuries BCE are often the least represented in the archaeological record in Dalmatia due to later Roman construction at key sites (Čače and Milivojević 2017:436), meaning that further analysis of Nadin's role in the Liburnian landscape can offer insight into the role of contemporary hillfort sites in the Ravni Kotari during the convergence of local Liburnian cultures of ceramic consumption and burial practices with broader Roman and Hellenistic cultural practices.

Hellenistic Mold-Made Relief Ceramics

The term "Hellenistic mold-made relief bowls," or "*helenistička relefna keramika*," Hellenistic relief pottery, refers to ceramic vessels with raised designs that were referred to as "Megarian bowls" in older literature (Kamenjarin 2014:132; Brusić 1999; Rotroff 1982). It should be noted that their designation as "Hellenistic" is largely in reference to the geographic region and cultural zeitgeist in which they were created and gained popularity, rather than a strict definition of their temporal use. While previous research suggested a start date between 240 and 220 BCE, with Susan Rotroff arguing for a possible invention in 224/223 BCE, Rotroff's current research supports a start date between 226 and 211 BCE in Athens (Rotroff 2006:357, 360–

[1] The period in question (the last two centuries BCE and first century AD) falls under several established chronologies for the Adriatic and the wider Mediterranean. In Liburnia, this period represents the transition from the Late Liburnian period (also called Last or Fifth Phase Liburnian) lasting from 400-150 BCE and the Roman period in Dalmatia, 150 BCE to CE 500 (Chapman, Shiel, and Batović 1996:7). This period is also included under the general definition of the Hellenistic Period, lasting roughly from 323-31 BCE.

361). However, following their initial creation, these mold-made vessels did not reach their peak of production in Athens until approximately 180-186 BCE, and they became less popular in Athens in the first century BCE (Rotroff 2006:373). This loss of popularity in Athens does not seem to have hindered their production elsewhere and possibly by the end of the third century BCE production of mold-made bowls spread to Corinth and Argos, and production centers later appear across the wider Mediterranean (Rotroff 1982:10).

These mold-made vessels were decorated with four common categories of motifs: pine cone (scales) (Figure 2), floral (non-overlapping petals and leaves) (Figure 3), imbricate (overlapping petals and leaves) (Figure 4), and figural scenes (human or animal representation) (Figure 5) (Rotroff 1982:15). Signatures of the potter, or more likely the production workshop, appear occasionally on examples of relief pottery and can aide in the determination of the vessel's production center (Rotroff 1982:40). Their popularity may have stemmed from accessibility, as the

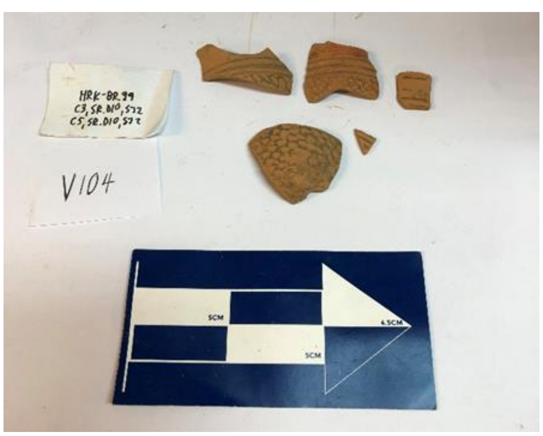

Figure 2: Example from Nadin of "pinecone" decoration. Photo credit: Elizabeth Proctor, 2018.

Figure 3: Example from Nadin of "floral" decoration. Photo credit: Elizabeth Proctor, 2018.

Figure 4: Example from Nadin of "imbricate" decoration. Photo credit: Elizabeth Proctor, 2018.

Figure 5: Example from Nadin of "figural" decoration. Photo credit: Elizabeth Proctor, 2018.

molded technique could meet market demands for relief vessels because molds could make “countless identical copies” (Kamenjarin 2014:132–133).

Zdenko Brusić’s 1999 analysis is the most in-depth study of these ceramics for the Liburnian region. Brusić’s work sought to better understand not only the origins and importation of these vessels, but the potential motivations behind those who used them in Liburnia and what they used them for – funerary ritual, status symbol, or both (Brusić 1999:2). Brusić’s work consists largely of a descriptive catalog of mold-made relief vessels found at sites throughout Liburnia, classified to different production centers on the basis of typology and decoration (Brusić 1999:2). According to Brusić, mold-made relief ware makes up a large portion of imported pottery in Liburnia, noting that mold-made vessels were a “luxurious and more expensive ceramic import” in contrast with the “bad quality of native pottery” (Brusić 1999:1). Past attributions of

Hellenistic pottery to local production sites were made on the basis of clay color, fabric texture, and vessel shape (Miše and Šešelj 2008:6), as well as the underlying assumption that these styles were imported to suit the demands of a "Hellenized" local population (Brusić 1999:1).

The shapes of relief ware found in Liburnia, for example kraters, chalices, cups, skiphoi, etc., are those most commonly associated with drinking, and coupled with common decorations of floral vines and Bacchic motifs, the function of these vessels seems tied to serving and drinking wine (Brusić 1999:48). Ivanka Kamenjarin connects the appearance of Hellenistic mold-made cups at the ritual sites of Nakovana, Palagruža and Cape Ploča to the "ritual libation of wine" (Kamenjarin 2014:136). Charles Barnett argues for a view of the adoption Hellenistic drinking vessels not only as indicators of a surge in trade between Dalmatia and the wider Mediterranean and the adoption of wine consumption, but also the changing role of these vessels in indicating political power within local groups (Barnett 2014:19). To better understand the implications of the presence of these vessels at Nadin, it is important to first contextualize the Liburnian culture in the Adriatic during the late second century BCE to first century CE through their history of interactions with Greek and Roman cultural influences.

Liburnian Context

The place-name "Nadin" refers to a collection of sites made up of several hillforts, mortuary structures, and stone enclosures. Nadin-Gradina, or just Gradina, is the largest of these hillforts. As noted by Danijel Dzino, the challenges to understanding the history of Liburnian and other indigenous eastern Adriatic cultures stems not only from an “insufficiently studied and excavated” archaeological record of the pre-Roman era, but also a dearth of historical sources (Dzino 2012:72–73). The literary evidence available consists of largely anachronistic comments about Liburnian society before Roman conquest and ethnographic works, reflecting both ancient and modern biases towards indigenous cultures in the Classical world. The author Caius Iulius Solinus even identifies the Liburnians as *gens Asiatica,* Asiatic people, further solidifying their status as a barbarian Other to the civilized Greeks and Romans (Dzino 2017:62,65). These disparate sources do generally agree that the Liburnians dominated the eastern Adriatic region before Greek colonization (Dzino 2014:52), while the centuries following saw a loss of Liburnian influence and territorial control (Brusić 1999:1).

The scholarly consensus is that Liburnian society prior to the Roman period consisted of loose associations of tribes sharing territory on the Adriatic coast (Čače 2013:13). Dzino suggests the available evidence indicates a heterarchical social organization, citing the “small, family-centered communities, concentrated around scarce fertile plains in the Dinaric *karst* or in the river valleys…the ‘civilisation of the *gradine*’” (Dzino 2012:73–74, emphasis in original). Additionally, there is little archaeological evidence to suggest “the existence of significant social and state institutions in Liburnia, which would support a political infrastructure that would enable Adriatic-domination in the early and mid-Iron Ages” (Dzino 2014:52–53). This stands in contrast to the opposing view held by some scholars that the Liburnians were powerful players in key maritime trade routes in the Adriatic. Pierre Cabanes proposes that an ancient trade route existed that mirrors the modern trans-Adriatic route connecting Zadar and Ancona, on the Italian coast (Cabanes 2008:175). Evidence for strong Greek trade routes along the coast of the Adriatic can be found at the Sanctuary of Diomedes on Cape Ploča. This strategic point represented the boundary between the Liburnian controlled waters and the Delmetean controlled waters (Čače and Milivojević 2017:437).

The major urban settlement on the Liburnian coast was the ancient city of Iader, now Zadar. Iadar has a long history of continuous occupation, and was the largest Liburnian settlement from the beginning of the Iron Age (Čače 2013:14). Iader's importance to the region can be attested by the fact that it was the only Liburnian city designated as a *colonia* in the Roman province of Dalmatia (Gazić 2011:180; Wilkes 1969:210). Beyond Zadar, ongoing excavations in the Ravni Kotari allow for further analysis of the role of municipal centers in the Liburnian whole and how they were impacted by increased involvement with broader Mediterranean powers.

Nadin

One such site that is proving useful in examining this period of change in Liburnia is Nadin. Nadin provides material evidence dating to the last two centuries BCE, an era of change and development for influential Liburnian settlements like Iader, Aenona, and Nadin (Čače and Milivojević 2017:433). As noted by Sineva Kukoć, "Nadin was recognized long time ago [sic] as a site particularly suitable for the study of relations between the autochthonous Liburnian and Roman elements" (Kukoć

2009:51). These relations are well documented in the treatment of Nadin under Roman expansion in the Adriatic and paint a picture of favorable treatment towards an established cultural center.

The Nadin settlement is made up of a collection of sites along the Nadin Ridge, and the walled Gradina at one time made up the site's main administrative and economic center. This centrally located area lies at the crossroads of two major routes from Zadar to sites in the west, the hillfort Asseria and the Roman legionary site of Burnum (Batović and Batović 2013:181). The associated sites of the Nadin ridge include four hillforts – the Gradina, Starine, Križova glavica, and Vijenac – and other sites like the stone enclosure of Čauševica, covering an area of 32.6 ha (Batović and Batović 2013:181; Chapman, Shiel, and Batović 1987:129; Chapman, Shiel, and Batović 1996:117; Kukoć 2009:14). Chapman, Shiel, and Batović propose that these associated sites "[imply] traditional, long- term approaches to land, its management and division as well as the minor additional manpower investment that makes the boundaries possible" (Chapman, Shiel, and Batović 1987:129).

In pre-Roman Liburnia, settlements like Nadin served as the center of power for smaller tribes; according Mate Suić's interpretation of Pseudo-Scylax's list of Liburnian cities, the *Nedetai* were the tribe that inhabited *Nedinum* (Wilkes 1969:4). As Roman influence spread over the Adriatic, Nadin received the designation of *municipium* and residents "acquired Italian status;" however, local elites were still allowed to maintain positions of power, and the city retained its "Liburnian character" (Wilkes 1969:212–213). Previous scholarship has established that *Nedinum* was a well-connected urban center (Borzić et al. 2018:50). During the first century AD, Nadin's control over the landscape is evident through its success in boundary disputes with the city of Corinium to the north (Wilkes 1969:212). According to Gregory Zaro and Martina Čelhar, "it seems reasonable to conclude that the Nadin-Gradina hillfort site represented a primary cultural center in Zadar's extended urban hinterland for a period of about one thousand years or more before abandonment of the summit" (Zaro and Čelhar 2018:57). Exactly what this prominence meant for the economy, politics, and social life in the Ravni Kotari before Roman rule is a question that is under investigation through current ongoing archaeological research.

Archaeology at Nadin

Archaeological study of Nadin's history has occurred intermittently over the past century and a half. The first reference to the Gradina and graveyards appeared in the late nineteenth century and the scientific publications regarding the finds from Nadin began in the early twentieth century (Kukoć 2009:13; Batović and Batović 2013:181). This was followed by Šime Batović's 1968 excavation of two accidentally discovered Hellenistic burials (Batović and Batović 2013:181). The first field survey at Nadin was conducted as a part of the Neothermal Dalmatia Project from 1983-1986. This project was a collaboration between the Archaeological Museum of Zadar, the University of Zadar, and Newcastle University, and was directed by Dr. John Chapman, Dr. Šime Batović, with the help of Dr. Robert Shiel and Dr. Wendy Bracewell (Batović and Batović 2013:181; Chapman, Shiel, and Batović 1996:3–4). This project represented the last archaeological study of the site before the Croatian War of Independence. This extensive field survey covered a large part of the Ravni Kotari and sought to identify settlement patterns, land-use and the agents of cultural and ecological change in Dalmatia (Chapman, Shiel, and Batović 1996:3–4). The Neothermal Dalmatia Project also sought to study "[t]he interplay between tradition and change [which] implied significant social relationships both within the study area and with surrounding areas" (Chapman, Shiel, and Batović 1996:4). At Nadin-Gradina, further excavations were conducted within the fort's walls in areas thought to be animal enclosures and areas related to Roman occupation, as well as a potential domestic context outside the walls (Chapman, Shiel, and Batović 1996:231). These excavations revealed a pattern of occupation beginning potentially in the Late Bronze Age, and intensifying during the Iron Age and through the Roman period, with potential abandonment and intermittent reoccupation during the Medieval and Ottoman periods (Chapman, Shiel, and Batović 1996:251).

The Gradina is one of the largest settlements in Liburnia (Batović and Batović 2013:181). The limestone walls at the top of the Gradina hill enclose an area about 7.1 ha (Figure 6) (Chapman, Shiel, and Batović 1996:117). The hilltop contains evidence of Roman and Ottoman building material, while the hillside around Nadin is marked by limestone quarries, ancient roads, and tombs (Chapman, Shiel, and Batović 1987:129–130). The hillfort is a distinct feature of the Liburnian landscape, and provided a defensive area for the living, while the dead resided in separate burial areas, often located along the road (Brusić 2005:22). The necropolis at the foot of the Gradina follows these conventions, and visitors had to walk past the necropolis to enter by the west gate. The slopes to the north, east, and south-east of the fort walls contain the limestone quarries whose products furnished the walls and some interior buildings of the hillfort (Chapman, Shiel, and Batović 1996:119). Simon Ellis divides

Nadin Gradina into three districts: the north-west cemetery district, the north-east trading district and market, and the southern agricultural district (Ellis 1996:123).

The excavation of some burials at Nadin began in the 1960s (Batović and Batović 2013; Kukoć 2009:13–14). The Neothermal Dalmatia Project identified additional Bronze and Iron Age burial mounds associated with Nadin, but it was not until 2002-2003 that excavation of the mounds began (Kukoć 2009:15). The study of Nadin's mortuary practices moved to the "flat necropolis" in 2004, 2005, and 2009 (Kukoć 2009), and necropolis excavations continue in conjunction with the Nadin-Gradina Archaeological Project (NGAP), run by the University of Zadar and the University of Maine. NGAP was designed to "lay the foundation for an intensive,

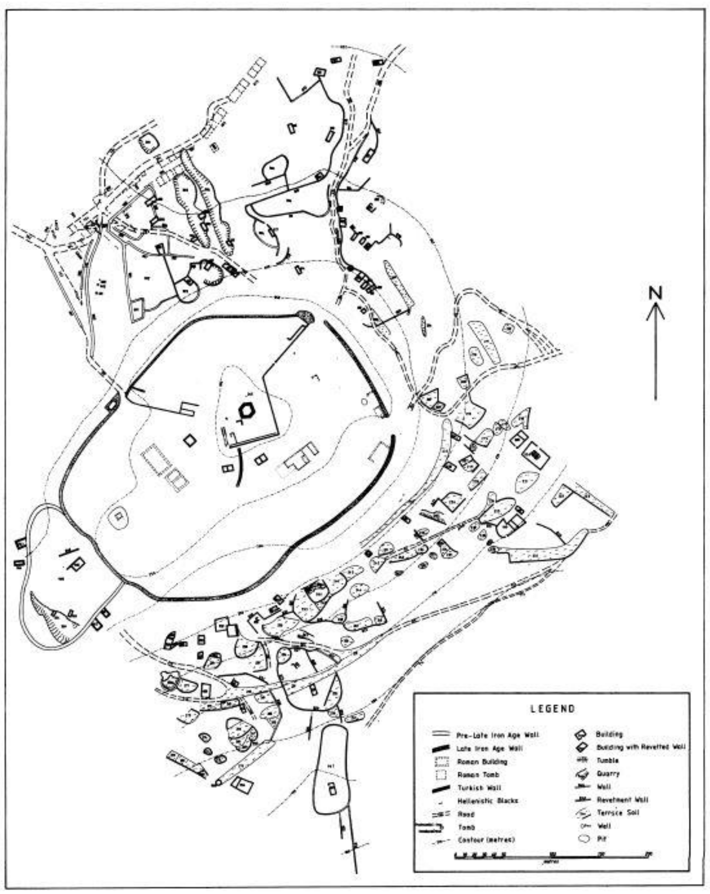

Figure 6: Site Plan of the Gradina, from Chapman et al. 1987: 130. The location of Grave 105 is not shown, although its location is to the left side of the road which approaches the West Gate.

multi-year program of field research at Nadin-Gradina centered on long-term urbanization, landscape change, and climate in the eastern Adriatic" (Zaro and Čelhar 2018:55). Further information about the findings of NGAP can be found in *Landscape as Legacy in Northern Dalmatia* (Zaro and Čelhar 2018), and forthcoming publications by Zaro and Čelhar.

There are two types of burials found at Nadin, the "barrows" and the flat cemeteries, (Batović and Batović 2013:182). These burial mounds, located along a generally parallel track just north-east to the line of the Nadin Ridge, are associated mainly with the Bronze Age, although two of the mounds excavated in 2002-2003 were identified as Iron Age (Kukoć 2009:15–16). During the late Liburnian and Roman periods, burial practices shifted to the flat necropolis closer to the north-west side of Gradina (shown at the top of Figure 6) (Kukoć 2009:50). There appear to be two phases to the necropolis: an earlier, Iron Age Liburnian phase, and the later Roman-Liburnian phase, from the "Romanization period" (Kukoć 2009:54). There is evidence that the graves from the Roman-Liburnian period were built partly over older sections of the necropolis (Kukoć 2009:55–56, 59).

Common features of this necropolis are lined limestone cists, many of which were disturbed in the past, before systematic study could be made of their contents (Kukoć 2009:60). As of 2013, the Hellenistic graves were identified in a 150 m long area of necropolis between the Gradina and Križova glavica, to the south of the area containing the Roman graves (Batović and Batović 2013:182). These Hellenistic graves show a change from previous Liburnian burials, introducing burials in the extended position and cremation burials in stone lined family graves, a rarity for

Liburnia (Batović and Batović 2013:182). An analysis of Grave 1 determined the presence of the remains of 5-10 people through the biological remains as well as the presence of 5 rings and 7 belt buckles (Batović and Batović 2013:183). The inclusion of large quantities of pottery in the burials is notable for the region, and comparable only to Velika Mrdakovica in Liburnia (Batović and Batović 2013:183–184; Kukoć 2009:73). Interestingly, previous excavations note the presence of locally produced cups among the contents of the necropolis that perhaps indicates "an old ritual act in the cult of the dead" from earlier Liburnian traditions (Kukoć 2009:74).

Other artifacts, in addition to the pottery, suggest that the community of Nadin may have been engaged in far-reaching networks of trade. For example, a glass head pendant found in the flat necropolis during the 2012 season is similar to beads of Phoenician and Punic origin from across the Mediterranean and at the time of its discovery was the sole example of a glass head pendant on the eastern Adriatic (Čelhar and Kukoć 2014:91, 93). Whether this pendant, in the shape of a bearded male face, came to Nadin through direct or indirect means, for Martina Čelhar and Kukoć its presence at the site supports the hypothesis of Nadin's long term involvement in widespread Mediterranean trade networks and a "Liburnian creativity in accepting outer forms…into their own, very often…composite, but still authentic attire style and artistic expression" (Čelhar and Kukoć 2014:99). There are examples of imported Gnathia, Italic, and Campanian ware (determined on formal stylistic grounds) and imported glass vessels (determined due to their rarity) in previously excavated Hellenistic burials, alongside the Hellenistic relief ware (Batović and Batović 2013:183).

In terms of grave structure, materials and presentation of the dead, the cemetery graves at Nadin are most comparable to the graves at Greek colonies like Issa (Batović and Batović 2013:184), and other authors have suggested that interpretation of the necropolis and its contents should be framed in comparison with other Hellenistic Adriatic sites and Roman necropolises (Kukoć 2009:72).

Grave 105

The vessels analyzed in this study come largely from a recently excavated grave (Grave 105) in a section of the necropolis that lies south of the previously studied burials (Figure 7). This is a lined limestone burial, containing both the cremated and more articulated remains of approximately 200 people (Martina Čelhar, personal communications). Preliminary typological analysis of grave goods from Grave 105 dates it to the last two centuries BCE and the first century CE (Martina Čelhar, personal communication)[2]. Grave 105 contained over 100 mold-made relief vessels, mostly in the form of kraters (Figure 8, Table 1). The *terminus post quem* for Grave 105, based on the presence of these mold-made ceramics, cannot be earlier than the mid-third century BCE and their quantity suggests a date after 175 BCE (Rotroff 2006:376). Initially, multiple context levels and features were noted in the field, but further examination has narrowed these to four main levels. The tomb contained several layers of deposits, suggesting it represented a series of successive burials over at least two generations during the last two centuries BCE (Martina Čelhar, personal

[2] Bioarcheological analysis of Grave 105 and conservation of artifacts from Grave 105 are currently ongoing at the University of Zadar, in collaboration with the University of Maine and SUNY New Paltz.

communication). The upper layers (SJ 272, SJ 274/279) are separated by a thin burnt layer (SJ 280/281) from the oldest layer in the grave (SJ 283).

Figure 7: Excavation of Grave 105 in June 2018. Photo credit: Elizabeth Proctor, 2018.

Figure 8: Hellenistic relief ceramics in situ in east corner of Grave 105. Photo credit: Elizabeth Proctor, 2018.

Before the excavation of Grave 105, Nadin's collection of mold-made relief vessels consisted of over 75 different vessels (Batović and Batović 2013:183). With the addition of finds from the 2018 excavations, Nadin's collection may be the largest corpus of mold-made ceramics in Liburnia. The Hellenistic mold-made relief ceramics from Nadin are mainly kraters, and the infrequency of mold-made cups/bowls could indicate that mold-made kraters are characteristic of Liburnian production (Šešelj and Ilkić 2015:424; Brusić 1999:11). All four decorative schemes occur on the kraters and cups/bowls from Nadin. While Hellenistic mold-made relief vessels are not uncommon in settlements throughout Liburnia, Nadin's collection is a rare case where these vessels are found in such quantities in mortuary settings (Batović and Batović 2013:184), indicating their use not just in daily life, but in ritual and mortuary practice as well.

Table 1: Tabulation of mold-made vessels from Grave 105 at Nadin included in initial data collection.

	SJ 272	SJ 274/279	SJ 280/281	SJ 283	SJ 280/283		Total
Krater	1	47	19	15	1		83
Bowl	0	6	2	6	1		15
Total	1	53	21	21	2		98

Justification of Archaeometric Study

Taking an archaeometric approach to the study of the Hellenistic Adriatic is a relatively new development in Croatian archaeology (Šegvić et al. 2016:26; Ugarković and Šegvić 2018:89). Past approaches to changes resulting from the spread of Greek and Roman culture through colonization, trade, and travel have often regarded these transformations as "a natural and inevitable result of contact" of the barbarian Other to an "inherent superiority and attractiveness of Greek culture" (Dietler 1997:296). Indeed, Jessica Nitschke writes that "[i]t has become conventional for Classical archaeologists to apply the term 'hellenized', with all its implications of the passive absorption of culture, to any material or cultural group that exhibits an element of borrowing from Hellenic culture" (Nitschke 2011:101). As Chapman et al. noted in 1996, "[m]ost of Dalmatian archaeological thinking has been, and still is, conducted within an invasionist/diffusionist paradigm peopled by archaeological cultures" (Chapman, Shiel, and Batović 1996:7). However, this thesis attempts to move beyond past assumptions about Nadin and Liburnian culture through an archaeometric study of mold-made relief ceramics.

Due to their frequent abundance among archaeological materials, ceramics are often used as indicators of trade network intensity, local production, or markers of social organization, (Miše 2015:61; Vrkljan and Konestra 2018:20). As noted by Olivier Gosselain, pottery making is not just a technical process – it involves the potter in cultural networks of behavior (Gosselain 1998). To Gosselain, the study of ceramic collections with attention to style and technique offers insight into "social interaction networks and population movements" (Gosselain 1998:104). Brusić suggests that significant questions for future projects studying the mold-made relief vessels of the Adriatic focus upon these networks, looking towards "the tradition of ceramic import to Liburnia and its relation towards other regions" (Brusić 1999:47). An archaeometric approach also offers insight into human networks, considering potential source groupings as indicators of the multiplicity of clay sources accessible to a site through both production and trade.

Recent archaeometric studies in Croatia offer new insight into issues of production and trade in ancient Liburnia and other indigenous territories. Boris Čargo and Maja Miše conducted a geological survey of the island of Vis in 2007 and 2008 to determine potential raw material used by the Issean workshops and compared these to Gnathia fragments found on Vis through XRD (Čargo and Miše 2010:27). In 2016, Branimir Šegvić et al. published an archaeometric study of tableware from Issa (Šegvić et al. 2016). Their goal was also to use archaeometric methods to better understand the trade networks that impacted the production of ceramics along the eastern Adriatic coast (Šegvić et al. 2016:24). Marina Ugarković and Šegvić's recently published archaeometric analysis of Hellenistic grey-ware includes mold-made relief ware similar to those analyzed in this thesis (Ugarković and Šegvić 2018). They analyzed 33 samples of grey-ware through ICP-MS (Ugarković and Šegvić 2018:94–96). Their findings offer important new interpretations of the production of Hellenistic relief ware in the Adriatic, determining that production of fine-wares at Issa was established by the end of the fourth century BCE, and that clay was collected from multiple spots on the island (Ugarković and Šegvić 2018:93). They also determined that much of this gray fine-ware is low-Ca, hypothesizing that local potters may have favored non-calcareous paste, which has implications for future provenance studies (Ugarković and Šegvić 2018:96). Their results indicate more local-regional production than imports, and at least two production centers in Dalmatia (Ugarković and Šegvić 2018:101).

As a tool for analyzing the chemical composition of artifacts, portable x-ray fluorescence (pXRF) is advantageous for a variety of reasons (Forster et al. 2011:389; Shugar 2013:173–174). Handheld XRF machines cost significantly less than their stationary counterparts and they can be shared by multiple people and projects, making them a more cost-effective option for a university department. Portability is a key advantage of the pXRF, allowing researchers to bring their equipment to their collections. However, potential barriers to the use of pXRF on archaeological ceramics lies in the clay itself. The physical composition of clay used for pottery making, which naturally includes soil, minerals, and often added materials such as temper, is not chemically homogenous. These issues should not be seen as an indictment against the use of pXRF on ceramics, but rather should be kept at the forefront of research design to successfully utilize pXRF.

It is possible to design a research project that utilizes the strengths of pXRF and minimizes error in data measurements and misleading results. Such research design must account for the fact that, unlike other types of archaeometric ceramic analysis such as INAA, non-destructive pXRF applications must be used to produce qualitative, not quantitative, results. In such studies, the focus is precision, rather than accuracy, and the goal is to describe relationships between the objects samples rather than defining their composition. Without destructive sampling techniques and the development of matrix matched standards, pXRF data cannot be accurately quantitative (Scott et al. 2018:968–969). Nevertheless, the concentration patterns presented by pXRF can be comparable to stationary XRF and INAA, despite inaccuracies in the elemental concentrations themselves – due in part to the matrix effects of clay discussed below and due in part to the limitations of the hand-held technology (Johnson 2014:564). Thus, when the goal is not to match vessels to a specific source, but to compare them to each other, pXRF is a suitable technique (Shugar 2013:183). This research design underlines the assumption of the generally accepted “provenience postulate” – that is, that there are recognizable differences among the chemical composition of sources, and that there is greater difference between sources than within sources (Weigand, Harbottle, and Sayre 1977:24). The presence of distinct compositional groupings would seem to indicate different clay sources and changes in the distribution of these groupings over time may reflect different accessibility to or preference for different clay sources. As the focus of this paper lies in comparing the compositional groupings of the pottery relative to other vessels in the collection, not in determining the source itself, pXRF is a suitable approach.

The ideal conditions for creating source groups requires vessels that meet the following criteria: there is a standardization of operation in clay sourcing and preparation, there is continuous exploitation of sources over a known period of time, and the raw materials need to be significantly distinct from other potential sources (Wilke, Rauch, and Rauch 2016:142). Additionally, vessels used in pXRF studies should be homogenous samples with similar small particle size, similar densities, infinite thickness, sufficient size to cover the x ray beam, and flat, dry and non-porous surfaces (Shugar 2013:180). In this study, only those vessels that reasonably met these criteria were selected for analysis. Potential sources for these vessels, based on previous identification of production centers and known Liburnian trade connections, indicate a wide range of geologic contexts and temporal continuity of production. Production centers of broadly defined Hellenistic mold-made relief ware have been identified across the Mediterranean, with potential for a wide range of geologic origins. Artifacts from Liburnian graves, like the glass pendant from Nadin, indicate a wide range of potential direct or indirect trading partners. Therefore, it is possible for this collection of Hellenistic mold-made ceramics to exhibit the wide range of distinct raw materials that Wilke, Rauch, and Rauch call for. There is a potting tradition for this vessel type that was established in the third century BCE, and there is little to suggest the method for making these vessels changed drastically over the following centuries in which they were produced. The mold-made relief vessels from Nadin have a fine fabric, with few visible inclusions. There were a small number of cups from Nadin that were not included in this paper, as there were not spots on the vessel that met the criterion for infinite thickness.

Methodology

The sampling procedures and instrument settings used in this study were developed from a comparison of multiple sourcing and geochemical studies[3] as well as instrument-specific user guides. The instrument used in this study is the Bruker Tracer III-SD. The Bruker Tracer III-SD uses a silicon drift detector and a better Si-PIN detector than previous models (Tykot 2016:43). The instrument was operated under two settings, designed to capture a wider range of elements than one setting alone. The first was 40 kV, 30 μA with a 12mil Al/1mil Ti/ 6mil Cu (Green) filter. These energy settings (both with and without the filter) were suggested by multiple studies as a method to capture mid-range elements (Del-Solar-Velarde et al. 2016; Forster et al. 2011; Hunt and Speakman 2015; Johnson 2014; Scott et al. 2018). The second is 15

[3] Brorsson, Blank, and Fridén 2018; Ceccarelli et al. 2016; Del-Solar-Velarde et al. 2016; Emmitt et al. 2018; Forster et al. 2011; Frahm 2018; Frankel and Webb 2012; Goren, Mommsen, and Klinger 2011; Hunt and Speakman 2015; Ikeoka et al. 2012; Johnson 2014; Karacic and Osborne 2011; Raudino, Tykot, and Vianello 2017; Scott et al. 2018; Shackley 2010; Shugar 2013; Speakman et al. 2011; Tykot 2016; Tykot et al. 2013; Ueda et al. 2017

kV, 20 µA with no filter. This is a more experimental setting for this study, designed to capture lighter elements. While there is support for the exclusion of lighter elements in pXRF provenance studies (see Hunt and Speakman 2015, Johnson 2014, Scott et al. 2018), those studies were not done on this ceramic type within this area of interest, and there is some evidence that low-Z elements other than P and Na can be measured well with the right setting (Speakman et al. 2011:628).

When developing a list of potential elements of interest, it is important to consider the limitations proposed by previous examinations into the capabilities of pXRF. There are certain elements that should not be used, especially Ca, Ti, P, S, Cl, and Mg (Forster et al. 2011:391; Hunt and Speakman 2015:631, 636). Generally, elements that work well are those with a Z numbers of 26 or higher (starting with Iron and heavier) (Forster et al. 2011:396). It should be noted that V, Cr, Co, and Ni can only be measured semi quantitatively, and the use of filters can improve their detection (Hunt and Speakman 2015:629). The original elements selected for this study, chosen after considering the resulting spectra which showed the presence of Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Rh, Pb, and Th, and elements suggested by previous research were Fe, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Pb, Nb, and Th. These elements were chosen with consideration given to the geographic area of the study and the equipment used. Starting with a larger list of elements allows the user to narrow down the list into the most influential elements later in the analytical process (Frahm 2018:24).

In cases where destructive testing, i.e. grinding, abrading, or creating pressed pellets, is not an option, the location of the assay on the ceramic sample is an important consideration for pXRF testing. When choosing where to sample, it is important to understand the attenuation effects on surface typology: structural or physical irregularities can affect measurement – air attenuates the x-rays, causing a drop in intensity, and there can be an obstruction of emerging x-rays to the detector (Forster et al. 2011:392). While flat surfaces are preferable, convex surfaces can work well because they can be placed flush against the window (Forster et al. 2011:393; Scott et al. 2018:970). The area chosen for the assay must have no visible pre- or post-depositional alterations – i.e. paint, slip, decomposition, surface encrustations (Del-Solar-Velarde et al. 2016:3; Forster et al. 2011:393; Hunt and Speakman 2015:637; Karacic and Osborne 2011:7; Raudino, Tykot, and Vianello 2017:250; Scott et al. 2018:970; Speakman et al. 2011:3485; Tykot 2016:46; Ueda et al. 2017:63). Also, a direct assay of the ceramic paste, done on a broken edge, was included whenever possible, to mitigate the possibility of results influenced by unseen surface treatments and the matrix effects discussed below. Additionally, broken edges must be at least $7mm^2$ thick, enough to encompass the entirety of the x-ray beam and not include visible temper (Karacic and Osborne 2011:6–7).

Due to the nature of ceramics – their paste, décor, and shape – and the constraints of non-destructive sampling, multiple assays per sample are a necessity. Taking multiple short measurements allows the user to correct for ultra-short-term drift (u-drift), drift which occurs when there are different intensity counts for consecutive measurements with identical parameters (Johnson 2014:568). Additionally, multiple assays are needed because the result of a single assay may misrepresent the sample, as the elements closer to the center of the analytic window contribute more to the fluorescence signal than those at the periphery (Forster et al. 2011a:391). These “matrix effects” are due to the grain size of the ceramic paste, the heterogeneous nature of ceramics fabrics, and the effect of radiation on different minerals (Hunt and Speakman 2015:632). The matrix effects are the reason that many studies advocate for the preparation of samples as ground powders and pressed pellets (see Forster et al. 2011, Hunt and Speakman 2015, Johnson 2014). However, as the creation of pellets from the Nadin samples was not possible, multiple assays from a variety of spots on the vessel or sherd were taken. Wilke et al. recommend a minimum of two assays per sample and the data can be averaged or cleaned later (Wilke, Rauch, and Rauch 2016:149).

All samples were washed and then dried for at least 48 hours prior to pXRF sampling. Each sample was subjected to at least 3 assays, on a combination of broken edges and exterior surfaces when possible. The morphology of some vessels made it impossible to obtain more than the minimum 3 assays, or assays from both exterior and interior (fabric) points. Each assay was taken from an area that was at least 7 mm thick and had an area of 5 by 5 mm to cover the window and provide infinite thickness. The length of each assay was 60 seconds, determined in the lab after a preliminary test assay of 10 minutes on at least 2 samples. Following Johnson’s (2014: 570) recommendations to address short-term drift (s-drift), multiple samples were chosen to serve as s-drift controls. In order to randomize the effects of s-drift, the first sample measured during each use session was measured again at least twice throughout the use session, including at the end of the use session. The control sample from the first use session was measured each day throughout the data collection period to ensure consistency throughout the project. Additionally, measurements from samples determined to be from the same vessel can be used to ensure reliability and repeatability of methods.

Data Processing and Analysis

This study differs from previously published pXRF ceramics studies in part because it is not a true sourcing study, and in part because the 98 vessels upon which the following analysis is based are limited to a single grave at a single site. In research utilizing multiple vessel types and vessels found at multiple sites there is additional criteria with which to subdivide and analyze these vessels. Considering the restrictions of the current dataset, the methods of statistical analysis used needed to suit the study of a large number of vessels from a single site and be conducive to the study of only a few vessel types – in this case, kraters and cups.

When using pXRF to source ceramics, most scholars use three main statistical methods to analyze their results - hierarchical clustering by Ward's method, principle components analysis (PCA), and bivariate plots representing the ratios of elements chosen for analysis. Hierarchical clustering is used to determine whether assays taken from the same vessel group together and whether the assay may have hit an inclusion, resulting in an outlier that is not representative of the vessel's overall composition, as well as comparing potential grouping clusters. In this study, hierarchical clustering was a crucial first step to determining the suitability of the vessels for geochemical study. Principle components analysis can be used to reduce a large number of variables into a two-dimensional view representing a percentage of variability within the sample data. This approach allows the researcher to easily view the impact of multiple variables selected for analysis, but the researcher has little control over the process of analysis as it runs through statistical software and the resulting charts vary based on the software input (Beier and Mommsen 1994:288–289). In this research, PCA was used to manage the elements selected for analysis and quickly render data into a two-dimensional chart. Bivariate plots present almost opposite advantages and disadvantages to PCA, as the researcher is in control of the variables used to create the plots, but it can be difficult to determine which elements yield the most distinct and accurate plots. Each of these statistical approaches is useful at different levels of interpretation.

This study used JMP Pro 14 for statistical analysis. Initially, all elements present in the spectra were considered for the filtered and unfiltered assays[4]. After consideration of the resulting PCA plots and cluster analyses, it appeared that the large number of elements used in the analysis was obscuring distinctions between source groups. Out of the initial list of selected elements, the elements Cu, Ga, Nb, Th, Y, Zn, and Zr were selected for further analysis. Alice Hunt and Robert Speakman identified Cu, Zn, Rb, Sr, Y, Nb, Th, and Pb as low/mid-Z trace elements that work well with pXRF studies of archaeological ceramics (Hunt and Speakman 2015:630). However, Rb and Sr measurements were removed from analysis after consideration of recent, non-pXRF archaeometric studies from this region and on this ware type, whereas Ga was included in these studies (Šegvić et al. 2016:29; Ugarković and Šegvić 2018:96–

[4] While the initial goal of this research was to compare the results of the filtered and unfiltered assays, the unfiltered assays proved difficult to work with and the results presented below are based on analysis of the filtered assays.

101). Wilke et al. also recommend Ti, Ga, Rb, Sr, Y, and Nb, as well as Th if detectable(Wilke, Rauch, and Rauch 2016:160).

Before any clustering or grouping, the data first underwent a $\log_{10}$ transformation in JMP Pro 14. Logarithmic transformations of data in geochemical studies are considered useful when the data is not initially normally distributed, when there is a difference in magnitude between the elements selected, or when performing multivariate statistical procedures that assume a normal distribution like PCA and clustering (Baxter 2001:132, 136; Beier and Mommsen 1994:303; Bieber et al. 1976:62; Glascock 1992:16). Following $\log_{10}$ transformation, missing values were imputed using the Multivariate Platform in JMP Pro 14.

After the logarithmic transformation of data, clustering was used to establish whether the multiple assays from the individual vessels were similar enough to each other to represent the same clay source. When the assays from the same vessel cluster together, the readings can be used for source grouping. When the assays from a single vessel do not cluster, it may be the result of an outlier reading due to inclusions, encrustations, or decoration, the general unsuitability of the vessel for pXRF analysis, or user error. These outlier readings and unsuitable vessels must be removed from analysis. To determine whether assays from each vessel were statistically close to one another, hierarchical clustering by Ward's method were performed in JMP Pro 14.

After this data screening, the original dataset of 98 vessels was reduced to 78 vessels suitable for further analysis.[5]

Data Analysis[6]

Following the screening of vessels for suitability, the dataset of 78 vessels was considered in an initial PCA covering 62.6% of variation (Figure 9). Given the overlap between vessels and the lack of distinct grouping, the dataset was divided into subgroups based on vessel type and stratigraphic layer. After analysis of these subgroups, the resulting groupings were compared. A comparison of cluster analysis and a PCA covering 71.5% of variation for the vessels identified as cups/bowls revealed three potential groups – the first containing vessels 32/34, 33, 35, the second vessels 54, 76, 77, 79, the third vessels 31, 59, 78, 94, 96, and vessel 90 unattributed (Figure 10). The second and third groups were more closely related to each other than the first group. The analysis of the krater group in a PCA covering 61.9% of variation compared to cluster analysis returned five rough groups, with 12 vessels unassigned (Figure 11). In total, analysis by vessel type assigned 65 vessels into groups, with 13 unassigned to a group.

Following an analysis by vessel types, the data was subdivided into stratigraphic layers. There were 3 vessels not included in this line of inquiry, either as the sherds of the vessel were found in different stratigraphic layers or there was only a single vessel for that layer. The analysis of SJ 274/279, which now contained 44

[5] The vessels removed from further analysis were 10, 13, 18, 19, 25, 29, 39, 50, 53, 60, 62, 66, 68, 71, 79, 81, 86, 91, 95.

[6] The figures and tables referenced in the following sections can be found in the appendix.

vessels, indicated at least 4 and as many as 7 different potential source groupings (Figure 12). The other 2 levels analyzed each had fewer vessels which resulted in clearer distinctions in clustering and PCA. SJ 280/281 now contained 15 vessels and resulted in 4 groups with 2 vessels unassigned (Figure 13). Finally, the analysis of SJ 283, which now contained 16 vessels resulted in 4 groups with 2 vessels unassigned (Figure 14.). These initial groupings served as a starting point for comparison between the two approaches.

Given the subjective nature of both PCA and cluster analysis, comparing the resulting groupings from the different subgroups analyzed allows for more confidence in the final groupings. After comparison and further clustering, 37 vessels were assigned to 9 different source groups (Table 2, Figure 15). There is some possibility that some of these 9 groups could be combined further, such as Group 1 and Group 2, and Group 6 and Group 7. While these groups are not a definitive categorization of the whole sample, they do offer opportunities for further analysis and research. There is a clear distinction between Groups 1, 2, 3, 4, and 5, and Groups 6, 7, 8, and 9. This indicates that, at minimum, there are two clay sources represented in the group of defined vessels.

Interpretation

After cleaning and analyzing the data from both filtered assays, it became clear that the results lend themselves to multiple potential interpretations, and that any definitive discussion about the origins of most of these vessels would require further analysis. From the current data, several possible conclusions emerge regarding the number of potential sources whose products were found in Grave 105. As previously noted, there are at least 2 sources present in the sample of defined groups and some of these groups may be consolidated with further analysis. If these were consolidated following further research, this would suggest a primary clay source that was used in the production of most of the dataset, alongside a small number of secondary clay beds. Alternatively, it is also possible that there are multiple primary clay sources with some outlier sources represented. A comparison within the identified groups of the oldest layer (SJ 283) and the most recent layer with substantial examples of mold-made vessels (SJ 274/279) begins to shape an understanding of how consumption from these sources may have changed over time (Figure 16). Of the 9 defined groups, only Group 6 was present solely in SJ 283, while Groups 1, 2, 4, 5, and 8 were represented in SJ 274/279, while both Groups 3 and 9 were present in both SJ 274/279 and SJ 283. Although this comparison utilizes a little more than a third of the overall dataset, it cautiously suggests the presence of at least 2 clay sources available at Nadin throughout the centuries in which Grave 105 was in use. Despite the acknowledged limitations of the current analysis, the results of this study further add to hypotheses about Nadin's role in the local economy during the last two centuries BCE and the beginning of the first century CE.

The presence of a single main source group in the sample would either indicate a strong trade connection between Nadin and the area of the workshops that produced these vessels or, from an economic perspective, localized production. If there were a clear distinction between multiple large source groups, this would suggest strong trade connections with multiple sources without any clear preference for a certain source.

The current lack of production evidence from any of the sites along the Nadin ridge suggest that an interpretation of a strong trade connection with a general production area seems more likely. Given the prominence of kraters in this collection and Brusić's proposal that the relief krater was more prevalent in Liburnian workshops, this could indicate connections with knows production sites like Issa, Pharos and potentially Siculi, as well as support for a production center in Zadar. A single mold used to make Hellenistic relief vessels were found in Zadar, although no production site was ever found (Vrkljan, Konestra, and Ugarković 2018:1). Localized production of previously imported goods is a recognized side effect of the "relative globalization" of the Mediterranean during the Hellenistic and early Roman periods, designed to promote maximum profit (Morel 2014:331–334). Considering economic aspects, Zadar would be the most economically and physically accessible production center. A recent archaeometric study of Hellenistic gray ware supports at least two, but potentially three, production sites in Dalmatia that were active from the second century BCE to the end of the first century BCE (Ugarković and Šegvić 2018:101). Based on their statistical analysis and the geography of the find spots, Ugarković and Šegvić suggest further support for a production center in Zadar (Ugarković and Šegvić 2018:101). If these ceramics were not made in Zadar, they could still have been produced in Dalmatia, as the workshops at Issa, Pharos and Siculi continued production potentially into the first century BCE (Vrkljan, Konestra, and Ugarković 2018:1). Imports could also be from production centers in Asian Minor, Albania, and Delos, or even late production from the Athenian and Corinthian workshops, which stopped producing relief vessels of this kind sometime in the second century BCE (Kamenjarin 2014:138; Brusić 1999:5).

The geochemical similarities expressed in the dataset are not wholly unexpected, as pXRF can yield large groupings with ambiguous results when the clay sources of the sample have similar chemical compositions (Brorsson, Blank, and Fridén 2018:666). One possible explanation for the difficulty in dividing the bulk of the samples into distinguished groups lies in the possible geochemical similarity of the source groups. There are two distinct geologic areas to modern Croatia – the Pannonian and the Dinaric-Coastal regions (Halamić 2009:12). All the known or hypothesized production centers for mold-made relief ware in Dalmatia (Issa, Pharos, Zadar, Siculi) are within the Dinaric-Coastal region. If most of the vessels from Grave 105 originated from production centers within the Dinaric-Coastal region of Croatia, their sources would be difficult to distinguish with certainty using pXRF. In the future, more accurate geochemical methods or other mineralogical methods may help differentiate between these currently similar vessels.

It should also be noted that the results of the current analysis represent the ceramic consumption of a defined social unit – consisting of those people interred in Grave 105 and those that buried them. The collection of mold-made relied vessels used in this study reflect their location in the social economy of Nadin, brought together through mortuary ritual. Their consumption of mold-made relief vessels involved them in multiple networks of interaction. They were involved in the networks of production and economy that created and demanded these vessels as well as the social or even political networks that influenced the decision to include this ceramic style in Grave 105. However, there is still much uncertainty about the status of this grave, pending further research. Whether this mortuary context is representative of site-wide customs or is evidence of elite burial practice. Further speculation can be made when considering the prevalence of certain motifs over others, which opens complicated discussions about the availability of specific designs from specific workshops and preferences of the consumer. These are difficult to infer from the current evidence. While the abundance of a certain motif does not necessarily indicate preference and may reflect the availability of imports (Kamenjarin 2014:139), the reverse may also be true. The cost of production may inhibit certain styles, as would the accessibility of workshops producing mold-made relief ware. Accessing more mold-made relief vessels at Nadin through archaeometric study in the future will add insight into the sociology of the site. Considering the human element in the selection of these vessels, in addition to the practical constraints of their construction, allows for a more nuanced interpretation of the various networks and relationships connecting residents at Nadin to other sites in the Ravni Kotari and beyond.

Conclusion

This thesis represents a preliminary analysis of some currently available Hellenistic mold-made relief vessels from Nadin. Indeed, as Neff et al. write, the “initial exploration of subgroup structures is very far from the end of the story” (Neff et al. 2006:65). It offers an attempt at interpretation of the resulting data and suggestions for further exploration but is still largely hypothetical (Wilke, Rauch, and Rauch 2016:157). As further investigation of the Nadin settlement and necropolis continues, the expectation is that the collection of Hellenistic mold-made relief vessels at Nadin will continue to grow, and with it a better understanding of the role of Nadin in the Ravni Kotari. This current work indicates that Nadin had connections, whether direct or indirect, to multiple production centers, although which production centers cannot be determined at this time. The size of the collection, larger than other area hillforts which presumably would have had similar opportunities for connection to trade through Zadar, indicates a site of some importance in the Ravni Kotari during a time of considerable change and uncertainty in the Mediterranean.

Considering the ambiguity of the current results, there are several avenues of further research that could be pursued. Immediately, the application of a modified Mahalanobis formula, as suggested by Beier and Mommsen, would allow for the currently unassigned vessels to be placed within established groups, and reaffirm the validity of the groupings (Beier and Mommsen 1994). Such research could continue expanding the database of mold-made relief vessels sampled with pXRF in Liburnia or could remain focused on Nadin. An approach that continues to focus on Nadin's previously excavated Hellenistic mold-made ceramics could determine whether the distribution pattern expressed in the dataset from Grave 105 is representative of the overall patterns of consumption of this vessel type or whether individual graves show different distribution patterns. Further examination of the collection from Nadin would help to support or refute the hypotheses presented in this paper.

Expanding the dataset to include vessels from other sites would allow for comparison between collections from both hillforts and potential production centers, including vessels whose clay sources may have already been determined. These vessels could be used to build a larger comparative database of source clusters and the non-destructive nature of pXRF makes it preferable to collections that are now housed in universities and museums across Croatia. Expanding the dataset to multiple sites could be beneficial identifying not just production centers, but also intermediary trade sites in this exchange system (Stoltman et al. 2005:11217). Neff et al. note that "even large samples may miss low-frequency compositional groups" (Neff et al. 2006:72). Additionally, the ongoing development of pXRF technology is improving its suitability for archaeometry, especially on ceramics. Bruker's latest Tracer series (5i) offers selectable collimation, an expanded element detection range, and includes software to create user designed custom calibration, improvements on the Tracer III-SD that facilitate the analysis of archaeological ceramics.

A contrasting approach would move away from pXRF and utilize other archaeometric methods of ceramic analysis. Like Brorsson, Blank, and Fridén's 2018 analysis of Middle Neolithic pottery on the coasts of the Kattegat, the current pXRF analysis at Nadin could serve as a guide for future research. In their study, preliminary pXRF analysis was used to select sherds for further testing; out of the 520 sherds analyzed with pXRF, 105 were selected for analysis with ICP-MA/ES and a further 60 were selected for thin section analysis (Brorsson, Blank, and Fridén 2018:664–665). Stoltman et al.'s critiques of the application of INAA to ceramic materials note that, like pXRF, INAA recognizes only elements in the clay, which may be affected by the rocks of the clay source as well as the production method (Stoltman et al. 2005:11214). Instead, they propose petrographic thin-section analysis as an alternative to INAA because it can be used to link ceramics to sources through bedrock minerals (Stoltman et al. 2005:11214). However, this critique was leveled at a study of Olmec ceramics by Blomster et al. whose particular conclusion Stoltman disagreed with and should not be seen as an indictment of all INAA sourcing studies. Indeed, in a response published by Neff et al. in 2006, the authors pointed to INAA and petrography as complementary techniques which are not in opposition to each other, but rather help researchers further explore their dataset (Neff et al. 2006:65). In the future, these techniques could be applied to the ceramic dataset from Nadin if further destructive techniques were allowed. One potential path forward using these techniques might, following the example of Brorsson, Blank and Fridén, choose a small number of vessels, each belonging to proposed clay source groups could be analyzed. Either the vessels would be determined to belong to the same compositional source or to different compositional sources, expanding upon the hypothesized groups proposed in the previous sections. To complement further analysis of these vessels, the sampling of known clay beds used in the production of Hellenistic mold made ceramics could provide baseline measurements for comparison and allow for the attribution of vessels to specific production centers. In closing, continuing to engage with the history and legacy of Nadin-Gradina through further archaeometric analysis will further complement research resulting from ongoing excavations at Nadin and in Dalmatia.

Appendix

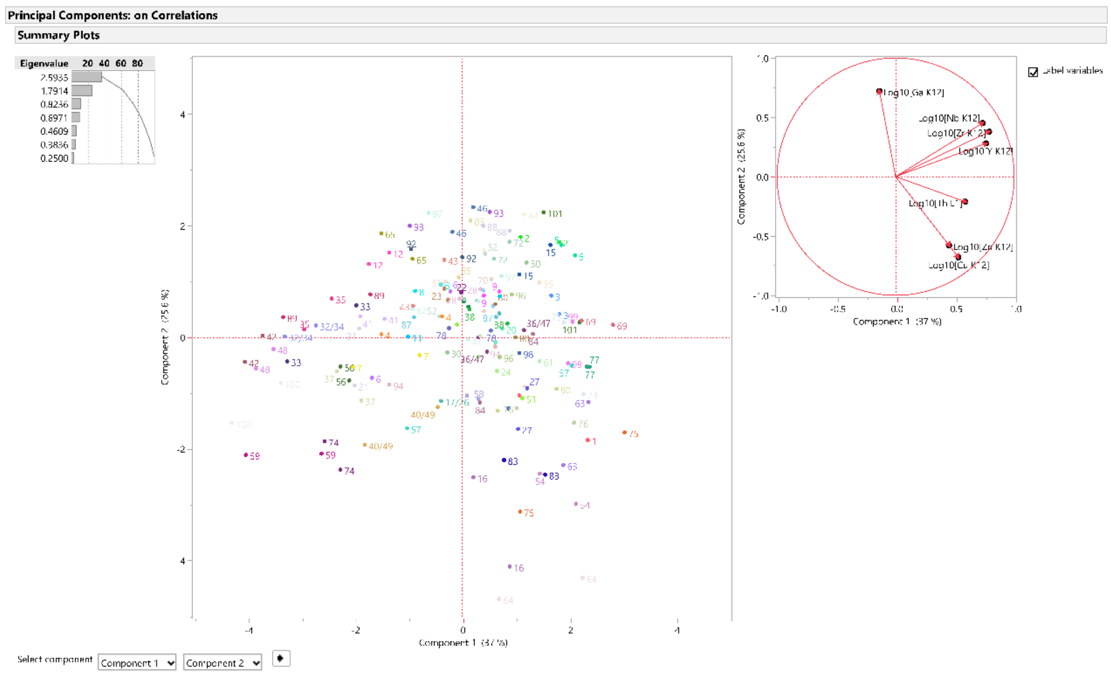

Figure 9: Initial PCA of 78 vessels suitable for analysis. Each vessel is represented by 2 points.

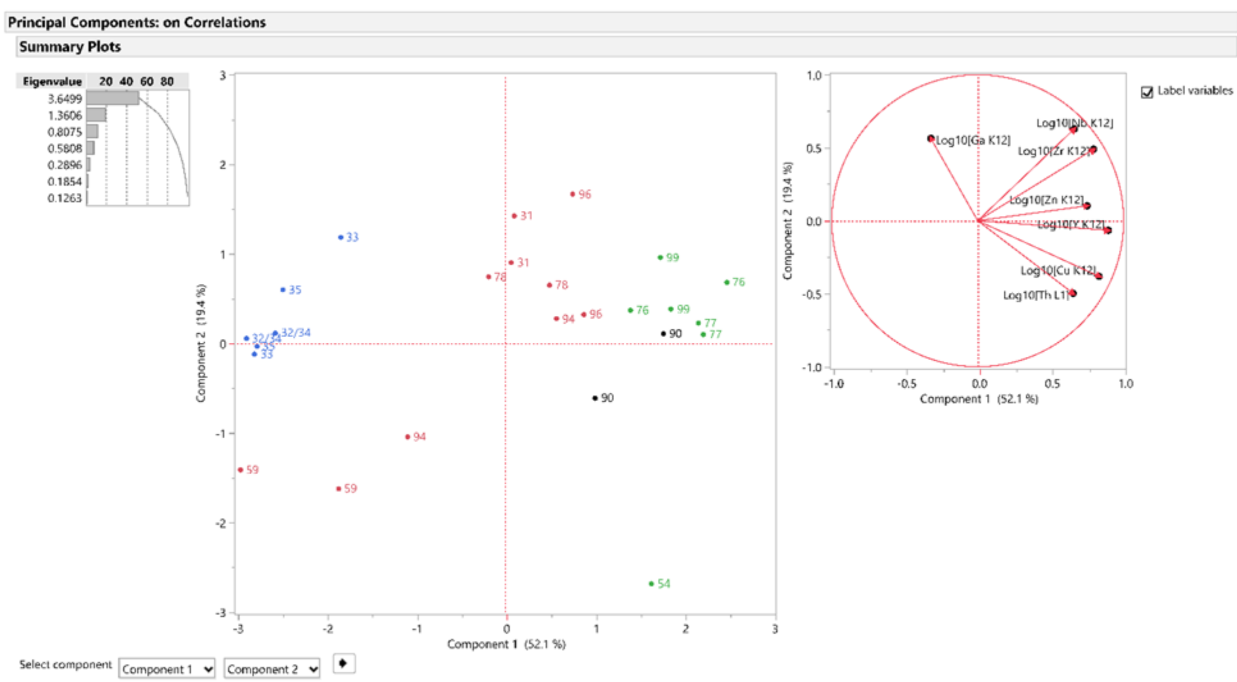

Figure 10: PCA using just cups/bowls. Blue is the first group, Green is the second group, and Red is the third group. Vessels marked in black are unattributed.

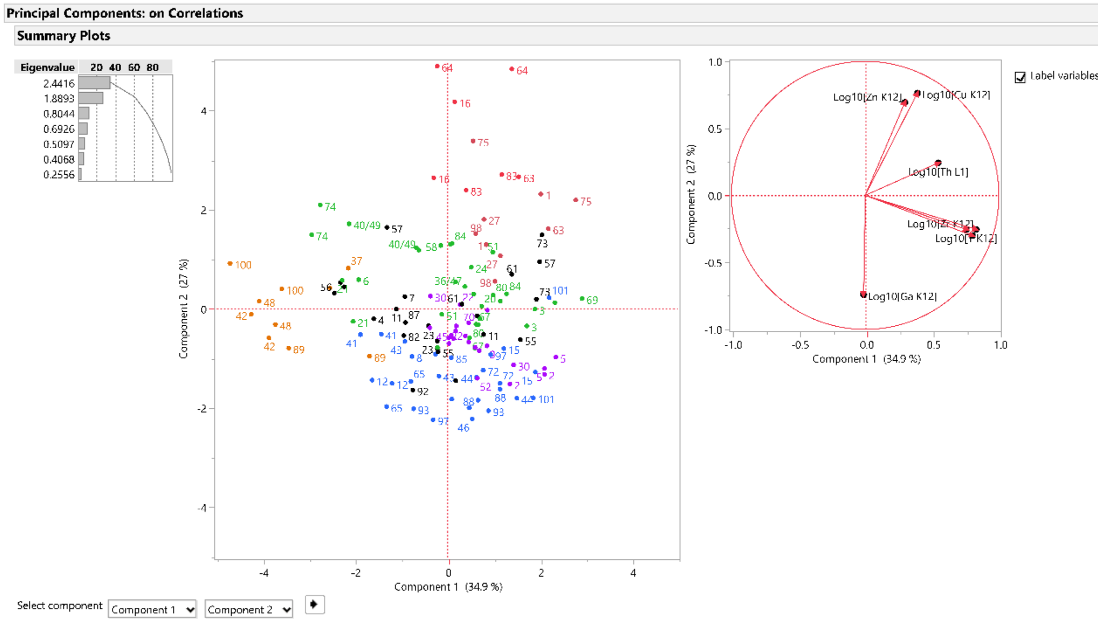

Figure 11: PCA of just kraters, with groups identified by clusters. Vessels marked in black are unassigned.

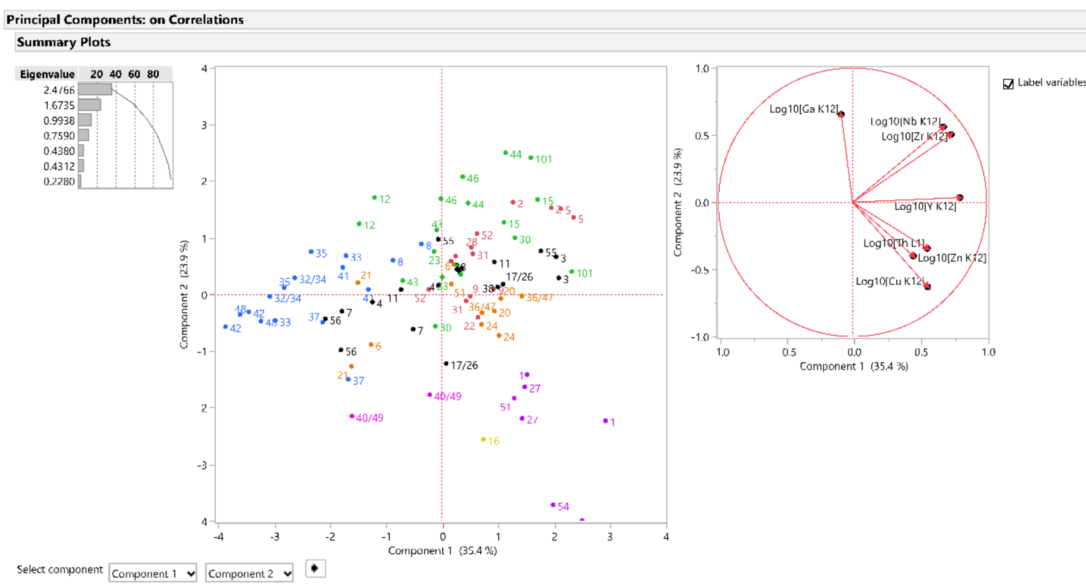

Figure 12: PCA of vessels from SJ 274/279, colored by cluster.

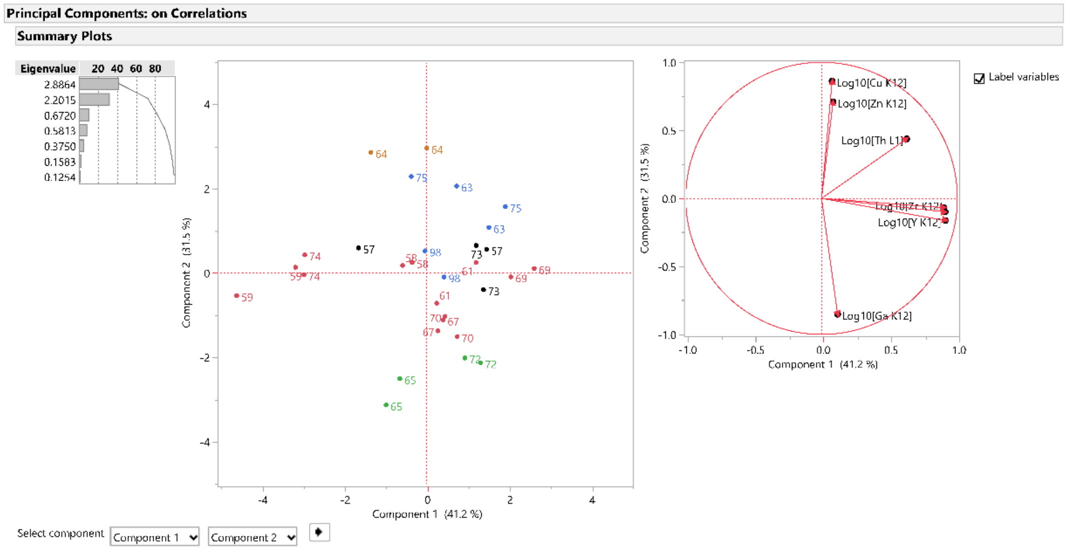

Figure 13: PCA of vessels from SJ 280/281, with clusters colored.

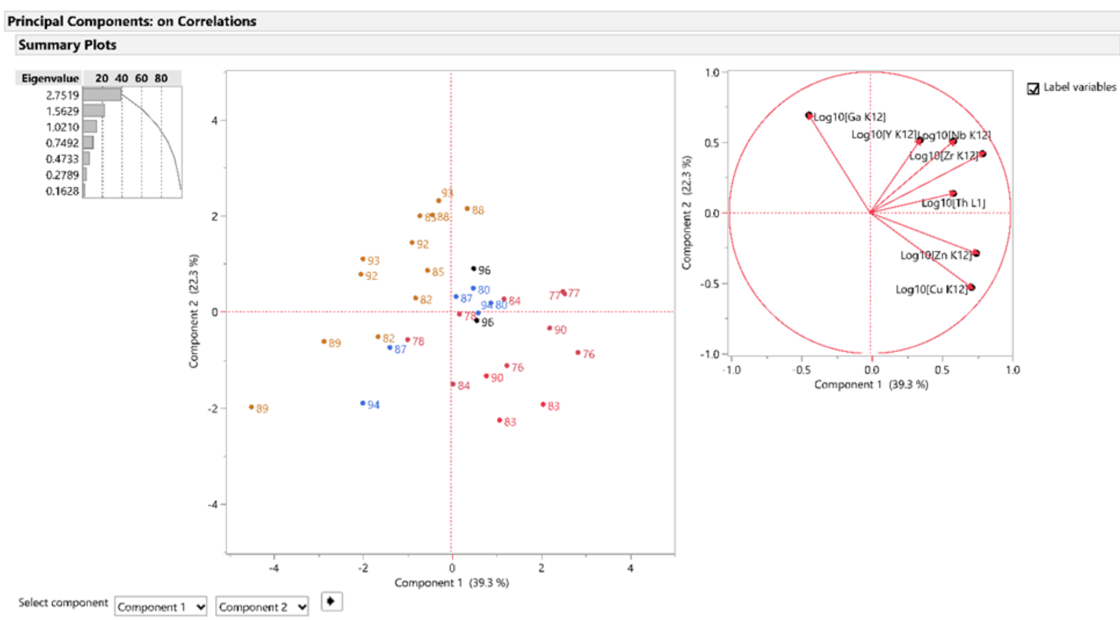

Figure 14: PCA of vessels from SJ 283, clusters colored.

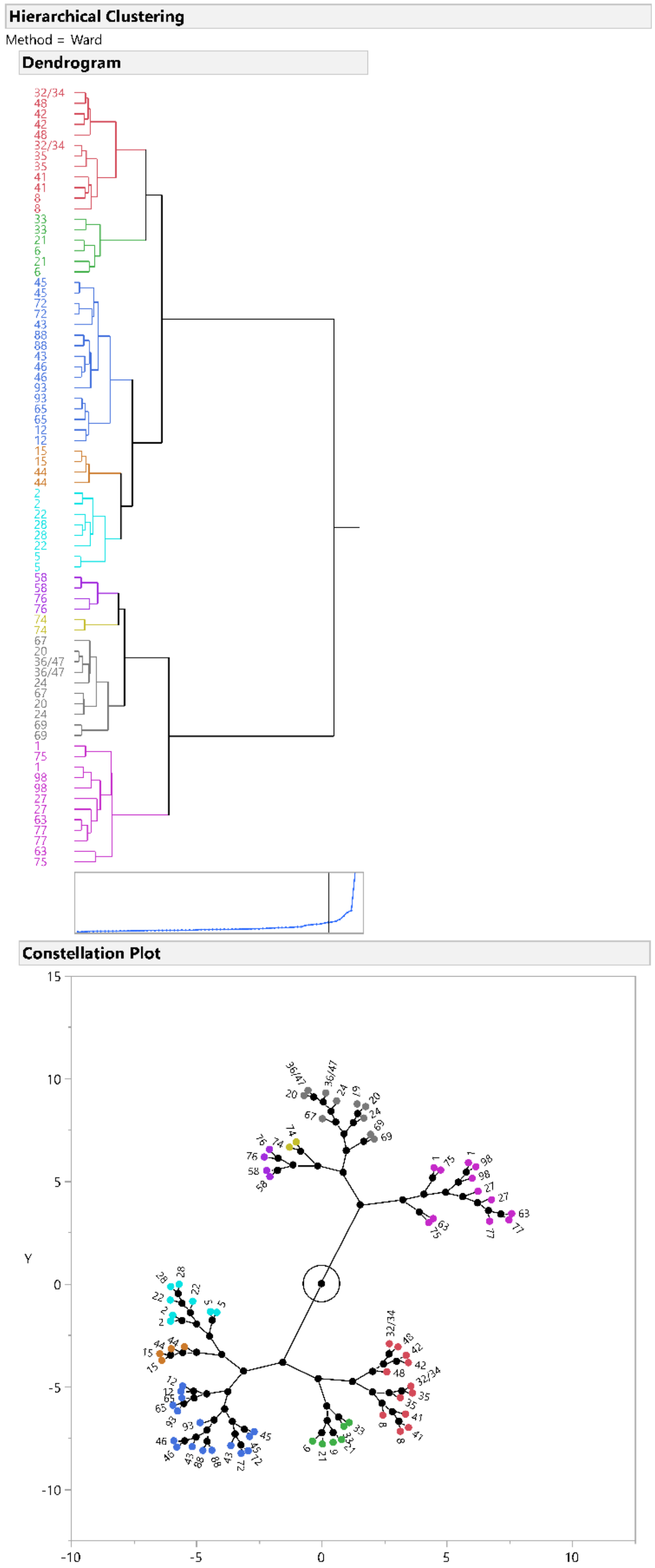

Figure 15: Clustering of final groups.

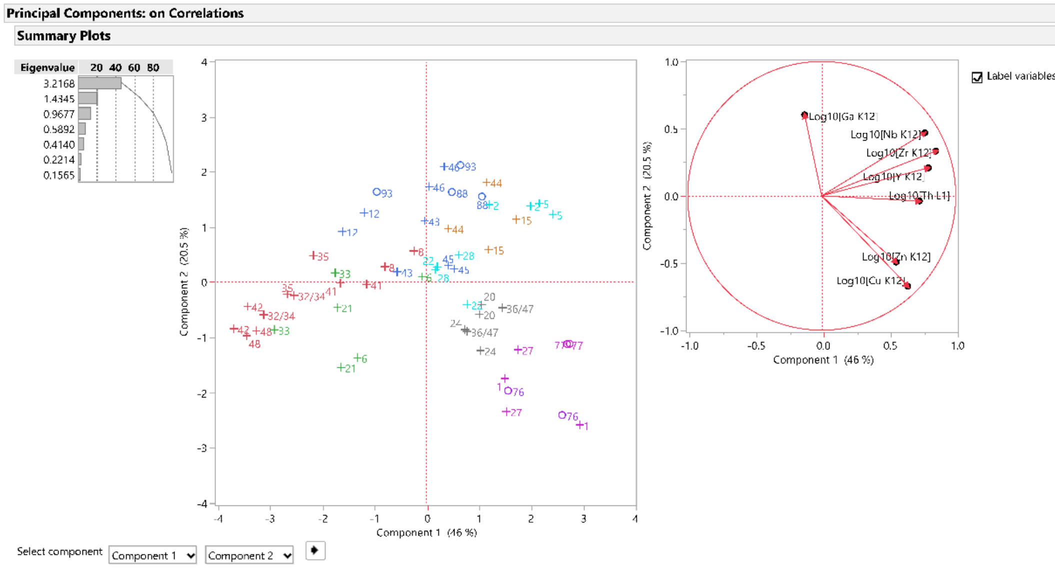

Figure 16: Comparison between layers among final groups. Groups are color coded, and layers marked. Vessels from SJ 274/279 are marked by + and vessels from SJ 283 are marked by ◯.

Table 2: Assigned Vessels and Groups.

Vessel ID	Assay Number	Vessel Type	Layer	Log10[Cu K	Log10[Ga K	Log10[Nb K	Log10[Th L	Log10[Y K1	Log10[Zn K	Log10[Zr K	Group
32/34	V32.N1.GF	Bowl	274/279	2.621176	1.380211	1.863323	1.431364	2.164353	2.506505	2.899821	1
32/34	V34.N4.GF	Bowl	274/279	2.676694	1.322219	1.963788	1.579784	2.09691	2.396199	2.96895	1
35	V35.N2.GF	Bowl	274/279	2.668386	1.544068	1.982271	1.70757	2.082785	2.4133	2.984527	1
35	V35.N3.GF	Bowl	274/279	2.621176	1.414973	1.913814	1.643453	2.100371	2.432969	2.925312	1
41	V41.S2.N2.GF	Krater	274/279	2.627366	1.30103	2.130334	1.633468	2.143015	2.478566	2.931458	1
41	V41.S2.N3.GF	Krater	274/279	2.695482	1.361728	1.986772	1.748188	2.25042	2.465383	2.977266	1
42	V42.E2.GF	Krater	274/279	2.550228	1.425211	1.763428	1.612784	2.071882	2.460898	2.835691	1
42	V42.E3.GF	Krater	274/279	2.552668	1.518514	1.763428	1.518514	2.220108	2.495544	2.808886	1
48	V48.E1.GF	Krater	274/279	2.547775	1.431364	1.90309	1.568202	1.977724	2.607455	2.839478	1
48	V48.E2.GF	Krater	274/279	2.456366	1.380211	1.763428	1.431364	2.240549	2.588832	2.85248	1
8	V8.E1.GF	Krater	274/279	2.772322	1.322219	2.100371	1.748188	2.252853	2.40824	3.131619	1
8	V8.E2.GF	Krater	274/279	2.585461	1.146128	2.037426	1.653213	2.33646	2.344392	3.077368	1
21	V21.S1.N1.GF	Krater	274/279	3.10721	1.39794	1.799341	1.568202	2.283301	2.642465	2.922725	2
21	V21.S2.N1.GF	Krater	274/279	3.143327	1.591065	1.995635	1.39794	2.190332	2.668386	2.976808	2
33	V33.N2.GF	Bowl	274/279	2.941014	1.531479	1.832509	1.579784	2.064458	2.528917	2.904716	2
33	V33.N3.GF	Bowl	274/279	2.957128	1.633468	1.973128	1.556303	2.120574	2.561101	3.044148	2
6	V6.S1.N1.GF	Krater	274/279	3.051153	1.544068	2.049218	1.414973	2.456366	2.718502	3.044932	2
6	V6.S2.N1.GF	Krater	274/279	3.226084	1.447158	1.919078	1.544068	2.212188	2.690196	2.954725	2
12	V12.N1.GF	Krater	274/279	2.78533	1.653213	2.049218	1.491362	2.264818	2.514548	2.977724	3
12	V12.N2.GF	Krater	274/279	2.661813	1.662758	2.113943	1.612784	2.155336	2.532754	3.076276	3
43	V43.E1.GF	Krater	274/279	2.644439	1.716003	2.021189	1.740363	2.350248	2.662758	3.082426	3
43	V43.E2.GF	Krater	274/279	2.70927	1.612784	1.838849	1.778151	2.294466	2.641474	3.113275	3
45	V45.E1.GF	Krater	274/279	2.719331	1.518514	2.09691	1.799341	2.292256	2.722634	3.080266	3
45	V45.E2.GF	Krater	274/279	2.717671	1.462398	2.133539	1.845098	2.30963	2.690196	3.03543	3
46	V46.E1.GF	Krater	274/279	2.593286	1.681241	2.161368	1.763428	2.352183	2.541579	3.042969	3
46	V46.E2.GF	Krater	274/279	2.612784	1.732394	2.127105	1.69897	2.424882	2.537819	3.124504	3
65	V65.E1.GF	Krater	280/281	2.528917	1.716003	2.004321	1.544068	2.290035	2.521138	3.062582	3
65	V65.E3.GF	Krater	280/281	2.627366	1.518514	2.045323	1.531479	2.350248	2.545307	3.06558	3
72	V72.S2.N1.GF	Krater	280/281	2.713491	1.70757	2.064458	1.857332	2.376577	2.695482	3.148294	3
72	V72.S2.N2.GF	Krater	280/281	2.732394	1.755875	2.10721	1.90309	2.404834	2.658011	3.143951	3
88	V88.S1.E1.GF	Krater	283	2.697229	1.653213	2.227887	1.662758	2.38739	2.720159	3.170848	3
88	V88.S2.N1.GF	Krater	283	2.733197	1.623249	2.143015	1.643453	2.416641	2.559907	3.153205	3
93	V93.S1.N1.GF	Krater	283	2.609594	1.591065	2.209515	1.832509	2.338456	2.432969	3.172019	3
93	V93.S1.N2.GF	Krater	283	2.623249	1.623249	2.079181	1.544068	2.307496	2.456366	3.10721	3
15	V15.N2.GF	Krater	274/279	2.758155	1.322219	2.25042	1.716003	2.38739	2.580925	3.308991	4
15	V15.N3.GF	Krater	274/279	2.780317	1.278754	2.178977	1.732394	2.276462	2.586587	3.323252	4
44	V44.E2.GF	Krater	274/279	2.622214	1.255273	2.214844	1.579784	2.352183	2.502427	3.206016	4
44	V44.N1.GF	Krater	274/279	2.687529	1.414973	2.292256	1.690196	2.267172	2.494155	3.351796	4
2	V2.E2.GF	Krater	274/279	2.959041	1.50515	2.262451	1.819544	2.423246	2.575188	3.22917	5
2	V2.N1.GF	Krater	274/279	2.974051	1.579784	2.176091	1.69897	2.41162	2.552668	3.219585	5
22	V22.E1.GF	Krater	274/279	2.893207	1.50515	2.049218	1.633468	2.334454	2.671173	3.139879	5
22	V22.E2.GF	Krater	274/279	3.02735	1.491362	2.037426	1.838849	2.369216	2.737193	3.029384	5
28	V28.N1.GF	Krater	274/279	2.865104	1.447158	2.181844	1.763428	2.283301	2.620136	3.118595	5
28	V28.N3.GF	Krater	274/279	2.972666	1.39794	2.146128	1.672098	2.305351	2.563481	3.079543	5
5	C1.1	Krater	274/279	3.081707	1.770852	2.212188	1.857332	2.382017	2.736397	3.243782	5
5	C1.5	Krater	274/279	3.147367	1.681241	2.255273	1.886491	2.369216	2.716003	3.253096	5
58	V58.N1.GF	Krater	280/281	3.580925	1.255262	2.004321	1.690196	2.217484	2.718502	3.172019	6
58	V58.N2.GF	Krater	280/281	3.631849	1.342423	2.056905	1.690196	2.143015	2.7348	3.149219	6
76	V76.E2.GF	Bowl	283	3.595717	1.431364	2.021189	1.748188	2.30103	2.980458	3.127105	6
76	V76.E3.GF	Bowl	283	3.639387	1.20412	2.184691	1.70757	2.305351	3.080626	3.197281	6
74	V74.S1.N2.GF	Krater	280/281	3.549739	1.255273	1.724276	1.716003	2.09691	2.624282	2.943	7
74	V74.S2.E1.GF	Krater	280/281	3.503791	1.361728	1.716003	1.778151	2.139879	2.4843	2.874482	7
20	V20.S1.N3.GF	Krater	274/279	3.199206	1.361728	2.139879	1.716003	2.363612	2.676694	3.101059	8
20	V20.S1.N4.GF	Krater	274/279	3.280351	1.462398	2.049218	1.792392	2.30103	2.716003	3.146438	8
24	V24.S1.N1.GF	Krater	274/279	3.411788	1.30103	2.143015	1.70757	2.290035	2.748188	3.084219	8
24	V24.S2.N1.GF	Krater	274/279	3.425208	1.544068	2.025306	1.748188	2.267172	2.770852	3.11059	8
36/47	V47.N1.GF	Krater	274/279	3.207904	1.322219	2.149219	1.740363	2.352183	2.702431	3.171434	8
36/47	V47.N2.GF	Krater	274/279	3.154728	1.255273	2.089905	1.716003	2.274158	2.68842	3.158362	8
67	V67.N1.GF	Krater	280/281	3.236285	1.477121	2.167317	1.591065	2.278754	2.598791	3.183555	8
67	V67.N2.GF	Krater	280/281	3.354876	1.568202	2.120574	1.70757	2.303196	2.640481	3.146748	8
69	V69.E1.GF	Krater	280/281	3.460597	1.340256	2.198657	1.944483	2.38739	2.587711	3.23477	8
69	V69.N3.GF	Krater	280/281	3.442166	1.278754	2.170262	2.004321	2.495544	2.60206	3.243534	8
1	V1.N1.GF	Krater	274/279	4.197005	1.342423	2.075547	1.857332	2.361728	2.93044	3.173186	9
1	V1.N3.GF	Krater	274/279	3.814048	1.414973	1.959041	1.755875	2.344392	2.776701	3.172895	9
27	V27.S1.E1.GF	Krater	274/279	3.76552	1.30103	2.064458	2.08636	2.385606	2.469822	3.014521	9
27	V27.S1.E2.GF	Krater	274/279	3.801129	1.113943	2.053078	1.845098	2.382017	2.64836	3.028164	9
63	V63.E1.GF	Krater	280/281	3.807264	1.20412	2.158362	1.897627	2.363612	2.788168	3.196176	9
63	V63.E2.GF	Krater	280/281	3.732876	0.845098	2.193125	1.880814	2.285557	2.804139	3.120903	9
75	V75.S1.N1.GF	Krater	280/281	4.047197	1.041393	2.037426	1.869232	2.235528	2.918555	3.033826	9
75	V75.S2.E1.GF	Krater	280/281	4.135927	1.380211	2.08636	2.037426	2.468347	2.92737	3.135133	9
77	V77.E1.GF	Bowl	283	3.797821	1.261574	2.190332	1.869232	2.372912	2.672098	3.22037	9
77	V77.E2.GF	Bowl	283	3.977724	1.342423	2.139879	1.869232	2.409933	2.64836	3.218798	9
98	V98.E2.GF	Krater	280/281	3.934751	1.380211	2.041393	1.740363	2.31597	2.751279	3.081347	9
98	V98.E3.GF	Krater	280/281	3.945272	1.477121	2.181844	1.740363	2.380211	2.582063	3.023664	9

Table 3: Unassigned vessels.

Vessel ID	Assay Number	Vessel Type	Layer	Log10[Cu K	Log10[Ga K	Log10[Nb K	Log10[Th L	Log10[Y K1	Log10[Zn K	Log10[Zr K	Group
100	V100.N1.GF	Krater	280/283	2.832509	1.255273	1.939519	1.623249	2.060698	2.428135	2.802774	
100	V100.N2.GF	Krater	280/283	2.806858	1.255273	1.643453	1.518514	2.071882	2.519828	2.840106	
101	V101.E1.GF	Krater	274/279	2.915927	1.20412	2.158362	1.845098	2.290035	2.819544	3.409087	
101	V101.E3.GF	Krater	274/279	2.671173	1.643453	2.238046	1.812913	2.292256	2.64836	3.354876	
11	V11.E1.GF	Krater	274/279	2.820201	1.380211	2.049218	1.591065	2.198657	2.719331	3.053078	
11	V11.E3.GF	Krater	274/279	2.975891	1.462398	2.117271	1.748188	2.346353	2.668386	3.161068	
14	V14.N2.GF	Krater	274/279	2.843233	1.491362	2.139879	1.812913	2.326336	2.620136	3.0187	
14	V14.N3.GF	Krater	274/279	2.771587	1.380211	2.08636	1.924279	2.281033	2.531479	3.137037	
16	V16.S1.N1.GF	Krater	274/279	3.272306	0.90309	2.120574	1.568202	2.274158	3.062958	2.961421	
16	V16.S1.N2.GF	Krater	274/279	3.213783	0.60206	1.924279	1.886491	2.330414	3.162564	2.990339	
17/26	V17.S1.N2.GF	Krater	274/279	3.280578	1.579784	2.11059	1.681241	2.374748	2.749736	3.098298	
17/26	V26.N2.GF	Krater	274/279	3.641177	1.262271	2.037426	1.477121	2.255273	2.733197	3.044932	
23	V23.E1.GF	Krater	274/279	2.799341	1.672098	1.954243	1.845098	2.332438	2.694605	3.068928	
23	V23.E3.GF	Krater	274/279	2.744293	1.612784	2.103804	1.857332	2.240549	2.630428	3.049218	
3	V3.E2.GF	Krater	274/279	3.332842	1.278754	2.30963	1.732394	2.389166	2.658965	3.154728	
3	V3.E3.GF	Krater	274/279	3.082785	1.477121	2.232996	1.643453	2.416641	2.869232	3.186674	
30	V30.E1.GF	Krater	274/279	2.716838	1.414973	2.173186	1.886491	2.436163	2.556303	3.150142	
30	V30.E2.GF	Krater	274/279	2.937518	1.255273	1.919078	1.799341	2.292256	2.582063	3.135769	
31	V31.E2.GF	Bowl	274/279	3.161667	1.50515	2.1959	1.724276	2.222716	2.624282	3.13258	
31	V31.E3.GF	Bowl	274/279	3.168497	1.612784	2.079181	1.869232	2.198657	2.764176	3.080987	
37	V37.N1.GF	Krater	274/279	2.729165	1.176091	1.799341	1.763428	2.232996	2.611723	2.955688	
37	V37.N3.GF	Krater	274/279	2.704151	1.447158	1.869232	1.755875	2.021189	2.675778	3.020361	
38	V38.E1.GF	Krater	274/279	2.939519	1.255273	2.113943	1.80618	2.311754	2.643453	3.1959	
38	V38.E3.GF	Krater	274/279	3.131619	1.50515	2.056905	1.819544	2.243038	2.558709	3.159567	
4	V4.E1.GF	Krater	274/279	2.740363	1.623249	1.959041	1.778151	2.294466	2.803457	3.079904	
4	V4.E2.GF	Krater	274/279	2.642465	1.531479	1.934498	1.755875	2.218962	2.69897	2.97174	
40/49	V49.N1.GF	Krater	274/279	3.394277	1.285835	1.982271	2.037426	2.238046	2.498311	2.922206	
40/49	V49.N3.GF	Krater	274/279	3.309204	1.113943	1.934498	1.897627	2.075547	2.478566	2.889862	
51	V51.E2.GF	Krater	274/279	3.207096	1.278754	2.127105	1.531479	2.303196	2.571709	3.104487	
51	V51.E3.GF	Krater	274/279	3.175222	1.079181	1.929419	2.068186	2.437751	2.587711	3.098298	
52	V52.S1.N1.GF	Krater	274/279	3.024075	1.414973	2.037426	1.778151	2.298853	2.491362	3.046495	
52	V52.S2.E2.GF	Krater	274/279	2.914872	1.591065	2.071882	1.748188	2.447158	2.509203	3.113275	
54	V54.N1.GF	Bowl	274/279	4.080302	1.477121	1.763428	2.274158	2.485721	2.763428	2.956168	
54	V54.N2.GF	Bowl	274/279	4.098644	1	1.995635	2.30103	2.423246	2.655138	2.969416	
55	V55.E1.GF	Krater	274/279	3.122544	1.653213	2.100371	1.690196	2.235528	2.562293	3.112605	
55	V55.E2.GF	Krater	274/279	3.431364	1.556303	2.217484	1.690196	2.40824	2.625312	3.165244	
56	V56.S2.N1.GF	Krater	274/279	3.028978	1.380211	1.919078	1.681241	2.170262	2.582063	2.893207	
56	V56.S3.E1.GF	Krater	274/279	2.893762	1.230449	1.963788	1.568202	2.09691	2.517196	2.989005	
57	V57.N1.GF	Krater	280/281	3.499412	1.113943	2.068186	1.748188	2.068186	2.561101	2.991669	
57	V57.N2.GF	Krater	280/281	3.750817	1.278754	2.225309	1.886491	2.324282	2.656098	3.182129	
59	V59.S1.N1.GF	Bowl	280/281	3.364363	1.361728	1.633468	1.477121	2.004321	2.592177	2.883093	
59	V59.S2.N1.GF	Bowl	280/281	3.382917	1.230449	1.770852	1.681241	2.064458	2.576341	2.921166	
61	V61.E1.GF	Krater	280/281	3.167317	1.462398	2.017033	1.869232	2.311754	2.627366	3.104487	
61	V61.N1.GF	Krater	280/281	3.216957	1.113943	2.093422	1.913814	2.334454	2.608526	3.219585	
64	V64.N1.GF	Krater	280/281	3.763802	1.113943	1.832509	1.869232	2.193125	3.489677	2.994317	
64	V64.N2.GF	Krater	280/281	3.846585	1.176091	1.995635	1.845098	2.235528	3.693639	3.114277	
7	V7.E1.GF	Krater	274/279	2.940018	1.431364	1.959041	1.643453	2.021189	2.668386	3.037825	
7	V7.N1.GF	Krater	274/279	3.080626	1.380211	1.90309	1.690196	2.287802	2.618048	3.064832	
70	V70.N1.GF	Krater	280/281	3.073352	1.491362	2.075547	1.832509	2.264818	2.621176	3.164947	
70	V70.N2.GF	Krater	280/281	3.16465	1.633468	2.060698	1.819544	2.320146	2.549003	3.18327	
73	V73.S1.N1.GF	Krater	280/281	3.831678	1.256854	2.149219	1.662758	2.40824	2.91698	3.217221	
73	V73.S2.E1.GF	Krater	280/281	3.586475	1.462398	2.247973	1.724276	2.367356	2.748188	3.188647	
78	V78.E2.GF	Bowl	283	3.584331	1.477121	2.064458	1.662758	2.33646	2.58995	3.141136	
78	V78.N1.GF	Bowl	283	3.602603	1.579784	2.060698	1.579784	2.307496	2.583199	3.045714	
80	V80.E1.GF	Krater	283	3.226084	1.556303	2.130334	1.716003	2.269513	2.691081	3.182129	
80	V80.E2.GF	Krater	283	3.18949	1.36715	2.152288	1.869232	2.276462	2.683947	3.153205	
82	V82.E1.GF	Krater	283	3.027757	1.230449	2.071882	1.361728	2.324282	2.499687	3.079181	
82	V82.N1.GF	Krater	283	2.758912	1.477121	2.164353	1.770852	2.178977	2.567026	3.117603	
83	V83.N1.GF	Krater	283	3.621592	0.69897	2.060698	1.880814	2.307496	2.701568	3.168203	
83	V83.N3.GF	Krater	283	3.569608	0.845098	2.075547	1.748188	2.255273	2.745855	3.109579	
84	V84.E1.GF	Krater	283	3.524656	1.339268	2.232996	1.556303	2.378398	2.748963	3.144574	
84	V84.E2.GF	Krater	283	3.586812	1.272782	2.053078	1.724276	2.290035	2.725912	3.046105	
85	V85.N1.GF	Krater	283	2.595496	1.477121	2.146128	1.681241	2.389166	2.4133	3.167613	
85	V85.S3.N1.GF	Krater	283	2.766413	1.653213	1.991226	1.944483	2.25042	2.559907	3.169674	
87	V87.E1.GF	Krater	283	3.16346	1.50515	2.155336	1.70757	2.348305	2.745075	3.077004	
87	V87.E2.GF	Krater	283	3.065206	1.662758	2.060698	1.755875	2.120574	2.656098	3.065953	
89	V89.S1.N2.GF	Krater	283	2.713491	1.380211	1.792392	1.342423	2.193125	2.399674	2.990783	
89	V89.N1.GF	Krater	283	2.868644	1.431364	1.968483	1.477121	2.296665	2.44248	3.013259	
9	V9.S1.E1.GF	Krater	274/279	3.206556	1.633468	2.029384	1.986772	2.460898	2.472756	3.030195	
9	V9.S1.E2.GF	Krater	274/279	2.892095	1.462398	2.064458	2.10721	2.450249	2.376577	2.957128	
90	V90.S1.E1.GF	Bowl	283	3.48373	0.954243	2.033424	1.612784	2.340444	2.671173	3.15564	
90	V90.S1.E3.GF	Bowl	283	3.534787	1.176091	2.149219	1.880814	2.278754	2.749736	3.220631	
92	V92.S1.N1.GF	Krater	283	2.624282	1.662758	2.021189	1.740363	2.287802	2.474216	3.069668	
92	V92.S3.E1.GF	Krater	283	2.759668	1.556303	1.939519	1.732394	2.453318	2.488551	3.153205	
94	V94.E1.GF	Bowl	283	3.168497	1.380211	1.973128	1.838849	2.30963	2.675778	3.197556	
94	V94.N1.GF	Bowl	283	3.137671	1.278754	1.799341	1.763428	2.240549	2.503791	3.045323	
96	V96.E1.GF	Bowl	283	3.320977	1.30103	1.973128	1.60206	2.423246	2.748963	3.167613	
96	V96.E3.GF	Bowl	283	3.276921	1.643453	2.143015	1.662758	2.380211	2.761176	3.133219	
97	V97.N1.GF	Krater	272	2.424882	1.531479	2.045323	1.69897	2.303196	2.354108	3.200303	
97	V97.N2.GF	Krater	272	2.549003	1.041393	2.170262	1.799341	2.313867	2.394452	3.269279	
99	V99.E1.GF	Bowl	280/283	3.589167	1.342423	2.133539	1.892095	2.350248	2.741939	3.213252	
99	V99.E2.GF	Bowl	280/283	3.553762	1.477121	2.1959	1.863323	2.389166	2.691965	3.197832	

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