AN ABSTRACT OF THE THESIS OF

Savanna Buehlman-Barbeau for the degree of Master of Science in Applied Anthropology presented on September 11, 2020.

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Abstract approved:

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Leah Minc

The recent recovery of Dalma Ware at the archaeological site of Surezha, Northern Mesopotamia (modern-day Iraqi-Kurdistan), has raised questions regarding the method of its arrival in the region (Stein 2017; Stein & Fisher 2018). In order to assess Dalma Ware's potential modes of dispersal into Northern Mesopotamia, ceramic petrography and paste analysis was used to identify communities of practice among the local and Dalma ceramics from Surezha, as well as the Dalma assemblage from Dalma Ware's type-site, Dalma Tepe (modern-day NW Iran). Comparison between the Dalma Ware from Surezha and Dalma Tepe revealed a similar *chaîne opératoire* of ceramic production, despite results of their contrasting origins of geologic provenance (Minc & Buehlman-Barbeau 2020). However, the Dalma assemblage from Surezha also had distinct differences with the assemblage from Dalma Tepe, including a lower average amount of mineral inclusions per ceramic sample, and larger organic inclusions. Overall, the Dalma Ware at Surezha displayed significant similarities to Surezha's local wares in addition to its resemblance to the

community of practice found at Dalma Tepe. The petrographic and paste results from the ceramics at Surezha and Dalma Tepe were compared with expectations for four possible modes of dispersal to explain the presence of Dalma Ware at Surezha: trade, pastoralism, itinerant specialists, and displacement (i.e., exogamy, migration), and suggest that more than one mode may have been operative. Regardless, the recovery of Dalma Ware at Surezha is highly suggestive of Northern Mesopotamia's connections with communities in Western Iran during the late 5th millennium BCE.

MAPPING MINERALS, CHARTING COMMUNITY: A PETROGRAPHIC STUDY OF DALMA WARE IN THE CHALCOLITHIC NEAR EAST

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Savanna Buehlman-Barbeau, Author

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TABLE OF CONTENTS

TABLE OF CONTENTS (*Continued)*

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF APPENDIX FIGURES

Figure Page

LIST OF APPENDIX TABLES

Table Page

DEDICATION

To my parents, who never doubted me.

Chapter I

The Tale of Two Sites: Introduction

In 1958, archaeological excavations in northwestern Iran began at a site previously untargeted by researchers, the site itself having been found by happenstance during the excavation of a nearby tell. While initially documented for its early presence of sedentism in a region otherwise known in the archaeological record by its semi-nomadic practices, Dalma Tepe's legacy soon shifted into something more material. A number of archaeologists began to study a previously unseen tradition of pottery later to be dubbed "Dalma Ware". At first, this pottery was primarily distinguishable in its painted and impressed designs, which quickly set it apart from its regional contemporary wares. However, its distinctive character gained further importance when archaeologists then began to recover it in reaches far from Dalma Tepe. Reports of Dalma Ware came from Iranian provinces in the southwest, to the north in the Nakhchivan Autonomous Republic, and even as far west as Northern Mesopotamia. Archaeologists employed material analyses in order to further understand what binds such a widespread yet cohesive ceramic tradition together in an area that is so often touted for its unforgiving terrain. However, it wasn't long before regional differences within the Dalma Ware type became just as diagnostic of the tradition as its more primary attributes. Questions of just *where* Dalma Ware had spread in the ancient past quickly turned to focus on the *how* and *why* as well.

Over the years, many hypotheses regarding the spread and general homogeneity of Dalma Ware have worked to further understand the type, as well as its place in the Chalcolithic era. Among the hypotheses rise three major theories which speak to practices and behaviors accountable for such dispersal, including trade, emulation, and transhumant pastoralism.

Mechanisms of trade, highly capable of such spread, are broadly considered in study but have yet to be substantiated through chemical testing, as research thus far has shown (Henrickson and Vitali 1987; Tonoike 2009). Emulation of the pottery type, on the other hand, may account for the seemingly sporadic spread and local production, paired with overall exterior consistency; however, there is no observed political or economic framework to bind this type across extended time or space, making it difficult to theorize why seemingly unconnected communities would adopt such a ceramic tradition at the level seen in the archaeological record (Tonoike 2009, 2014). Theories of transhumant pastoralism have continued to be popular, pertaining both to Dalma Ware and the Chalcolithic Near East (Abdi 2003; Tonoike 2009; Abedi *et al.*, 2015). Dalma Ware as a tradition perpetuated by groups within a community moving across the landscape as pastoralists keenly upholds the idea of Dalma Ware being produced locally, and further suggests a framework from which the tradition is maintained. However, the patterns and overall distance of distribution as well as the morphological variations within the type itself imply a need for further analysis per the interpretation of the tradition's spread during the Chalcolithic, as even transhumant pastoralism does not fully explain its variable presence and characteristics in the archaeological record (Tonoike 2009).

The study of Dalma Ware has great potential to further perceptions of human movement, sustainability practices, and inter-regional connections in the Chalcolithic Near East. As many scholars of the ancient Near East are currently focused on the rise of urbanization in Northern Mesopotamia and its periphery, one of the major factors of that urbanization rests on the North's interactions and connections with the rest of the ancient world. Thus, traditions such as Dalma Ware are of particular interest to such research, as it may lend insight to such social landscapes of interaction (Stein 2017). The implications of Dalma Ware's distribution may not only illuminate Dalma community, but their ties with other communities and regions in the southern Caucasus, west-central Iran, and, of course, Northern Mesopotamia. In that regard, the study of Dalma Ware is much greater than ceramic analysis: It is a synthesis of human behavior within social and environmental landscapes of the Chalcolithic.

Following the archaeological recovery of Dalma Ware in the Ushnu-Solduz Valley south of Lake Urmia, Dalma Ware has, to date, been found north into the southern Caucasus, west into the Erbil, Kirkuk, and Diyala Governorates of Iraqi-Kurdistan, as far south as the Luristan and Kermanshah provinces of Iran, and finally east into the Zanjan province of Iran. According to recent radiocarbon dates taken from Dalma-bearing sites, it is currently theorized that the Dalma tradition flourished in the southern Caucasus and northwestern Iran from ca. 5000 – 4500 BCE, and then in the southerly region for the latter half of the 5th millennium (Abedi *et al.*, 2015). In searching to explain its distribution, key to the discussion is understanding why Dalma Ware was apparently pushed from its northern reaches around 4500 BCE. Dalma Ware in Iraqi-Kurdistan, however, has not been researched nearly as extensively as it has been in the Iranian and Caucasus sites.

This thesis provides an in-depth analysis of material evidence for the production of Dalma Ware recovered from two Chalcolithic archaeological sites: Surezha of the Erbil Plain (present-day Iraqi-Kurdistan), and the type site of Dalma Tepe in the northern Zagros Mountains (present-day Iran), in order to shed light on the environmental and social structures accounting for the spread of Dalma Ware into Iraqi-Kurdistan. Building on the results of previous chemical analysis via Instrumental Neutron Activation Analysis (INAA) (Minc and Buehlman-Barbeau 2020), this investigation utilizes petrographic analysis to assess the behaviors and practices undertaken by the Dalma community which account for the tradition's distribution, as well as its role in the Chalcolithic Near East. Where INAA offers interpretation into the chemical signature and geologic provenance of a given ceramic sample, petrography then may contextualize the cultural choices and behaviors contributing to the morphological makeup of the vessels themselves. This study uses the perspective of "communities of practice" to evaluate the technological traditions in which Dalma Ware was produced. Specifically, this thesis delves into the mineral composition and paste characteristics of Chalcolithic ceramics of Surezha and Dalma Tepe in order to assess the scope of variation or homogeneity within the Dalma community of practice as seen across the landscape. By analyzing ceramic samples from two sites, Surezha and Dalma Tepe, the research that follows explores the potential connectedness between these two regions by discussing communities of practice as illustrated in the material record by said ceramic samples. Through this exploratory analysis, a comparison may be served between the ceramic tradition of Dalma Ware in two found locations in order to assess the scope of variation or homogeneity within the Dalma community of practice as seen across the landscape. This comparison will better inform theoretical modes of Dalma dispersal, whether pastoralism, displacement practices, or the work of itinerant specialists, from which archaeology can understand the larger implications of Dalma Ware's presence in Northern Mesopotamia.

Chapter II: Background and Research Questions

Chapter II details the geography, general chronology, and archaeological history of the study region. This includes a review of the study's time period, the climate and general geology of the region, and previous and current archaeological endeavors. This informative introduction stands to contextualize the region and era to which the Dalma tradition is known, and to outline the research questions and aims taken on in this thesis. Furthermore, Chapter II offers a detailed review of Dalma Ware as it is currently known, and the main hypotheses theorizing its dispersal.

Chapter III: Theories and Research Objectives

Chapter III explores Dalma Ware as community of identity, produced by one or more communities of practice, as observed in previous studies. Chapter III then introduces the methods employed to analyze the Dalma community of practice, and synthesizes how different modes for its dispersal may present in the archaeological record, as reflected in the communities of practice methodological approach. Specifically, the thesis presents expectations for variability in ceramic technology for four alternative explanations for the spread of Dalma Ware, including trade, transhumant pastoralism itinerant specialists, and displacement practices such as exogamy and migration.

Chapter IV: Methods and Materials

Chapter IV details materials and results used to assess Dalma community of practice and dispersal as detailed in Chapter III. Methods of microscopic paste analysis and ceramic petrography are used to evaluate inclusion size, shape, and abundance, from which this study will make comparisons between community of practice between two sites. Additionally, INAA data of the same sample collection from a previous study (Minc & Buehlman-Barbeau 2020) is consulted to build an in-depth analysis of Dalma production and technology.

Chapter V: Discussion and Conclusion

Chapter V delves into a discussion of the petrographic and paste analysis results as outlined in Chapter IV. This chapter then assesses results relative to expectations detailed in Chapter III in exploration of how they might apply to theory of Dalma dispersal. Chapter V concludes this study by revisiting the thesis’ aims and subsequent theories as developed in previous chapters, and further addresses the state of current theory regarding the Dalma community of practice and tradition in this study and others.

Chapter II

Northern Mesopotamia and Beyond: A Brief Introduction

Interest in Chalcolithic Mesopotamia (ca. 5300 BCE - 3100 BCE) has held steady in the field of archaeology for over a century. Mesopotamia is traditionally defined as the area surrounding the Tigris and Euphrates rivers and their tributaries; this includes regions in their periphery: the modern-day countries of eastern Syria, southeastern Turkey, northwestern Iran, Iraq, and Iraqi-Kurdistan. Where past research was heavily concentrated on Southern Mesopotamia's vast empires, including Uruk, Sumerian, and Akkadian, current archaeological approach now focuses on the rise of Northern urban centers (Stein and Özbal 2007). Due to political and regional stressors, study of Northern Mesopotamia has only recently opened up to archaeological pursuit (Ur *et al.*, 2013), which has since ushered in archaeological teams from across the globe seeking to understand Northern Mesopotamia and its role in the ancient world.

Throughout the Chalcolithic, Northern Mesopotamia was known to be jointly interconnected with its neighbors in Southern Mesopotamia and eastern Anatolia. The region saw such a remarkable influx of goods and commodities across a vast physical landscape due to these inter-regional connections, including pottery, obsidian, and other material culture (Stein 2012a). This thesis looks to offer further insight into Northern Mesopotamia's inter-regionality by exploring a potential material connection with sites in modern-day Iran. It examines Chalcolithic ceramics dating to ca. 5000 – 4200 BCE from sites including Surezha from Northern Mesopotamia (modern-day Iraqi-Kurdistan) and Dalma Tepe from the Ushnu-Solduz Valley in northwestern Iran.

The following table, adapted from Stein (2017) and Abedi *et al.* (2015), may be considered as the chronological illustration of the Chalcolithic Near East during the specific timeframe of this thesis (ca. 5000 BCE – 4200 BCE). For the purposes of this study, it is imperative to note that while the chronology in northwestern Iran was originally measured by dates measured by the Hasanlu Project (Voigt 1983), recent radiocarbon dates instead suggest a revised chronology for the region, as illustrated in Table 2.1 (Abedi & Omrani 2013; Abedi *et al.*, 2015). These new dates push Dalma Ware back ca. 500 years to the beginning of the fifth millennium BCE in NW Iran.

Table 2.1: Regional Chronology of the Chalcolithic Near East.[a,b]

Dates	**Northern Mesopotamia**	**Northern Mesopotamia *Ceramic Ware Types***	**Northwest Iran**	**Northwest Iran *Ceramic Ware Types***
3900 - 3700 BCE	Late Chalcolithic 3	Chaff Tempered Buff; Fine Paste Buff; Gray Ware	Late Chalcolithic 3	Chaff-Faced Ware
4200 - 3900 BCE	Late Chalcolithic 2	Chaff Tempered Buff; Grit Tempered Buff; Fine Paste Buff; Sprig Ware; Blister Ware	Late Chalcolithic 2	Chaff-Faced Ware
4500 - 4200 BCE	Late Chalcolithic 1	Ubaid-derived painted wares; Chaff Tempered Buff; Grit Tempered Buff *Minority presence:* **Dalma Ware**	Late Chalcolithic 1	Pisdeli Ware (Black on Buff)
5000 - 4500 BCE	Ubaid 3 - 4	Ubaid Fine Paste Buff	Dalma	**Dalma Ware**
5300 - 5000 BCE	Ubaid 3 - 4	Ubaid Fine Paste Buff	Late Neolithic/ Transitional Chalcolithic	*Transitional Phase*
5800 - 5300 BCE	Halaf	Halaf	Late Neolithic	Hajji Firuz Ware

a) Chronology in Northern Mesopotamia specific to Surezha, defined by Stein (2012a; 2017). Dates are approximate.
b) Chronology of Northwest Iran as defined by Abedi *et al.* (2015; Abedi 2017). Dates are approximate.

Regional Outlooks: Summary of Geology, Climate, and Archaeological History

In order to further evaluate the role of Northern Mesopotamia in the ancient world, study must be done in efforts to accentuate its inter-regional connections with neighboring communities. For that reason, this thesis looks specifically to a ceramic culture, known as Dalma Ware, that is shared between both Surezha and multiple Iranian sites, including Dalma Tepe. The following section provides a brief climatic, geologic, and archaeological overview of the regions surrounding Surezha and Dalma Tepe.

Surezha: Iraqi-Kurdistan - Erbil Plain

The geologic landscape of Iraqi-Kurdistan is shaped by the Zagros Mountain range, which follows along the modern-day borders of Iraq and Iran, northern Iraqi-Kurdistan, and into southeastern Turkey. The Zagros range is the result of a Miocene-age collision between the Arabian and Eurasian plates and is still relatively active today (Oveisi *et al.,* 2009). This collision created a series of distinct thrust and fold zones as they now decline westward into the Iraqi and Kurdish plains: the Zagros Suture Zone (over-thrusted), the Imbricate Zone (thrusting), the High Folded Zone ("simply" folded), and the Low Folded (or "Foothill") Zone. The Zagros Suture Zone is characterized by high mountain peaks and plunging valleys consisting of Triassic – Jurassic carbonates, as well as ophiolites, radiolarites, limestones, and conglomerates. The High Folded Zone is made of steep folds formed from Cretaceous and Tertiary carbonates, and the Imbricate Zone is narrow and densely folded, containing marine carbonates and Cretaceous flysch. Lastly, the Foothill Zone of the Zagros is characterized by syntectonic deposits, which result in gently folded Cretaceous through Miocene era marine deposits topped by Quaternary sedimentary units (Reif *et al.*, 2011; Al-Qayim *et al.*, 2012; Awdal *et al.*, 2013; Zainy *et al.*, 2017) The site of Surezha is located in the Erbil Plain, which lies within the Foothill Zone.

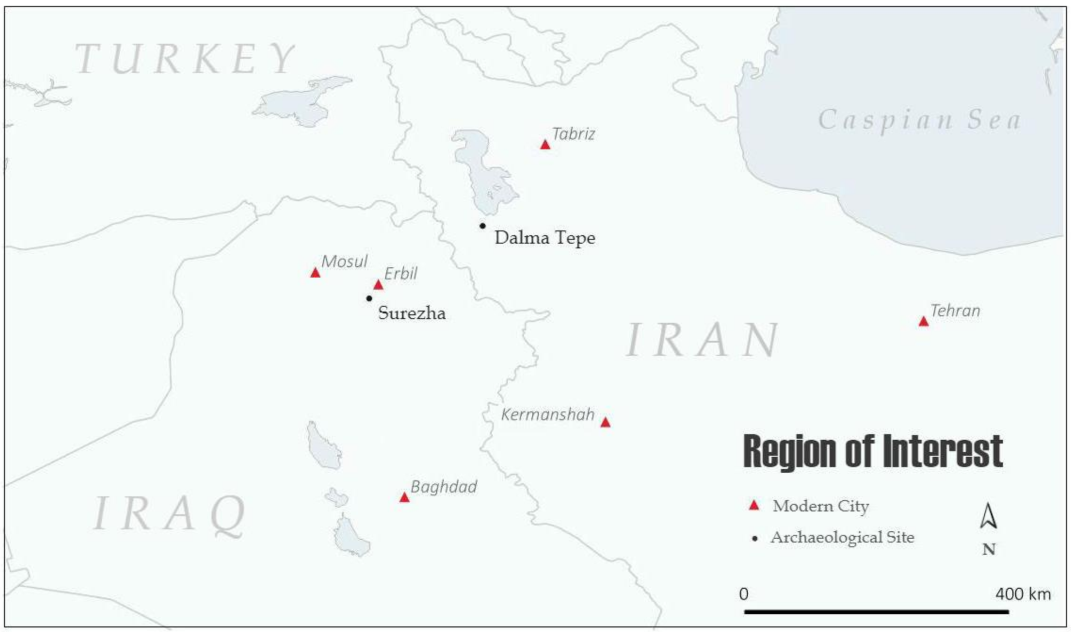
Located within the gently rolling foothill zone, the Erbil Plain is locked between the Upper and Lower Zab Rivers to the north and south, respectively, and the Makhmur Plain binds it in the southwest and the Chai Bastora valley to the northeast (Ur *et al.*, 2013). The Erbil Plain itself is categorized as a moist-steppe zone, with cool, wet winters and warm, dry summers. Annual precipitation averages at roughly 500 mm annually. Paleobotanical studies of the surrounding area, focused on sediment core samples from lakes Van, Zirabar, and Mirabad, demonstrate an oak and pistachio woodland environment with grasses by the transition to the Holocene (van Zeist 1967; Altaweel *et al.*, 2012). Pollen analysis from Lake Zeribar exhibits an abundance of flora from the genus *Rheum* during the middle Chalcolithic, indicative of overgrazing by this early date (Abdi 2003), and suggesting considerable antiquity for a mixed farming and herding lifeway. Archaeological surveys (Ur *et al.*, 2013) have suggested that the Erbil Plain was one of the most densely settled regions in Mesopotamia, with settlements dating back at least into the Chalcolithic. Human-built water canals and channels are seen extensively throughout the plain, which are thought to date back to the Bronze Age (ca. 2500 BCE) with the Neo-Assyrian empire. These water transport systems are hypothesized to indicate systemic agricultural practice across the Erbil Plain.

Archaeology of Surezha

The archaeological site of Surezha was first academically recognized during Harvard University's Erbil Plain Archaeological Survey (EPAS) in 2012, led by Dr. Jason Ur (Ur *et al.*, 2013). Excavation began in 2013 under the direction of Dr. Gil Stein of the University of

Chicago, and continues from the year 2016. Primary research into Surezha looks to clarify its development and role as a large settlement of the Chalcolithic era. With much of Surezha's chronology falling within the LC (Late Chalcolithic) 1 - 4 periods, the site stands as an opportunity to explore urbanization in Northern Mesopotamia as a process entirely divorced from colonization and expansion efforts of the south (Stein 2017; Stein & Fisher 2018).

Fig. 2.1: Map of Study Area



Surezha is a mounded site in a modern-day village that shares the same name, located 20 km south of Iraqi-Kurdistan's contemporary capital of Erbil (*Fig. 2.1)*. The site is roughly 22 hectares in total, including the mound, the adjoining terrace, and the lower town. Evidence of mudbrick architecture, indicative of a sedentary lifestyle, is present. The site of Surezha would have been attractive in the ancient past times for several reasons, such as its location, prime not only to Southern Mesopotamia, but regions in modern-day Turkey and northwestern Iran as well. Indeed, its inter-regionality is clearly stated as excavations yielded obsidian from Turkey's

Lake Van region, namely the sources of Nemrut Dağ and Meydan Dağ (Stein & Alizadeh 2014; Khalidi *et al.*, 2016), and ceramic traditions both local and not, including that of Dalma Ware. Surezha's Dalma Ware includes both Dalma Painted and Dalma Impressed, and is found within contexts of other ceramic types. To date, it is explicitly found at the uppermost levels of the LC1, dating to around 4200 BCE. (Stein & Fisher 2018). Though Dalma Ware represents only a small part of the site's ceramic collection, it nevertheless indicates Surezha's connections with communities in Iran. The presence of artifacts such as obsidian and the Dalma type are highly suggestive of the paramount positionality of the site (Stein 2017).

Northwestern Iran – The Ushnu-Solduz Valley

The site of Dalma Tepe lies within the Ushnu-Soludz Valley, which is located within the Zagros Imbricate Zone. The Imbricate Zone is characterized by a diversity of highly deformed metamorphic rocks from the Late Proterozoic – Mesozoic. Alongside the prolific presence of calc-alkaline granitic bodies, these rocks include schist, gneisses, metacarbonates, and amphibolites, all of which are covered by gabbroic Phanerozoic layers, as well as quartzite. This zone is also characterized by its many plutonic outcrops and Mesozoic volcanism (Berberian *et al.*, 1981; Voight 1983; Mazhari *et al.*, 2011a). The Ushnu-Solduz Valley, named for the surrounding Ushnu and Solduz districts (now Oshnavieh and Naqadeh, respectively) in the area, runs east to west for roughly 35 km with the Gadar River.

Within the West Azerbaijan province of Iran, the Ushnu-Solduz Valley region experiences a temperate, mountainous environment with an average rainfall spanning from 300 mm to 600 mm a year, variable within the valley itself. The West Azerbaijan province is divided into three vegetative zones: the Zagrosian oak forest, the pistachio-almond-maple forest, and the

Artemisia steppe zone. The Ushnu-Solduz Valley occupies the *Artemisia* steppe zone, otherwise known as the Afghano-Anatolian Steppe. This zone exists at a moderate elevation, with a relatively low annual rainfall measuring only 300 mm (Bobek 1968; Van Zeist 1967; & Bottema 1977; Voigt 1983; Danti 2013). Like the Erbil Plain, pollen analysis from lake and peat samples taken in the region proximal to the Ushnu-Solduz Valley indicate severe overgrazing as seen in the dramatic decreases in certain flora commencing near 5000 BCE, such as Poaceae and Cyperaceae, which cumulated at a severe low point ca. 4500 BCE (Leroyer *et al.*, 2016; Messager *et al.* 2016).

The Ushnu-Solduz Valley has been extensively settled since the Late Neolithic (ca. 6th millennium). As the surrounding region is known for its soil salinity and steep altitudes, the valley, in contrast, has long been a prime location for settled communities and agricultural systems due to its arable terrain, lower levels of salinity, and availability of freshwater from the Gadar River. Evidence of canal irrigation dates back to the Late Bronze and early Iron Ages. Archaeological record shows that irrigation and settlement patterns are more densely packed towards the eastern end of the valley, where the Gadar River slows (Danti 2013).

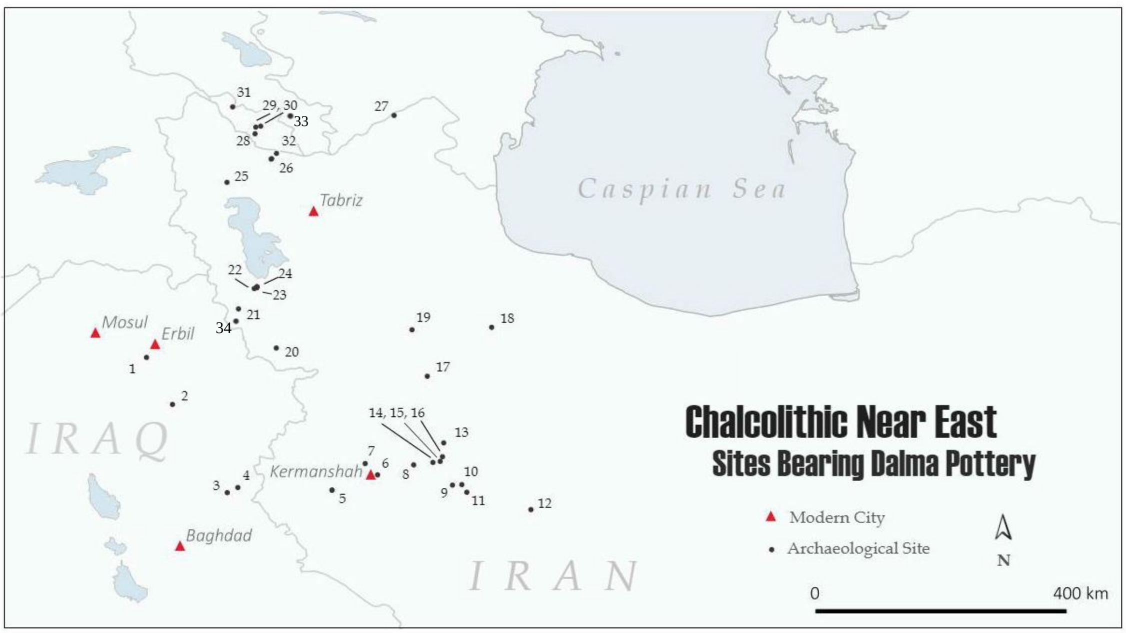
Archaeology at Dalma Tepe

Dalma Tepe is located roughly 25 km southwest from the southern shore of Lake Urmia in modern-day northwestern Iran (*Fig. 2.1)*. The site was academically recognized by a team of archaeologists from the University of Pennsylvania, who at the time were excavating a neighboring site, Hasanlu Tepe, less than five kilometers away. Excavation at Dalma Tepe was soon incorporated into the Hasanlu Project, first in 1958 and 1959 under the lead of Dr. Charles Burney, and then again in 1961 by Dr. T. Cuyler Young Jr. Reportedly, these excavations were minimal in scale; however, Dalma Tepe nevertheless provided the Hasanlu Project with evidence for one of the earliest examples of sedentism in the Ushnu-Solduz Valley system, as emphasized by the site's mudbrick architecture. The recovery of Dalma Ware greatly added to the site's importance. Based on one radiocarbon date from Dalma Tepe, Dalma Ware was understood as active between the years 4100 BCE - 3700 BCE (Henrickson 1985). However, a recent recalibration of this sample and more radiocarbon data tested from the region calls to revise these dates, instead suggesting that Dalma Ware in NW Iran should be attributed to the much earlier time frame of ca. 5000 BCE – 4500 BCE, abruptly replaced regionally by Pisdeli (Black on Buff) Ware come 4500 BCE; by contrast, the Dalma Ware tradition continues in the regions south during the second half of the 5th millennium BCE (Abedi & Omrani 2013; Abedi *et al.,* 2015).

Dalma Ware is distinctive by four types: Dalma Painted, Dalma Impressed, Dalma Red Slipped, and Dalma Plain. Though early study was primarily concerned with identifying the extent of the type itself (Braidwood *et al.,* 1961; Young Jr. 1961; Hamlin 1975; Young Jr. 1966), by the 1980s, research turned to consideration of the use and mode of dispersal seen by the Dalma Ware type.

Introduction to Dalma Ware

In the initial stages of research, Dalma Ware was primarily defined as a sequestered type abundantly yet briefly known to the Urmia region and the central Zagros of Iran, bounded to the west by the mountainous region known as the *chaîne magistrale* and confined in the south by the Khorasan Road, near the Kermanshah and Hamadan Provinces (Hamlin 1975; Henrickson & Vitali 1987). However, further investigation has vastly broadened the physical realm of Dalma tradition (*Fig. 2.4*). Dalma Ware has been found as far west as Iraqi-Kurdistan (Forest-Foucault 1980; Jasim 1983; Stein & Fisher 2018), as far east as Zanjan province in Iran (Zeynivand *et al.*, 2013; Alibaigi *et al.*, 2012), and north into the Nakhchivan Autonomous Republic (Hamlin 1975; Abedi *et al.*, 2017; Bakhshaliyev 2018; Marro *et al.*, 2019). At many of these sites, Dalma Ware represents a small fraction of the overall ceramic assemblage and is clearly distinct from local and regional style ceramics.



1.) Surezha
2.) Yorgan Tepe
3.) Kheit Qasim
4.) Tell Abada
5.) Chogha Gavaneh
6.) Siahbid
7.) Chogha Maran
8.) Sahneh Valley
9.) Tepe Giyan
10.) Nehavand Valley
11.) Baba Qassem
12.) Qal'e-ye-Sarakhti
13.) Assadabad
14.) Kangavar Valley
15.) Godin Tepe
16.) Seh Gabi
17.) Tepe Gheshlagh
18.) Tepe Nor
19.) Karvansara
20.) Tepe Namashir
21.) Lavin Tepe
22.) Dalma Tepe
23.) Hajji Firuz
24.) Hasanlu
25.) Dava Göz
26.) Baruj Tepe
27.) Idir Tepe
28.) Nakhchivan Tepe
29.) Uzun Oba
30.) Uçan Ağıl
31.) Qosha Tepe
32.) Kul Tepe
33.) Godedzor
34.) Tepe Ubaid

Fig. 2.2: The Currently Known Extent of Dalma Dispersal (not exhaustive; see Appendix A)

As mentioned previously, Dalma Ware is categorized into four types, as detailed below by Hamlin (1975).

1.) Dalma Painted is characterized by its bold, repeated geometric motifs and thick brushstrokes, with color ranging to a deep plum or maroon, to a warm brown. The motifs are cross-hatched, striped, or filled with lines; however, there is usually only one recurring motif per ceramic vessel. These designs are commonly painted over a matte white slip, and the interior of the vessels are either untreated or painted with matte red slip. Dalma Painted wares often come in the form of globular pots, chalice-type vessels, and straight-sided bowls.

2.) Dalma Impressed categorizes the vessels that have been manipulated, prior to firing, with various types of surface treatments that alter the vessel's exterior. For example, crescent-shaped fingernail impressions are common, as well as thin, long impressions most likely made from sticks or reeds. Vessels are also manipulated via small puncture holes, or impressed with textiles and comb tools. A mixture of impression-types has not been observed. These designs are present below a sort of "buffer zone" beneath the rim, which remains, by and large, smooth and unaltered by such manipulation. Some of the Dalma Impressed wares have a red slip painted over the design. It is important to note that such manipulations are characterized by their abundance and intended pattern; this category does not include vessels with single impressions that could otherwise be deemed accidental on the potter's part. Like Dalma Painted wares, the interior of the vessel is either left untreated or painted with matte red slip. Previous microscopic studies note the similarity in the matrix of both Dalma Painted and Dalma Impressed, though some of the Dalma Impressed samples appear denser in fabric and with less chaff. Dalma Impressed wares appear in the form of large pots, globular pots, and shallow plates.

3.) Dalma Red Slipped includes vessels that have no painted motifs or surface-manipulated patterns, but instead have their exteriors, and sometimes interiors, covered with matte red slip. The slip can range from a dark plum to maroon in color, with some vessels first treated with a white or cream slip underneath. The fabric of Dalma Red Slipped wares include chaff temper and small white grits. Vessel type includes forms such as globular pots of all sizes, shallow plates, and even miniature bowls.

4.) Dalma Plain wares include vessels sans surface impressions, painted motifs, or red slip treatment. These ceramics are subjected only to smoothing of the exterior. Plain wares are common in the form of trays, large pots, and shallow bowls.

Previous studies which have analyzed the technological tradition of Dalma production describe the ceramics as handmade and friable, tempered with chaff with small grit inclusions, leaving it with uneven breakage patterns. Because chaff temper makes clay prone to cracking when overextended during, for example, methods of coil construction, Dalma vessels are formed using slab construction (Vandiver 1987). The clay is fired to a pink, orange-buff, or even greenish color, and the cores are often darkened as a result of a lack of oxygen during a quick firing process (Hamlin 1975; Tonoike 2014). As a whole, Dalma Ware is most easily distinguishable by its outwardly design; further study has discovered that it is quickly made and quickly fired, from montmorillonite clay with chaff tempered voids and culturally added mineral temper. Early INAA data suggest that Dalma Ware is produced locally per site, with distinctive chemical markers which distinguish local ceramic samples from their neighbors (Henrickson & Vitali 1987).

Tonoike's petrographic study (2009) greatly expanded the scope of knowledge surrounding the tradition and production of Dalma Ware. With a collection of ceramic samples from NW Iran's Solduz Basin, and sites of the Central Zagros including Seh Gavi, Tepe Siahbid, and Godin Tepe, Tonoike analyzed over 100 sherds via ceramic petrography and electron microprobe analysis. Though these sherds were largely of the Dalma tradition; those from the neighboring Haiji Firuz and Pisdeli ceramic traditions were included for comparison. Tonoike found that Dalma Ware of both the NW and Central sites are distinguishable as a cohesive group against both the Haiji Firuz and Pisdeli wares. However, despite its uniformly similar exterior design and general cohesiveness in manufacture, Tonoike posits that Dalma Ware is difficult to describe as a single coherent group or tradition in absolute (2014). Though Dalma Ware is similar in terms of style and make across sites and types, variability within those similarities is plentiful, and is especially seen between types even within a single site's ceramic assemblage. Vessel function is cited as one of the leading causes of this differentiation, exemplified specifically in the variation between Dalma Painted, which usually exhibit a finer, thinner form, and Dalma Impressed, which demonstrate coarser, thicker vessel walls. Tonoike also cited some variation between Northwest and Central assemblages, though they were not as significant as those between types. Whereas Dalma Ware from NW Iran was found to have a moderate amount of voids, Dalma Ware from the Central Zagros had moderate to abundant voids, and less large inclusions than as exhibited in NW Dalma Ware (Tonoike 2009). To further accentuate these regional differences, material studies performed by Vandiver (1987) found that vessel forming technology varied depending on the region. While all of the Dalma ceramics were indeed handmade from sequential slab manufacture, Vandiver found that the potters in the Central Zagros's Luristan province used bevelled joins to form these slab-based Dalma vessels, where Dalma potters in NW Iran and the southern Caucasus used straight joins (Vandiver 1987; Henrickson & Vitali 1987; Tonoike 2014). Though initially synthesized as regional differentiations, given the recent recalibration and reinterpretation of the Dalma timeline (Abedi *et al.*, 2015), these variations now may not only be a dependent of distance, but of the variable of time as well. It is well stated that Dalma Ware, across great distances, maintains a great level of similarity consistent with a broad community of practice (Henrickson & Vitali 1987; Tonoike 2014); perhaps then inter-regional variability is a product of change over time, considering that such differences appears slight in comparison to those maintained between types.

Based on these previous studies and her own research, Tonoike interprets the Dalma tradition as represented production on a household level, as measurable by differences as seen with an individual or small group: "[The] great variability suggests that although the Dalma potters had a mental template for how a Dalma ceramic should look on the outside, the actual manufacturing techniques were probably up to the individual potters. These individual potters used whatever temper that was most suitable to the clay source they had access to, and they formed the Dalma ceramics according to local customs" (Tonoike 2014:72). Thus, based on the theories and practices as outlined, Dalma Ware may be conceptualized as a cohesive group across regions that bears levels of variability between site and type, which may be due to group or individual preference.

Theory of Dalma Dispersal

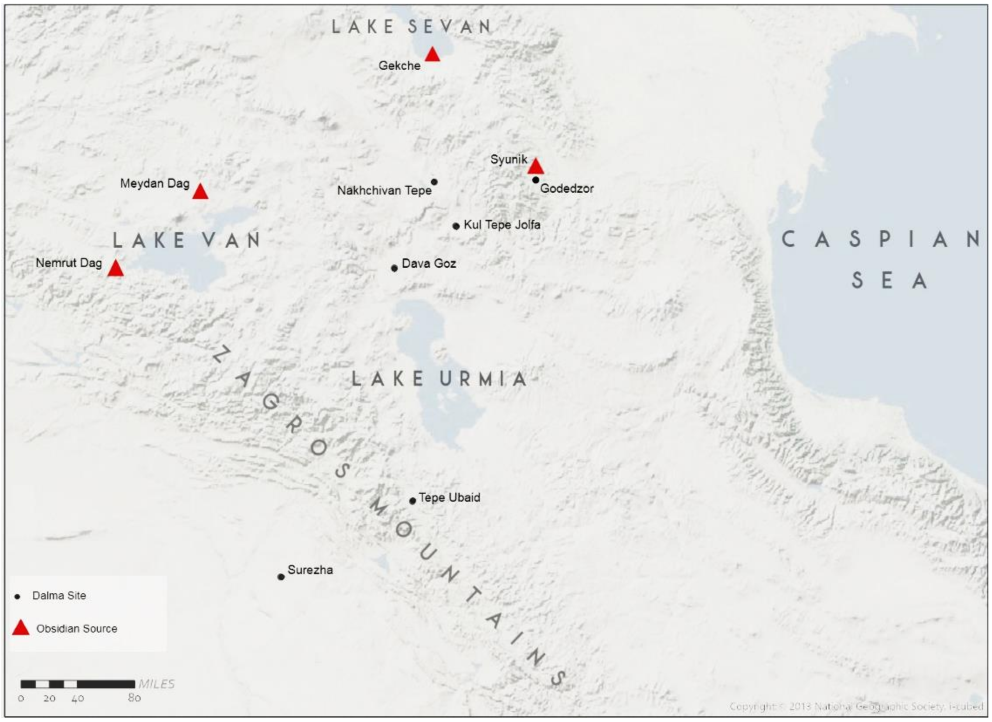
Various studies have sought to explain the broad dispersal of Dalma Ware. Where Henrickson & Vitali (1987) found through INAA data that Dalma Ware was locally produced per site, Tonoike (2009) found that the technology of Dalma Ware, though largely homogeneous, hosts variations on the household level. Under the revised understanding of Dalma's chronology in the greater Near East region (Abedi *et al*,. 2015), a new wave of hypotheses regarding the spread of Dalma Ware has come to light, mainly centered around transhumant pastoralism and migration (Tonoike 2009; Abedi *et al.*, 2015). In this thesis, I will explore four main mechanisms of dispersal that may be compatible with the Dalma presence in Northern Mesopotamia. These include trade, pastoralism, itinerant specialists, and displacement practices such as exogamy.

Theory of Dalma Dispersal: Trade and Exchange

Though prior research has pointed to the mineralogical, chemical, and technological differences within the Dalma type which suggest the improbability of Dalma dispersal by trade and exchange (Henrickson & Vitali 1987; Tonoike 2009), trade of this ceramic type has only recently begun to be explored in regions of Northern Mesopotamia. Certain commodities such as obsidian were known to link regions together, including Northern Mesopotamia. Procurement and exchange of obsidian in Chalcolithic Mesopotamia illustrates the long-distance routes that connected regions and communities. Archaeological sites in Northern Mesopotamia and Northwestern Iran are found to host obsidian artifacts from the Caucuses, as well as the Lake Van region in Turkey. Obsidian is thought to be especially commodified throughout the Late Chalcolithic, and it is shown in the archaeological record to be chosen over other resources at this time, such as chert, in many sites (Niknami *et al.,* 2010; Khalidi *et al.*, 2016). In such instances, seen especially in sites such as Tell Brak and Tell Hamoukar, the growing popularity of obsidian may have led to changes in economic, social, and political frameworks in order to accommodate the growing need for a new resource such as obsidian. This may not have only led to people seeking new routes to obsidian sources, but may have also led them to interact with other communities and groups via trade, or along the route to the source location itself. This would have expanded a single community's relationships with others, as well as the land itself (Khalidi *et al.,* 2016; Hole 1987), and in turn would have established routes of transmission for goods between communities. Studies have shown that Surezha's obsidian originates largely from the Lake Van region, namely that of Nemrut Dağ and Meydan Dağ (Stein & Alizadeh 2014; Khalidi *et al.,* 2016). Much of Surezha's obsidian is dated to the LC1 period, like site's Dalma Ware. It is important to note that Surezha shares obsidian sources with other sites containing Dalma Ware. Kul Tepe Jolfa, a site in NW Iran bordering the Nakhchivan Autonomous Republic, is an archaeological site evidencing both pastoralism and sedentism, with Dalma Ware dating back to the first half of the 5th millennium BCE. Though most of Kul Tepe Jolfa's obsidian was sourced to the Armenian site of Syunik and Lake Van's Meydan Dağ, some was likewise sourced to Nemrut Dağ as well (Nadooshan *et al.,* 2013; Abedi *et al.,* 2015). Obsidian from Dava Göz, another agro-pastoral Dalma site near Kul Tepe Jolfa, has been mainly sourced to Meydan Dağ and Syunik, and a small amount was traced to Nemrut Dağ (Abedi *et al.,* 2019). A series of excavations in the Little Zab Basin of NW Iran have yielded Dalma Ware at sites such as Tepe Ubaid and Silveh from the early 5th millennium BCE. The obsidian tested from these contexts at Tepe Ubaid has origins with both Meydan Dağ and Nemrut Dağ (Binandeh *et al.,* 2020). From this assessment alone, Surezha is, by some degree, potentially connected to four regions, including the obsidian sources at Lake Van, the Little Zab Basin southwest of Lake Urmia, the region to the northwest of Lake Urmia, and finally to obsidian sources in Armenia, courtesy of sites such as Kul Tepe Jolfa and Dava Göz (*Fig. 2.3)*. Of these four archaeological sites, the obsidian found within contexts alongside Dalma Ware all have some origins with Meydan Dağ, three share the obsidian source of Nemrut Dağ, and two share the site of Syunik. Notably, however, a fifth Dalma Ware site, Nakhchivan Tepe, does not share a direct obsidian source with Surezha, with the majority of its obsidian from the Gekche site near Lake Sevan, however some obsidian objects have sourced to Syunik as well (Bakhshaliyev 2018). From this small sample of Dalma sites alone, it is worth noting that obsidian procurement may thus have ties with communities which produce Dalma Ware, even if that source is not singular. This pattern also allows some insight into the timeline of Dalma occurrence across the landscape. While sites in NW Iran (Dava Göz, Tepe Ubaid, and Kul Tepe Jolfa) demonstrate their connections with both the Dalma tradition and Meydan Dağ during the first half of the 5th millennium (Nadooshan *et al.*, 2013; Abedi *et al.*, 2018; Binandeh *et al.*, 2020), studies of Surezha's obsidian exhibit its appearance starting in the LC1 (4500 - 4200 BCE), and the site's arrival of Dalma Ware does not occur until the very end of the LC1 (Khalidi *et al.*, 2016; Stein 2017; Stein & Fisher 2018). Furthermore, Khalidi *et al.* note that obsidian at Surezha was most prominent during the LC1, though it was always but a small part of the entire lithic assemblage (2016).

If Dalma Ware can be linked to trade routes for the procurement and distribution of obsidian from sources like Meydan Dağ, the question regarding which groups or individuals participated in such practices remains. Furthermore, given the recent attribution of Dalma Ware in NW Iran to the timespan of ca. 5000 - 4500 BCE compared to its dated presence in the Erbil Plain (4200 BCE), there is a significant gap of time yet to be addressed. According to this timeline, Dalma Ware had been absent roughly 300 years from this region's archaeological record, pending further research and recovery.

Fig. 2.3: Obsidian Sources and Key Archaeological Sites During the Chalcolithic



If obsidian sources such as Meydan Dağ can indeed be considered a common denominator in the Dalma Ware tradition, we must address possible drivers of movement: Are groups driven to procure and distribute obsidian? Or are they driven by something else entirely? At Kul Tepe Jolfa, Nadooshan *et al.* posit obsidian of the Chalcolithic and Early Bronze Age as a symbol of long distance trade, particularly between the Caucuses and the Lake Urmia Basin, as perpetuated by transhumant pastoralists (2013). In this theory, obsidian procurement and utilization was a byproduct of transhumant pastoralism, and would stay within the larger community as indicated by the obsidian cores and subsequent workshops found at Kul Tepe Jolfa itself. In connecting obsidian with Dalma Ware, pastoralism has long been the suggested carrier of Dalma Ware as well, as theorized by scholars such as Tonoike (2009), Abdi (2003), and Abedi *et al.* (2015). If obsidian can be considered a byproduct of transhumant pastoralist trade, perhaps Dalma Ware could be as well.

Theory of Dalma Dispersal: Pastoralism

Pastoralism can be generally defined as a mobile partnership with herding animals, whether that partnership is merely a mechanism of subsistence, or a lifestyle which involves animal-based subsistence practices (Dyson-Hudson 1972; Spooner 1973; Chang & Koster 1986; Abdi 2003). Though the definition itself is admittedly malleable, it is assumed that as a whole, pastoralism is a practice which depends on both mobility and domesticated animals. High mobility indicate pastoralism's ability to engage with a number of individuals and communities across a given region; studies have shown pastoral nomads traveling nearly 600 miles between sites (Tonoike 2014), whereas other pastoralists are known to trek 90 miles between seasonal pasture sites (Amanolahi-Baharvand 1975). Like trade, pastoralism has the potential to link communities of practices over great distances.

Pastoralism as a carrier of ceramic tradition has long been a topic of archaeological discussion, as seen in case studies around the world. Some studies have theorized that pottery would be a burden for mobile groups, as a large collection may prove tiresome and nonsensical to carry in a mobile lifestyle, and the amount of time it takes to collect clay resources, let alone time taken in drying, firing, and decorating ceramic vessels, may likewise be incompatible with groups who depend on their mobility for subsistence. In short, pottery is sometimes thought of a direct result of an abundance of time, resources, and demand likely experienced by settled communities (Arnold 1988; Gibbs 2012). In contrast, however, case studies have shown that ceramics are a fundamental part of the pastoral lifestyle, as shown, for example, by Grillo's ethnographic study of Samburu in Kenya (2014). As a pastoral group, Samburu herd animals such as cattle, goats, and sheep, and though in recent years many use animal hides and wooden bowls for storage and containing purposes, they have a history of ceramic culture. Grillo notes that Samburu own pots "not *despite* the fact that they are mobile herders, but rather *because* those pots have, historically, enabled their lives as mobile herders" (2014:125, emphasis original). In short, ceramic vessels, before the age of metal wares, enabled Samburu to cook, store meat, and prepare foods that may not have been readily edible without a proper boiling. Neighboring pastoral communities are known to use ceramic vessels to store water, beer, and honey. In combating the difficulty of transporting ceramic vessels, studies have shown practices which support the manufacture of vessels suitable for mobility: Where the use of fiber as temper can be used to lighten a vessel's weight by added porosity, similarly, a vessel's exterior can be decorated with handles or perforations to ease carrying practices (Gibbs 2012).

In the time of Dalma Ware, scholars of the Chalcolithic Zagros generally theorize that the rise of plant and animal domestication in the epi-Paleolithic (ca. 11,000 - 9,000 BCE), bore pastoralism in response as it emerged in the Chalcolithic around 6,500 - 5,500 BCE. As agricultural practices grew to dominate the land around settlements, those with herding animals in the community became pressed for available pasture. According to Abdi (2003), these pressures brought herders out of the community in search for better pastures in three main forms: 1) Mobile pastoralism, where herders would take their animals out to graze at maximum of a few days' time from their settled community; 2) Transhumant pastoralism, which involves the seasonal movement of the herds, perhaps between settlements; and finally 3) Nomadic pastoralism, with high mobility and continuous movement between campsites. In this case, pastoralism is a result of resource and capacity stress. However, this does not necessarily mean that pastoralists were forced from their own community; on the contrary, pastoralists were oftentimes a part of a larger community consisting of themselves and sedentary or semi-sedentary agriculturalists. These communities were bound by certain ties, such as kinship and economic dependency, and would rely on each other to maintain high levels of subsistence; while the pastoralists provided various goods, such as animal products and distanced resources, agriculturalists contributed grain and other necessary foodstuffs. Contemporary ethnographies and archaeological studies which document pastoralists of the Zagros Mountains note such relationships between settled and pastoral communities (Barth 1961; Amanolahi-Baharvand 1975; Hole 1987; Alizadeh 1988, 2004), and, speaking to the concept of dependency, Spooner argues that this co-reliance suggests that no community is solely pastoral, as evidence shows that foodstuffs such as grain have always been a staple of even those committed to a mobile lifestyle (1971). However, Amanolahi-Baharvand notes that Baharvand pastoral nomads are actively involved in the cultivation of choice crops in both their summer and winter pastures, including wheat and corn (1975), and Barth's account of Basseri notes that the group would plant cereal crops upon arrival to their summer pasture to be harvested before their seasonal departure (1961). Though it is unclear if such practices would have persisted into the ancient past, it speaks to the independence certain pastoral groups did have. Nevertheless, both Barth and Amanolahi-Baharvand note interactions between pastoralists and sedentary groups despite varying levels of subsistence interdependence.

This independence speaks to the dual identities of pastoralists, who may hold ties to their partnered sedentary community, but also form their own community and culture as their time and distance away from the settlement increases (Abdi 2003). This results in the vast spread of knowledge, from languages to pottery traditions, across a region spanning the settled community and the routes of its partnered pastoralists, who in turn may interact with individuals or groups outside of their partnered settlement(s). Within the greater community of a nomadic or pastoral group, a broad variety of commodities would have been present, as, notes Barth, groups such as

Basseri would potentially be dispersed across 2,000 square miles at a given time. This would occur on account of groups within the Basseri population taking a number of alternate routes to the population's collective summer and winter pastures, and during which time said groups may encounter a number of other pastoral groups or individuals. This broad horizon of interaction would have fostered knowledge of commodities, goods, and of landscape itself, which would have been shared amongst both mobile and sedentary groups. Thus, mobile groups and individuals such as pastoralists and specialists may be conceptualized as major drivers of interregional interaction as it connects people, goods, and knowledge across a variety of population types (Alizadeh *et al.,* 2010).

Pastoralism in the Chalcolithic Near East is demonstrated in the paleobotanical record as well. As mentioned previously, sediment cores from regional lakes have exhibited numerous signs of overgrazing, which of course could result from a rise of lifestyle such as pastoralism. From Armenia's Vanevan peat, flora such as Cyperaceae begin a significant decline around 5000 BCE, and reach an ultimate low point ca. 4500 BCE before increasing once more. Likewise, measures of Poaceae sink to a low point around 4400 BCE, before increasing as well (Leroyer *et al.,* 2016). In Georgia, sediment cores from Nariani record a similar decline in Cyperaceae and Poaceae from 5000 BCE, reaching their lowest again at 4500 BCE. Here, there is an increase in *Artemisia* at this time as well (Messager *et al.,* 2016). An increase in *Rheum* beginning ca. 4500 BCE from sediment cores of Lake Zeribar similarly echoes the theory of overgrazing (Abdi 2003), as other studies have hypothesized genera such as *Rheum* and *Artemisia* thriving with the diminished competition of Cyperaceae as a result of overgrazing (Schlütz & Lehmkuhl 2009). If this dramatic change in the botanical landscape can be attributed to overgrazing, practices of pastoralism as the bearer of such a detrimental effect should be considered. Though there is a considerable gap between pastoralism's theorized inception (ca. 6500 BCE - 5500 BCE) and the beginning of such a rapid decline in botanical types, it is not inconceivable to hypothesize the popularity of such a practice increased over generations. This is especially meaningful when considering theories of pastoralism changing from smaller scale, mobile pastoralism to transhumant and nomadic pastoralism over a long period of time as suitable, nearby pasture grew scarce (Abdi 2003). What is equally if not more telling, then, is the sudden return of such flora and subsequent botanical recovery of overgrazing around 4500 BCE, which coincides with Dalma Ware's disappearance from NW Iran and the Caucasus and eventual reemergence in regions south of Lake Urmia. Of the Middle Chalcolithic site Qal'e Sarakhti in Iran's Luristan Province, Abedi *et al.* (2014) theorize that the presence of Dalma Ware is not the result of rapid migration, but instead a demonstration of pastoralist communities and their slow, continuous search for desirable pasture in the event that such terrain was devastated in their region of origin. This sentiment is echoed by Tonoike's own theory (2009), which linked the household-level variability of Dalma Ware with the concept of pastoralism.

Many sites hosting Dalma Ware in this region have evidence of pastoralism in the early 5th millennium BCE, including Tepe Ubaid, a temporary pastoral site (Binandeh *et al.,* 2020), Kul Tepe Jolfa and Dava Göz, found to be agro-pastoral (Abedi *et al.*, 2019), Godedzor, a seasonal agro-pastoral site thought to be the summer pasture of both Kul Tepe Jolfa and Dava Göz (Chataigner *et al.,* 2010; Abedi *et al.,* 2019), and Nakhchivan Tepe, where evidence of agriculture and nomadic cattle breeding was found (Bakhshaliyev 2018). Furthermore, the region of the Ushnu-Solduz Valley, where Dalma Tepe is located, has a strong history with transhumant pastoralism (Danti *et al.,* 2013). However, some Dalma sites, including Dalma Tepe, exhibit largely sedentary settlements. If Dalma Ware is found at both pastoral and sedentary sites, the question of Dalma Ware's origin may be explored as a tradition rooted in sedentary communities whose ceramic knowledge branched out with partnered pastoralists, or perhaps as a tradition maintained and shared by pastoralists alone. Although, the mantle of such maintenance, from sedentary community to itinerant or pastoral groups, may have shifted over time, especially as lifeway and subsistence practices changed. Thus it is not outlandish to hypothesize that a ceramic tradition such as Dalma Ware may have been retired in the sedentary communities which it originated from, while remaining popular in pastoral groups no longer as closely partnered with said communities as they once had been.

Theory of Dalma Dispersal: Itinerant Specialists

Childe was among the first to theorize the concept of itinerant specialists in the archaeological landscape, and of them he described professionals free from the social confines of communities and groups, instead existing as sort of free agents within their own specialties (Childe 1957). Since then, itinerant specialists have been integrated into archaeology and ethnography in a variety of ways, though some have argued for the rarity of such practices (Rowlands 1971). Regardless of its supposed scarcity, itinerant ceramicists has been documented in the Andes of South America (Ramón 2011), parts of Kenya (Grillo 2014), Korea (Sayers 1987), medieval Europe (Ashby 2015), and, of course, the ancient Near East (Amanolahi-Baharvand 1975; Alden & Minc 2016), just to name a few.

The practice and behavior of itinerant specialists were found to be highly specific to the region and community; where some itinerant specialists were engaged with part-time or seasonal itineracy (Ashby 2015), others fully depended on the sale of their craft year-round as a means of subsistence (Ramón 2011). Thus, the concept of itinerant specialists is highly complex and requires knowledge of the craft and its surrounding communities in order to understand its behavior per region. This thesis will briefly introduce four methods of itinerant specialty, including 1) Specialists whose year-round itineracy is their main form of subsistence; 2) Specialists hired or otherwise moving for the demand of their craft where and when it is needed; 3) Part-time or seasonal specialists who return to a home base after months or seasons of itineracy; and 4) Specialists who produce and trade their craft second to their primary source of subsistence, such as herding or pastoralism.

Itinerant specialists who move year-round to sell their craft do so as their main source of subsistence. An ethnographic study (Ramón 2011) of itinerant ceramicists in the Andes who are involved in a year-round system of movement found that these ceramicists have a "web of places" that they visit on a regular basis. These visits were found to intentionally coincide with a place's harvests, as the itinerant ceramicist would produce their craft in exchange for harvest product. These ceramicists would often travel with their own toolkit and materials; sometimes these materials (clay and temper) would be pre-mixed, which aided in the ease of their production time. Because these ceramicists adhered to their same "web of places", they were known in the region by the local communities.

In contrast, some itinerant specialists are known to move specifically when hired, or when demand warrants. This is seen on a small-scale level in the Andes, where specialists such as ceramicists are hired by a group or familial unit looking for skilled mass production of wares to sell; or on a larger scale, where itinerant ceramicists are hired by a community to aid their own potters as demand rises, for example, in preparation for festivals or holidays. This may also apply to the highland itinerant artisans and ceramicists of the Andes who accompany other members of their community looking to aid in the lowland harvests, and sell their craft accordingly (Ramón 2011). Interestingly, Ramón's (2011) ethnographic study found that ceramicists who are directly hired by a familial unit or community, produce vessels which outwardly adhere to their employer's desired outwardly appearance, whether in painted motif or appliqué, while maintaining their own technical traditions regarding the actual production of the vessel. This detail may prove essential in the identification of itinerant ceramicists in the archaeological record.

The idea of ceramicists moving for demand is seen elsewhere in the world; for example, in Grillo's ethnography (2014) of pastoral Samburu, she addresses the role of itinerant specialists in pastoral and settled communities. Whether they be potters, blacksmiths, or bards, Grillo notes that though they are considered to be "outsiders" to groups such as pastoralists, it is the pastoralist group that relies on the specialist and their produced goods and services to uphold certain practices and expectations of the group's lifestyle, as opposed to the specialist who relies on the pastoral group for, say, subsistence. The idea of specialists acting outside of larger groups have been the topic of research alongside that of pastoralists, as scholars such as Hole (1987) note that specific practices such as lithic production and the manufacture of fine ceramics may have been shared with but a subset of a region's population, creating a framework of interaction and interdependence between groups. Amanolahi-Baharvand's ethnography of Baharvand in Luristan likewise documents interactions with groups and individuals who offered specialized services in return for food or other goods. Groups such as Sar-Reshta-Dar specialized in medicine, where Halaj produced woven rugs and clothing, and Lutis produced wooden dishes for Baharvand groups, as well as preformed religious rites (1975). Both Grillo's and Amanolahi-Baharvand's ethnographies described specialists as communities of practice known to, but "outside" of, a region's other communities and groups, that nevertheless are relied upon by those same groups and hired when needed. This suggests the necessity of itinerant specialists in these ancient landscapes, and how those outside of specialized craft groups may have relied on them.

Next, ethnographic study suggests the practice of itinerant specialists moving from a home base to specific, neighboring marketplaces in order to sell their craft (Ramón 2011; Ashby 2015). According to Ashby (2015), this framework would amplify the specialist as a known and trusted professional to surrounding communities they work with, bettering their connections and therefore their marketability. Being trusted in the community may also aid a specialist's ability to gain local knowledge imperative to their specialty, such as where necessary craft materials, like clay or medicinal herbs, are found per locality. In the event that itinerant specialists do not travel with a fully assembled workshop of materials, they would most likely need local trust and knowledge to gain access to such materials (Ashby 2015). This type of seasonal or short-term craft itinerancy is also seen in the Andes, where Ramón (2011) describes potters which are sedentary most of the year, and spend a number of months in a neighboring community producing their craft. This community may be attractive to the potter due to their resources, which the ceramicist may not have access to otherwise. Ramón found that these potters were sometimes known to settle permanently in their communities of work, where they continued to produce their craft.

Finally, Ramón (2011) documented Andes ceramicists who produce and trade their craft second to their primary source of subsistence, such as herding or pastoralism. As seen in previous sections, pastoralists are known to produce pottery; in the case presented by Ramón, these pastoralists produced pottery during times of rest and later sold the wares in sedentary communities and marketplaces. These itinerant potters and their ceramic type are very well-known in the region and even in myth, where their specific style is detailed.

Based on the histories detailed above, the concept of itinerant ceramic professionals may be extremely specific to group and region; nevertheless, it is intriguing to consider when hypothesizing mechanisms of dispersal to explain the extent of Dalma Ware. Like pastoralists, these specialists may have ties to a given community or area in which they work, whether through kinship or otherwise, allowing them access to a marketplace, or certain materials needed to produce their craft if needed. At Surezha, the recovery of ring scrapers—a specialized tool for thinning the walls of ceramic vessels—suggests potential for itinerant ceramic specialists in the region (Alden & Minc 2016; Stein 2017), as many itinerant potters have been known to carry their own toolkit and supplies with them (Ramón 2011). The overall homogeneity within the manufacture of Dalma Ware, even between sites, speaks also to the possibility of specialized knowledge perpetuated by itinerant ceramicists.

Theory of Dalma Dispersal: Community Displacement and Exodus via Exogamy, Migration

The movement of an individual or a community, whether due to migration, exogamy, or other practices, has immense effect on the dispersal of material goods and artifacts. Where large-scale, community migration over from one region to another may result in large quantities of "foreign" material and goods at a given site, individual practices of movement, such as exogamy may likewise result in the appearance of "foreign" goods, though at a smaller scale. The goods and traditions from migrating outsiders may have great influence on like material culture in the new region, and vice versa, as members of new and local communities may interact. Material culture such as ceramics may be especially utilized in the identification of community and individual movement in the archaeological past.

Pottery is oftentimes used to evaluate practices of small-scale movement, such as exogamy, in the past. This has been seen countless times in both ethnography and archaeology, where studies have shown that a potter contributes in like ways across a variety of situations and time; for example, MacEachern (1998) found that communities participating in exogamic tradition in Cameroon's Mandara Mountains continue to produce ceramic vessels using their own techniques, morphologies, and decorations as per their familiar community of practice, even in their new environments. Over time, these individuals who married into the group are shown to eventually imitate the local customs of ceramic production, although they do not perfect it, as their own identity as members of their original community of ceramic practice persists. Núñez discusses the practice of exogamy as a catalyst for change; as new individuals are introduced to the group, so are new methods of production and morphology (1989; 1990). Though the new individual is likely to adapt to the dominant ceramic style of production at the site, aspects of their own ceramic style may be integrated into the dominant morphologies. Likewise, as an individual married into a group may be motivated to adapt to the customs and practices in their new home, this may result in a style of pottery which appears to be made in the dominant style in some ways, but "emulating" a foreign type at the same time. Indeed, studies have shown that individuals entering a new community are expected to adopt the local ceramic technological style, though they may not be fully proficient in it, having their own inherent technological style to compete with (Gosselain 1992; MacEachern 1998).

Stein (2012b) explores the concept of exogamy in Mesopotamia in study of Uruk and Anatolian networks. Marriage alliances, Stein argues, facilitate economic and political relationships between communities, where the individual marrying outside of their own community is key in the formation and maintenance of inter-regional alliance and relation formation. For Uruk and Anatolian communities, marriage alliances harbored the long-term presence of Uruk colonists in Anatolia without the necessity for violence or dominance.

Furthermore, the practice of exogamy allowed not only the dispersal but also the *maintenance* of ethnic identities across great distances. This maintenance would have been extraordinary instrumental in the facilitation of networks between communities. Stein continues in discussion of how pottery practice may be used to identify practices of exogamy in the archaeological record by analyzing the ceramics of intercultural households. Such households, Stein found, hosted the dual existence of ceramic types—local and foreign—which varied in certain contexts relating to gender roles. Thus, by considering gendered tasks, such as cooking, Stein was able to identify marriages born from exogamous practice by the ceramic traditions and technologies exhibited in a given household. These intercultural assemblages were found over long periods of time, suggesting the lasting relationship between Uruk and Anatolian communities built from marriage alliances.

The implications of exogamy in the world of Dalma Ware are compelling in light of the ongoing attempt to characterize Northern Mesopotamia. If the Dalma Ware at Surezha may be linked to that of exogamy, it is worth noting that the majority of its contemporaries are found, to date, in the Central Zagros. However, the closest Dalma site to Surezha is in actuality much closer, near the modern-day city of Kirkuk. Nevertheless, by the understanding that the majority of Dalma community inhabits that of the Central Zagros during the time it is found at Surezha, it is suggestive of the idea that Surezha and Northern Mesopotamia have the knowledge of communities to the east of the Zagros and vice versa, indicating Surezha's connectivity and status across great distances at this time. Like Stein's (2012b) conclusions regarding Uruk and Anatolian communities, this may also suggest a necessary alliance forged between two regions. Should communities in the Central Zagros maintain networks of social interaction with regions as far as Northern Mesopotamia via exogamy, it perhaps lends evidence towards theories of Northern Mesopotamia's position and power in the greater area, as well as in the Central Zagros.

Research Questions and Aims

This thesis investigates Dalma Ware from two sites on a petrographic and paste level in order to shed light on the inter-regional connections of Northern Mesopotamia. Furthermore, this study employs comparison with the trace element data of the same material, as gathered by Minc & Buehlman-Barbeau (2020), following in the footsteps of other exploratory material studies of Dalma Ware (Henrickson and Vitali 1987; Tonoike 2009). Information gained through this analysis may lead to insight regarding the mechanisms of this tradition's spread, whether driven by social, economic, or environmental players, which may lend to a further understanding of not only the community of Dalma ceramicists, but how they may connect two neighboring regions. This thesis offers an analysis of the Dalma ceramic community of practice, and their role in the Chalcolithic landscapes of Northern Mesopotamia through its discussion of the following:

1.) How does the community of practice of Dalma Ware at Surezha compare to the community of practice of Dalma Ware at Dalma Tepe?

2.) What practices, adaptations, and behaviors account for the spread of Dalma Ware?

In summary, the spread of Dalma Ware is seen as strongly suggestive of the social and environmental landscape of the Chalcolithic Near East, and may consequently have a hand in distinguishing connections between Northern Mesopotamia and Iran. To date, Dalma Ware is reported as north as the Nakhchivan Autonomous Republic, westward into north and east-central

Iraqi-Kurdistan and Iraq, south to the Khorasan Road, and east into the Zanjan province of Iran. Various mechanisms underlying this distribution have been considered, including trade, pastoralism, itinerant specialists, and more recently, displacement practices such as exogamy. However, due to recent revisions of the Dalma dispersal timeline (Abedi *et al.*, 2015), many of these theories may be reconsidered in a new light. This new timeline effectively expands the Dalma era into encompassing nearly the entire 5th millennium, which opens up new lanes of theory into its dispersal, especially in the hypothesis that mechanisms of such dispersal may have changed over time, and may have been highly influenced per the different regions it infiltrated. Going forward, the study of Dalma Ware and its spread must be highly involved with its presumably variable methods of dispersal in different places and different times.

Chapter III

Communities of Practice: Theory and Application

In order to understand how Dalma Ware spread across regions over the course of the 5th millennium BCE, this study utilizes a perspective drawn from theories of community of practice. I will begin with a definition of "community of practice", followed by a discussion of communities of practice in the archaeological record and how they may be used to identify potential modes of dispersal also defined in this chapter. I will then define the technological practices that are currently associated with Dalma Ware, and in turn outline expected outcomes for the variously proposed theories as may be correlated to communities of Dalma Ware and its known extent across regions. Specifically, theories of trade, pastoralism, itinerant specialists, and exogamy will be explored.

Communities of Practice

The theoretical framework surrounding communities of practice is perhaps best known to anthropologists and archaeologists as synthesized by Lave and Wegner (1991), through which scholars may interpret learned and repeating behaviors as developed social networks. A community of practice is built primarily by the behaviors and traditions an individual participates in, as they are made available either within or upon the periphery of their own lived community. This social network may spread to involve an entire community of people who practice the same behavior, much like Bourdieu's (1980) concept of the *habitus*. This behavior is built, learned, and maintained by members of its own practitioners, who may enter a revolving cycle of change that is, again, built and maintained by its own community. Wegner later went on to describe the idea of *boundary spanning*, that is, the concept of individuals who may bridge alternative worlds or communities they synchronously inhabit (Wegner & Snyder 2000). This is echoed in the theory of communities of identity, which involves the concept of a social network of practitioners who maintain the group identity through shared tradition despite their own social fluidity throughout life due to changes in social, marital, or economic status (Eckert *et al.,* 2015). Communities of identity differ from communities of practice in that communities of identity involve conscious decisions made to enforce their membership and identity, which can be present in material culture's style, including its decoration, symbols, and motifs. Meanwhile, communities of practice share a technological tradition which is maintained inherently; though it involves a taught tradition, it is not consciously intended to invoke identity upon the producer. Like Wegner's concept of boundary spanning, multiple communities of identity may exist within a single community of practice, and vice versa (Eckert *et al.,* 2015). Concepts of communities of practice and identities may help archaeologists in characterizing groups and group relationships as they existed in the archaeological record. Interpretation of the style and technology of material culture informs the researcher of the conscious and inherent processes, *habitus,* and activities of a given group or society, which may be compared and differentiated between other groups. Through technological tradition, archaeology can better understand the social structures of a group or groups as they perpetuate across regions and through time.

Traditions and style of material culture have not always been interpreted as markers of social frameworks. The style of a given material object was at one point conceptualized as a passive byproduct, second to the object's functionality in a social or economic framework (Sackett 1977; Hegmon 1998). However, where technology was once dismissed as a simple material adaptation created to manipulate the very nature it was born from, archaeology now focuses on the technology and its adjoining style, both technically and symbolically, as an opportunity to interpret a group's social framework and worldview. Where Lechtman (1984; Lechtman & Merrill 1977) enforces the theory that the style of and within technology can offer insight into a community's symbolic structures and ideologies, more recent theorists hold that such sociotechnical structures cannot be interpreted for without acknowledging the complexity of social agency within structures of identity and ideology (Hegmon 1998). However, reading an object or technological tradition as a strict correlate across seemingly similar groups may lead into dangerous waters, as communities which appear to share sociotechnical traditions may in reality bridge many different communities of identity, as discussed prior. Stylistic similarities among groups may be analyzed instead via their community of practice; that is, the technological traditions which produced the object in its entirety may lead to properly realized distinctions between social groups (Hegmon 1998). Because material production sequences are oftentimes group-specific, these community-taught methods of production become innate within a practicing individual. These production sequences can then be archaeologically analyzed and used to distinguish social groups and communities, even within object assemblages that may appear otherwise similar (Gosselain 1992; Hegmon 1998; MacEachern 1998).

Production sequences of material culture, including that of ceramics, can be broken down and analyzed by their *chaîne opératoire* in order to discern communities within archaeological contexts. The theory surrounding *chaîne opératoire* governs that a social group can be archaeologically ascertained by their community-specific processes of transforming raw material into objects or materials. The *chaîne opératoire* involves the choices made during each step of the transformative process to the point that they are hyper-stylized into a technological micro-style created, maintained, and inherent in a given group (Dietler & Herbich 1989; Gosselain 1992; Jeffra 2015). The unique combination of actions and behaviors synthesized into a *chaîne* *opératoire* become so specific to a given region or group that they can be used to identify the transmission or direct movement of material or style across regions and time. *Chaîne opératoire* study has become pivotal in the identification and analysis of ceramic tradition. Gosselain (1992) presents an ethnographic case study in Cameroon in which ceramicists' *chaîne opératoire* is detailed from the extraction of the raw clay material, to the processing and formation of the clay vessel, and finally to the shaping, decoration, and firing processes. Each stage of the production sequence is unique to the ceramic group, having been culturally inherited and subconsciously taught to the members of the community. Gosselain continues in comparison of three different groups of ceramicists at a given site. Though all three groups had access to the same tools and resources, they maintained considerable technological differences, and each group's ceramic products were distinctive from the others produced under different methods of *chaîne opératoire*, though the raw materials were similar. Meanwhile, Eckert *et al.* (2015) used both chemical analyses via INAA and petrographic analyses of Santa Fe Black-on-White Ware to identify or communities of practice among potters of the northern Rio Grande region. Results of different, intentionally chosen local temper types and clays per ceramic tradition, despite the general accessibility of all temper and clay types, were used to distinguish various communities of practice on site. Thus, the community producing Santa Fe Black-on-White Ware utilized materials and traditions which differed from other groups, despite their membership amongst other ceramicists on-site within separate communities of practice. This emphasizes the concept of multiple communities of practice existing within a larger identifiable group, here represented by Santa Fe Black-on-White Ware, while maintaining their own identifiable practice (Eckert *et al.,* 2015).

Ceramic analysis has routinely taken to the study of an assemblage's sequence of *chaîne opératoire* to identify the cultural patterning, processes, and boundaries of a given social group. With this knowledge, archaeology can better characterize communities of practice and identity as they exist in a given site or region. In this study, the concepts of "community of identity" and "community of practice" have great utility in understanding the spread of Dalma Ware. The widely recognized Dalma style is generally interpreted as reflecting a specific cultural identity, whereas the communities of practice producing such that type have yet to be archaeologically determined.

Method: Understanding the Community of Dalma Practice

This study analyzes ceramic pastes of Dalma Ware from two separate archaeological sites to analyze its ceramic technology as maintained by its community, or communities, of practice. The objective is to understand specific choices regarding raw materials and their modification, resulting in a specific paste recipe, used in the preparation of ceramic vessels. Specifically, this study used qualitative assessments of paste texture paired with petrographic analyses of ceramic inclusions to break down the community of Dalma practice per site.

Stoltman (2001) and Shepard (1956) both advocate for the benefits of paste analyses and ceramic petrography, in that they allows a researcher to understand the qualitative and quantitative habits of paste preparation, as well as distinguish naturally occurring inclusions from those that are culturally added. Ceramic petrography provides details on which mineral, or organic, inclusions are present that may be used to identify geographic provenance, and offer insight into the types of raw material potters were choosing in the past. The type, size, angularity, and abundance of these inclusions may further contextualize the sample's community of practice, as such patterns may illuminate the manner of *chaîne opératoire* which they were employed under (Stoltman 2001).

Paste analysis on this level can help in better understanding the ceramic recipe used to make the vessel, as well as the function of the vessel itself. For example, Barraclough's scale of sorting (1992), may lend evidence into production decisions, as well as the geologic origin of the clay itself. While some ceramic production strategies may call for the cleaning and modification of clay, whether levigating larger inclusions from the clay material or removing organic inclusions such as roots and fibers, others may instead add such large inclusions or organic material to their clay as temper (Rice 2015). This preparation is just one of many stages of the community's ceramic *chaîne opératoire*, and may help in distinguishing the Dalma community from others at a given site. The identification of production sequences and choices may also illuminate the functionality of the assemblage. Where cooking vessels require characteristics which allow them the ability to withstand levels of thermal shock, storage vessels, for example, may follow a different recipe and production entirely. Intended vessel function may similarly be suggested via analysis of inclusion size and percentage, as where more, larger inclusions can strengthen the vessel wall of large storage vessels. Grain shape, on the other hand, may be used to address theories of culturally added temper: Where naturally-occurring clay inclusions are subjected to generally uniform erosion and depositional processes creating rounded particles, minerals with angular or jagged corners alongside the clay's original fine inclusions may be suggestive of ground or processed materials added as temper (Rice 2015). This again allows for the analysis of the specific sequence of ceramic production which may then be identified with a community or identity. Finally, it is then through the analysis and identification of the community of practice that research may speak to its patterns and behaviors which may be accountable for the dispersal of the Dalma type, as the community is then recognizable and comparable across time and place.

Through paste analysis, this study will compare the Dalma Ware from both Dalma Tepe and Surezha to better assess their community of practice. In turn, this will illuminate the ceramic technology and tradition of Dalma Ware as it exists between sites, as well as over time. Furthermore, compositional analysis may better inform theory of Dalma dispersal.

Communities of Practice and Mechanisms of Dispersal

As described in the previous chapter, Dalma Ware is currently known as a tradition with broad consistencies bridging across regions and time. Though there is variation between types (Plain, Red Slipped, Painted, Impressed) at a given site, the tradition as a whole is fully distinguishable from its contemporaries. Dalma Ware is present in the NW regions of Iran and the southern Caucasus in the early 5th millennium, and then to regions in west-central and northeastern Iran, as well as eastern Iraq, and, recently, Iraqi-Kurdistan's Erbil Plain.

This thesis focuses on four main modes of dispersal as potential movers of Dalma Ware: trade, pastoralism, itinerant specialists, and the displacement of people, such as exogamous practice. Drawing on the community of practice perspective, a number of characteristics can be expected for each of these systems, as detailed below (*Table 3.1)*.

In Theory: Trade

As a mechanism of exchange, trade has the power to connect people within a given community, as well as across great distances. Non-local goods and artifacts recovered at an archaeological site may identify networks of interactions and exchange between communities that otherwise may appear quite different from one another. Attributes used to recognize ceramic trade include the given vessels' low abundance in the site's overall assemblage, as the local community of practice would act as the dominating percentage. Trade could also be apparent in the vessel's supposed value, if it is indeed traded for its status or as a highly regarded commodity in a given community; moreover, if vessels are traded for their own worth, a bulk assemblage may be identified because of their constructed ease of transport, such as their ability to be stacked, or easily packed. A ceramic assemblage used to contain items or goods to be traded would also be identifiable archaeologically, as these vessels would reflect their function as storage containers also made to be transported with ease, perhaps with handles or certain textures on the vessel. Regardless of functionality in regard to status or utility, ceramics which are the product of trade would be wholly distinguishable from its local contemporaries at a given site based on style, paste chemistry, and ceramic technology. As seen previously in Eckert *et al.*'s (2015) study of Santa Fe Black-on-White Ware, a local chemical signature collected by INAA and a shared, consistent ceramic recipe as presented in petrographic study invalidated the vessels as a product of trade. Thus, in looking for communities of practice as evidence of trade, in general, not only should a ceramic vessel's chemical signature differ from its site of recovery, the vessel's production technology and *chaîne opératoire* should exhibit differences from local contemporary ware, as constructed within a different community of practice.

As a mechanism capable of moving a plethora of goods and knowledge across great swathes of land, trade is a viable option when considering the dispersal of ceramic wares, though it is yet to be identified as the primary mover of Dalma Ware. Several key characteristics as seen in the archaeological record may allude to methods of trade with Dalma Ware. In the specific study of Dalma community of practice, these include:

1) The ceramic tradition of practice, or *chaîne opératoire,* will appear largely homogeneous across sites, representative of the specific ceramic knowledge of Dalma maintained by the trading group's community of ceramic practice.

2) The chemical signature of a site's Dalma Ware will be non-local on account of being produced off site for trading purposes.

3) Like the chemical signature, the assemblage of Dalma Ware will be stylistically, petrographically, and technologically different from other ceramic assemblages at the site. This again reflects the fact that Dalma Ware, as the product of trade, was produced off site by an otherwise unrelated community of practice and unique *chaîne opératoire*. This may be especially noted in the case of a ceramic vessel appearing as a specialty ware of high regard in the region.

In addition, the mechanism of trade may be reflected in a vessel's durability and ease of transport. In the event that vessels are not being traded for their own worth, but instead for their contents (i.e. honey, beer, dairy, agricultural products), these vessels would be crafted as functional storage containers as well as with the ability to withstand travel over possibly rough terrain. Thus, the dispersal of Dalma Ware as attributed by systems of trade will be recognizable in the archaeological record by Dalma vessels' low abundance, non-local chemical signature and a ceramic production or technology distinguishable as a product of a non-local community of practice. Though there is the possibility that Dalma Ware would display high durability in the event of long-distance trade, it is not expected in absolute.

In Theory: Pastoralism

Like trade, pastoralists have the ability to connect to regions and communities over a given region. In the Chalcolithic Zagros, pastoralists may be recognizable by their short term or seasonal campsites and material record reflective of a highly mobile lifestyle alongside their herds. The ceramics they may possess can be expected to be made for travel and serve a variety of utilitarian and quotidian functions, such as cooking or storage. The majority of pottery at a pastoralist site would be representative of the local community of practice. Under the assumption that these groups may produce pottery on-site and carry at least some amount of pottery from one seasonal site to the next, this mixture of origins would be appropriately represented in a collection's chemical signatures (Gilbert 1983). In contrast, studies have likewise suggested the possibility of pastoralists making "disposable" ceramic vessels to last the season (Gibbs 2012), leaving caches of stored goods in vessels for their seasonal return (Eerkens 2008), or even leaving said caches with partnered settled communities, again to be stored for their seasonal return (Akkermans & Duistermaat 1996). This would appear to the archaeological record in an abundance of storage vessels, in the case of caches, while vessels meant to be temporary are most likely to be quickly and crudely made, with specific utilization in mind, such as cooking. Regardless of the function or lifespan of a given vessel, the *chaîne opératoire* observable through material analysis would appear largely homogeneous across sites, though some variation may be expected on a household level. Despite this broad list of expectations, pastoral communities of ceramic practice should produce pottery that is lightweight, serves a utilitarian function, and has a chemical signature that is local to their mobile route. Furthermore, their ceramic production tradition should be homogeneous across sites with some amount of chemical and mineral variation.

In this study, I will look for a number of characteristics suggested by their identifiable community of practice that may suggest pastoralism as a mode of transportation where Dalma Ware is involved, including:

1) The ceramic assemblage's *chaîne opératoire* will appear largely homogeneous across sites with small amounts of variation, representative of the specific ceramic knowledge of Dalma maintained by pastoralists engaged in the same community of ceramic practice.

2) It is expected that Dalma vessels will have a chemical signature local to their place of recovery. This is due to the assumption that pastoralists make their pottery on-site.

3) However, some Dalma vessels may exhibit a chemical signature non-local to the site, but local to the pastoral group's route. This is a strong possibility, as it is assumed that pastoralists would keep at least a few vessels when traveling from site to site.

4) In the event that Dalma Ware is made by pastoralists but found at sedentary sites, there is the expectation that the Dalma technological and stylistic tradition will be reflective of a non-local community of practice, that is, the community of pastoralists, while paste chemistry and mineralogy may reflect a combination of local or non-local resources.

In addition to considerations based on communities of practice it is expected that Dalma Ware will make up the majority of the ceramic assemblage at the pastoralists' site, assuming that Dalma Ware is made by pastoralists for their own use. Because of this, there is a possibility that pottery production facilities would be found at the site of recovery, insinuating that the pottery was indeed made locally. Functionality and ware type may also be markers of pastoralism in ceramic vessels. It may be expected that the majority of the ceramic assemblage produced by pastoralists consists of household wares key to their daily activities. Though it is certainly not unheard of that pastoralists use finer, more specialized wares, it is nevertheless expected that most ceramics in a pastoralist's possession would be reflective of domestic practices. Moreover, the majority of Dalma Ware may be expected to be made for durability. As seen in the characteristics of trade, Dalma Ware made and used by pastoralists would be constructed as easily and safely transportable across long distances. Likewise, in the event that pastoralists are leaving Dalma Ware at a given site as, for example, storage vessels to be retrieved in the following season, vessels would likewise be made with durability in mind in order to preserve various goods.

In summary, the theory of pastoralism as an explanation for the spread of Dalma Ware is strong in its ability to explain wide dispersal patterns of the Dalma tradition, as well as how this ceramic tradition may be associated with both pastoral and sedentary sites. The main expected characteristics of pastoralism as a carrier of Dalma Ware are especially defined by a potential combination of both local and non-local chemical signatures, homogeneous technological style, present as the majority type in a given ceramic assemblage, the apparent durability of the majority of Dalma vessels, and their overall reflection of household functions.

In Theory: Itinerant Specialists

As documented both ethnography and the archaeological record (Amanolahi-Baharvand 1975; Ramón 2011; Grillo 2014; Ashby 2015), the concept of itinerant specialists is possible option in exploring methods of Dalma dispersal. Though 'itinerant specialists' are known by a variety of practices and region-specific definitions, they may best be understood as groups or individuals who produce their craft and are dependent on mobility for financial or subsistence means. Like both trade and pastoralism, itinerant specialists have the ability to reach an abundance of communities, while maintaining a specific community of practice. In identifying itinerant ceramicists in the archaeological record, one may expect small, on-site production facilities directly related to the ceramic type in question, and ceramic vessels which are stylistically and morphologically similar across sites, indicative of the community of practice with which the specialist claims membership. Furthermore, it may be expected that the ceramics are produced from local materials, resulting in a chemical and mineralogical signature which is similar to the site's contemporary wares (Ambrosiani 1981; Ashby 2015). However, as Ramón (2011) has contrastingly shown, some itinerant ceramicists are known to bring their own pre-mixed clay and temper materials.

Within the community of practice perspective, the following will be used in evaluating its potential as a Dalma carrier:

1) The ceramic *chaîne opératoire* will appear largely homogeneous across sites, representative of the specific ceramic knowledge of Dalma maintained by itinerant specialists engaged in the same community of ceramic practice.

2) Dalma Ware made by itinerant specialists may have a local or non-local chemical and mineral signature. This is dependent on the fact that while some specialists bring their own materials, others may rely on locally sourced clays and temper at the site of production. As this topic of procurement may largely be considered as part of the

community of practice's *chaîne opératoire*, it is expected that the chosen practice of local vs. non-local clays will be shared across Dalma sites.

3) It is expected that an itinerant specialist's ceramic technology would make it distinguishable from other vessels at the site, given that the specialist is introducing their own community of practice's product to a site which is otherwise not affiliated.

Additionally, it is expected that evidence of local production (wasters, firing pits, or kilns) directly related to Dalma Ware is found on site, as is consistent with the idea that the specialist is producing Dalma vessels per local site. Evidence of such local production may be seen on a smaller scale than that of the production associated with local wares, and a Dalma-specific toolkit relating to ceramic production may be shared across Dalma sites. There is a possibility that Dalma Ware would be the majority in a site's ceramic assemblage if the site's inhabitants rely solely on the specialist's skill to obtain ceramic vessels. Though this is perhaps unlikely, ethnographies have shown the necessity of and reliance on certain itinerant professionals (Amanolahi-Baharvand 1975; Grillo 2014). Finally, it is likely that the majority of the ceramic assemblage produced by itinerant specialists consists of household wares, if that is indeed what the market demands. On the other hand, an itinerant ceramicist may instead depend on their specialized, highly regarded wares that a given community cannot otherwise produce with ease, such as the light-weight water jars (*ongghi*) historically produced by itinerant Korean ceramicists (Sayers 1987).

Itinerant specialists would have had the capacity to spread a ceramic tradition such as Dalma Ware to both sedentary and pastoral sites. Its key identifiers are chemical signatures local to the site of recovery, a non-local ceramic technological tradition, and evidence of ceramic manufacture at the site that can be directly related to the production of Dalma Ware, such as the appearance of ceramic wasters.

In Theory: Community Displacement and Exodus via Exogamy, Migration

The movement of people due to community or individual displacement may be identifiable through material remains as they are transported across regions. As traditions and goods may be carried from region to region via the movement of a given community's member or members, their movements may be traced correspondingly as they move. In the act of large-scale migration, a community may bring with them large quantities of household goods, such as pottery, to their new home site. This would be seen with both chemical, mineralogical, and morphological differences, as members of the given community are introducing their own community of practice to a new area where it is otherwise considered foreign. Migration may occur in a smaller scale as well, whether due to colonization efforts or attempts to build economic and social networks between communities (Stein 2012b).

The practice of exogamy, for example, offers the opportunity to bridge individuals and communities over great distances and social boundaries (Núñez 1990; Gosselain 1992; MacEachern 1998; Esterhuysen 2008; Stein 2012b). As discussed by Stein (2012b), marriage alliances between Uruk and Anatolian cultures were used to build and maintain economic and political relations for extended periods of time. These alliances may be particularly identified in the archaeological record by pottery, as an extension of the producer's ethnicity and identity.

Ceramic culture as a product of displacement at a given site is expected to be distinct from the local ware in terms of morphology, production, and style, reflective of a production tradition distinguishable from the site or region's local contemporaries. In exogamic practice, the individual may enter the new community with their belongings or a dowry, including pottery from their place of origin, and it would be expected that then these wares would be found with a distinct chemical and compositional signature; further, their presence would be in lesser amounts than the site's majority, local assemblage. Over time, exogamy may result in a mixture of attributes, such as pottery with a local chemical signature but with distinct compositional attributes reminiscent of the individual's home origin, indicative of an individual's continual maintenance of their own identity and community of practice at a new site. As Núñez (1989) suggests, exogamy may also lead to certain "foreign" ceramic attributes being added to local wares as new knowledge is introduced to the group. This would again result in a mixture of attributes, where aspects of one ceramic tradition may emulate another. Likewise, as an individual married into a group, a potter may be motivated to adapt to the customs and practices in their new home, this may result in a style of pottery which appears to be made in the dominant style in some ways, but "emulating" a foreign type at the same time. In other words, vessels produced by the "foreign" individual may consciously adopt certain visible ceramic attributes, such as those related to exterior design, while unconsciously maintaining technological traditions associated with their own community of ceramic practice. This may occur in instances of communal migration as well, as migrating communities would come into contact with others during their journey, and may further adapt certain identities and memberships which would allow them to connect with other local communities.

Thus, the following expectations may be used to assess the practice of exogamy or other small-scale member displacement as it may relate to the dispersal of Dalma Ware.

1. Dalma ceramics in this assemblage may present vessels adhering to a familiar *chaîne opératoire* that is comparable across sites, representative of the specific ceramic knowledge of Dalma maintained by others engaged in the same community of ceramic

practice; however, other Dalma ceramics within this assemblage may be represented with a local *chaîne opératoire* as the individual learns the site's own ceramic production traditions.

2. It is expected that Dalma Ware made present by displacement will primarily have local chemical and mineral signatures, with a minimum of vessels produced with a non-local chemical signature. This is based on the assumption that an individual may bring a number of ceramic vessels from their place of origin, whereas most will be made on-site in an effort to maintain membership of their given community of practice and identity.

In addition to considerations based on a community of practice, it is expected that Dalma Ware resulting from exogamy or small-scale member displacement would not be in the majority of the site's entire ceramic assemblage, but rather represent the wares used by a small number of households within the community. It is also expected that exogamous Dalma pottery consists of mostly household wares, based on the needed possessions an individual would bring to their new home and reproduced after their arrival. Thus, displacement as a method of Dalma dispersal may be recognized by a mixture of both trace element signatures and technological traditions as perpetuated by an individual's inherent membership in a given community of practice and community of identity. Ceramics are furthermore expected to be in the minority percentage at a site or region, mostly reflective of household wares.

Table 3.1: Expectations of Communities of Ceramic Practice in Four Modes of Dispersal

Mode of Dispersal:	**Trade**	**Pastoralism**	**Itinerant Specialists**	**Displacement (i.e., exogamy)**
Ceramic technology	Homogeneous across region, reflecting a single community of practice at the place of origin.	Largely homogeneous across region, potential for slight variation due to multiple pastoral groups or familial distinctions.	Distinct to a sub-region served by potter and reflecting their community of practice.	Mixture of practices; some wares reflective of place of origin, others with attributes adapted from local community of practice.
Chemical signature	Local to place of origin; distinct from local pottery.	Local to scope of pastoral route; potential for chemical/mineral mix if region encompasses geological diversity.	Local to site of recovery; indistinct from local pottery.	Potential mix of chemical signatures in assemblage due to some transported wares, while the majority would match local pottery.
Abundance in overall assemblage	Low	High	Low	Low
Assemblage composition	Special forms, easily packed or transported; forms distinct from local wares.	Majority of vessels reflect a household assemblage.	Specialized forms meant for target market; distinct from local form.	Majority of vessels reflect a household assemblage distinct from local forms.
Presence of ceramic production facilities and tools at site	None	Expected on-site or within scope of pastoral route.	Expected on-site; evidence of (specialized) toolkit expected.	Expected on-site.

The following chapter will use petrographic and paste analysis to assess certain attributes of Dalma Ware at two sites in order to explore its communities of practice across regions and time. The outlined expectations as detailed above will be used in later chapters to specifically assess potential mechanisms of Dalma dispersal into the Erbil Plain at Surezha.

Chapter IV

Method of Study

To establish possible modes of dispersal accountable for the transmission of Dalma Ware, I assessed the practice of Dalma pottery from two sites. Previous ceramic analyses of the Dalma type have led scholars to believe that all Dalma Ware was made locally at its given site of recovery, and produced under a generalized community of practice which spanned broad distances (Henrickson & Vitali 1987; Tonoike 2009). This thesis focuses on the petrographic analysis of ceramic sherds from both Surezha and Dalma Tepe in seeking clarity on Dalma community of practice across space and time, particularly in the Erbil Plain of Iraqi-Kurdistan. In addition, this petrographic analysis draws on an INAA study (Minc & Buehlman-Barbeau 2020) that examined the chemical composition of Dalma Ware from these two sites, as well as stylistically local ceramics at Surezha.

More than 30 sherds were chosen for petrographic analysis, selected from both Surezha and Dalma Tepe. Ceramic petrography is often used in the study of ceramic assemblages' production practice, or *chaîne opératoire*. Petrography allows insight into the mineralogical and organic composition of the ceramic vessel, which may allude to traditions within communities of practice, as discussed in Chapter III. Furthermore, petrographic analysis may also lead to interpretations of geologic provenance and therefore methods of ceramic dispersal.

These petrographic results were compared with the INAA data of the study's entire ceramic assemblage completed by Minc & Buehlman-Barbeau (2020). Instrumental Neutron Activation Analysis (INAA) is commonly used in archaeological provenance studies, as it is known for its accuracy and ability to measure large quantities of attributes per sample (Glascock

1992; Minc 2008). In ceramic analysis, INAA measures the presence of certain trace elements in a given ceramic sample, which then can be used to identify a vessel's geologic origin. However, while INAA primarily seeks to report the chemical signature of a given sample, it is noted that this report is a sort of "average" of the sample's bulk composition. The clay matrix and its inclusions are measured as one, providing a blind analysis of the sample's physical and behavioral composition (Stoltman 2001). Thus, this detailed, measured approach is expertly paired with petrography, which can further contextualize the INAA chemical report.

Microscopic paste analysis of the entire assemblage was also performed in this study further to characterize the assemblages and identify their community of practice. This was done to achieve a fuller understanding of ceramic production at each site, with work aiming to document the size and shape of inclusions, color, potential slip application, and any observations into the firing process, all of which is otherwise absent in petrographic and chemical studies.

The Data

This study examines ceramic samples from Surezha and Dalma Tepe that were submitted to the OSU Radiation Center for INAA as part of an ongoing partnership between Surezha project director Dr. Gil Stein and the OSU Archaeometry Lab in studying the chemical and mineralogical signature of the Erbil Plain. Ceramic samples from Surezha were recovered during the University of Chicago's excavations at Surezha (Stein 2017; Stein & Fisher 2018), and permission was given by the Erbil Civilization Museum in Iraqi-Kurdistan to perform the necessary sampling for chemical and petrographic analysis. To date, 132 clay and ceramic samples from Surezha Operations 2, 9, and 10 have been analyzed via INAA; this collection is primarily composed of various local buff wares and wasters, including Fine Paste Buff, Chaff-

Tempered Buff, Grit Tempered Buff, and Gray Wares, representing LC1 through LC4 periods. This thesis specifically studied 36 samples from this collection, including the buff wares and wasters. The INAA sample from Surezha also includes 32 sherds of the Dalma tradition (*Table 4.1*), of which 21 were Dalma Impressed and 11 were that of Dalma Painted. All Surezha's Dalma Ware was found within the latest LC1 layers, dating to around 4200 BCE. From the INAA corpus, 26 Surezha sherds were chosen for petrographic thin-sectioning: 19 sherds represent the "Dalma Ware" subset and seven were selected as representative of the local ceramic traditions.

In addition, 38 ceramic pieces of Dalma Ware from the type site Dalma Tepe were provided by the Penn Museum at the University of Pennsylvania. With Dr. Gil Stein and Surezha's project ceramicist, Dr. John Alden, acting as liaisons, the Penn Museum graciously allowed the Dalma Ware artifacts from their collection to be submitted to archaeometric analysis at OSU's Radiation Center in 2019; 13 of those samples were Dalma Painted, and the remaining were Dalma Impressed. These ceramics were procured during Charles Burney and T. Cuyler Young Jr.'s excavations at Dalma Tepe under the University's Hasanlu Project (Hamlin 1975), and represent three Dalma types: Dalma Painted, Dalma Impressed, and Dalma Red Slipped. Based on initial documentation of Dalma Tepe and its later chronological recalibration, Dalma Ware is dated to ca. 5000 - 4500 BCE, and represents the Hasanlu IX period in the Ushnu-Solduz Valley sequence (Hamlin 1975; Abedi *et al.*, 2017).

Table 4.1: Total Sample Size of Dalma Tepe and Surezha

	Sample Size: Surezha	*# of Thin Sections: Surezha*	*Sample Size: Dalma Tepe*	*# of Thin Sections: Dalma Tepe*	**Total Sample Size**	**Total Thin Sections**
Dalma Ware	32	19	38	8	70	27
Local Wares	36	7	0	0	40	7
Total	68	26	38	8	106	34

Sample Selection

Samples were chosen for thin-sectioning based both on their ceramic type and on their chemical signature. For Surezha, Minc & Buehlman-Barbeau (2020) used principle components analysis, cluster analysis, and jack-knifed multivariate Mahalanobis distance measures to identify two main compositional groups (Surezha-1 and Surezha-2) within the entire ceramic assemblage, both of which appear to represent local ceramic production, along with several minor groups that may represent Imports. Though the sample size in these main groups is comparable (Surezha-1: n = 50; Surezha-2: n = 44), the majority of Surezha's Dalma Ware fell into the Surezha-2 group. In order to properly explore the petrographic attributes of Surezha's Dalma Ware, seven Dalma Ware samples from Surezha-1 were thin sectioned, and 12 from Surezha-2. Seven samples representative of Surezha's local, non-Dalma wares were likewise thin sectioned.

The Dalma Ware assemblage from Dalma Tepe was determined to be chemically different from the assemblage at Surezha (Minc & Buehlman-Barbeau 2020). Like Surezha, the INAA data from Dalma Tepe exhibited two distinct chemical groups: Dalma Tepe 1 (n = 31) and Dalma Tepe 2 (n = 7), along with several outliers. Four samples from the two main chemical groups were chosen for thin sectioning.

In summary, nineteen Dalma Wares from Surezha were sampled for thin sectioning, and eight from Dalma Tepe. These samples include both the Dalma Painted and Dalma Impressed types. Because these samples represent four distinct chemical groups, this will allow discussion into traditions of ceramic practice and its variability within sites. In addition, seven non-Dalma samples from the site of Surezha were included to allow comparison of local Surezha wares and those of the Dalma tradition to explore theories of dispersal as pertaining to Dalma's presence in the Erbil Plain. Circumstances concerned primarily with the conservation of the artifacts resulted in an uneven assortment of Surezha and Dalma Tepe ceramics; likewise, limitations on available ceramic artifacts not of the Dalma tradition from both sites caused a similar imbalance.

Paste Analysis

In order to visually characterize ceramic pastes, all sherds from Surezha and Dalma Tepe analyzed via INNA were photographed under 50x and 100x magnification using a Keyence digital fiber-optic microscope with depth-of-field compensation. These ceramic paste micro-photos of the matrix focused on a clean break to ensure an accurate depiction of paste attributes which will aid in the characterization of a theoretical community of ceramic practice.

For this study, paste photos were assessed for various characteristic attributes, including the type of inclusion sorting (Barraclough 1992), the percentage of inclusions in a given sample (Matthew *et al.*, 1991), and grain inclusion shape (Barraclough 1992). Matrix color, based on the Munsell Color Chart, was likewise recorded in this assessment (*see Appendix B).*

Dalma Tepe: Paste Analysis

Paste photos of the 38 ceramic samples from Dalma Tepe were assessed, including 14 painted wares and 24 impressed. The painted wares display a similar design of streaky, reddish brown bands of color which can appear as one or two centimeter in width (*Fig. 4.1*). In many instances, the reddish paint encapsulates the rim and folds over into the vessel interior, which is painted solidly, without the exterior's striping or streaked design, with the same color. This reddish interior paint is present, whether the rim is painted or not, in all samples in this study. The exterior designs are oftentimes streaky to the point where the white paint underneath is visible in some places. All of the Dalma Painted appear to have a white or buff colored slip or paint underneath their reddish brown designs. One of the painted wares in this assemblage does not appear to be of the Dalma type. It is buff colored with a single black band folded over its rim.

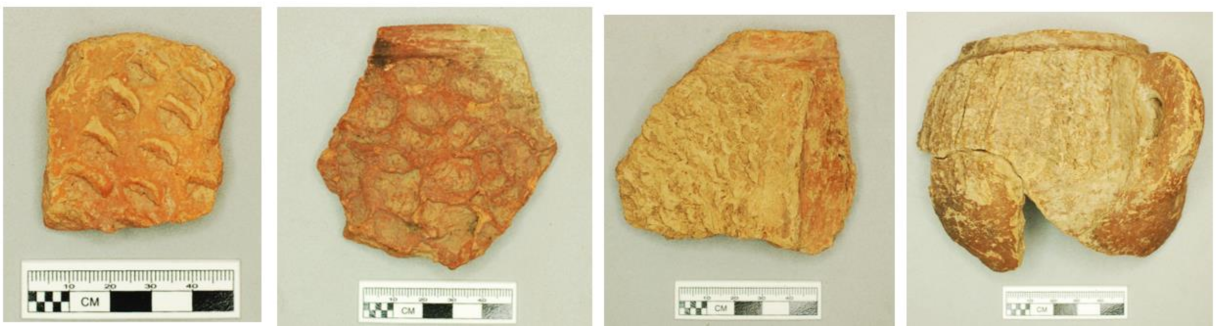
Fig. 4.1: Dalma Tepe Dalma Painted Ware

From left: DT6020530, DT6020544, DT6020665, DT6020585

The Dalma Impressed wares in this study also appeared to have a white slip underneath a reddish brown paint, sans streaks or other painted designs (*Fig. 4.2*). Like the painted wares, the interiors also exhibited solid reddish paint over the white slip. The impressed wares appeared more worn than the painted; oftentimes both the white and red paint had majorly degraded.

Many of these Dalma Impressed wares were blackened in some areas as well. The impressions themselves consisted of crescent moon-shaped patterns, honeycomb-like designs, and thin, vertically impressed lines. All of the Dalma Impressions leave one or two centimeters blank below the rim, which is not impressed in any sample of this particular study. A single sample has a handle, roughly five centimeters in length with an opening of two centimeters.

Fig. 4.2: Dalma Tepe Dalma Impressed Ware



From left: DT6020729, DT6020728, DT6020314, DT6020327

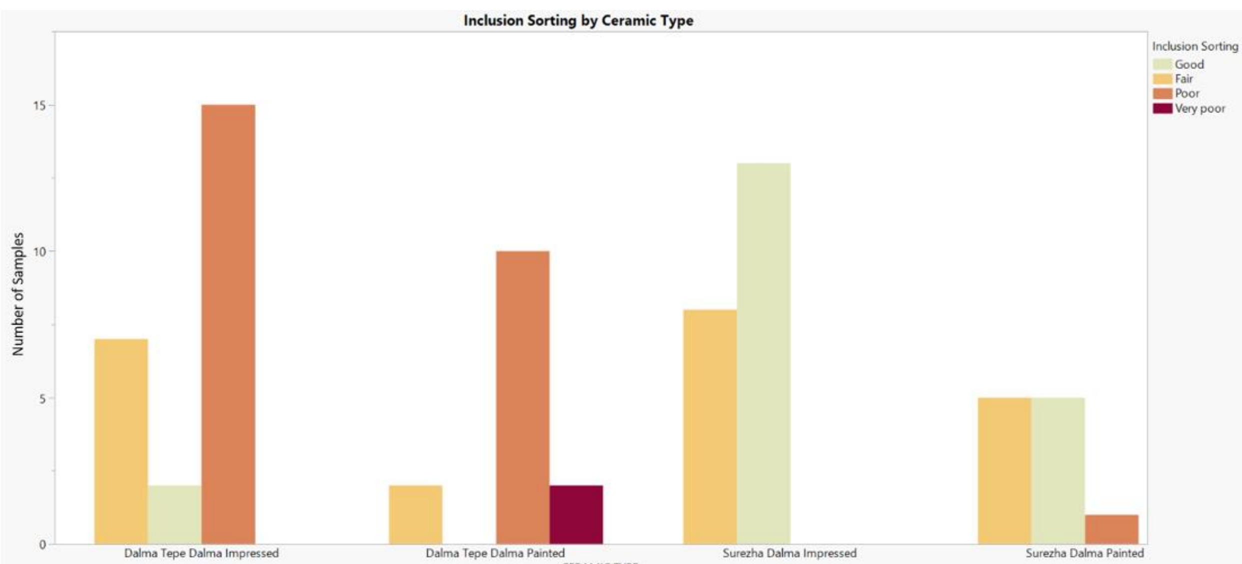
The assemblage as a whole portrayed Dalma Tepe's wares as having poorly sorted pastes, with 65.8% of sherds considered "very poor" or "poor", 23.7% considered "fair", and the sorting of 5.3% could be interpreted as "good". When considering types, the majority of both Dalma Painted and Dalma Impressed pastes were considered poorly sorted, with Dalma Painted at 71.4% and Dalma Impressed with 62.5% (*Fig. 4.3*).

All of Dalma Tepe's Dalma Ware had an inclusion amount no more than 20%, according to the estimation chart modelled by Matthew *et al.* (1991). However, most of the samples had estimated inclusion amounts between 5 – 10%. When separated by type, Dalma Impressed suggested a slightly higher amount of variability: 69% of the wares samples displayed inclusion amounts of less than ten percent, meanwhile, nearly 80% of Dalma Painted exhibited wares under this parameter (*Fig. 4.4*).

Grain color as observed under the Keyence digital microscope included mineral inclusions which had a diversity of colors which varied per sherd, including black, red, yellow, and various shades of white and grey. Based on Barraclough's grain sphericity estimation chart (1992), more than half of the ceramic samples have grain inclusions which are exclusively sub-rounded, less than a quarter of samples include grains which are sub-rounded or sub-angular, and only ten percent of samples exclusively have grains of both the rounded or sub-rounded type. This pattern generally continues between types (*Fig. 4.5*).

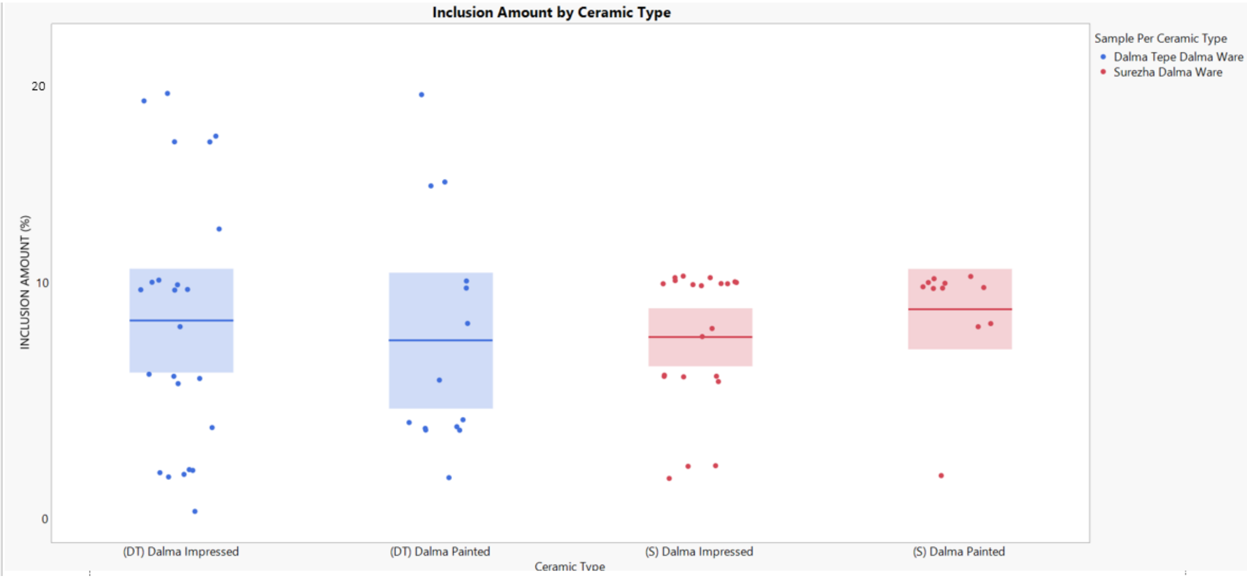
A total of four samples in the Dalma Tepe assemblage had dark firing cores. Dark cores are typically a measure of poor oxidation in the firing process, or as a sign of quick firing overall (Rice 2015).

Fig. 4.3: Inclusion Sorting: Dalma Ware[a]



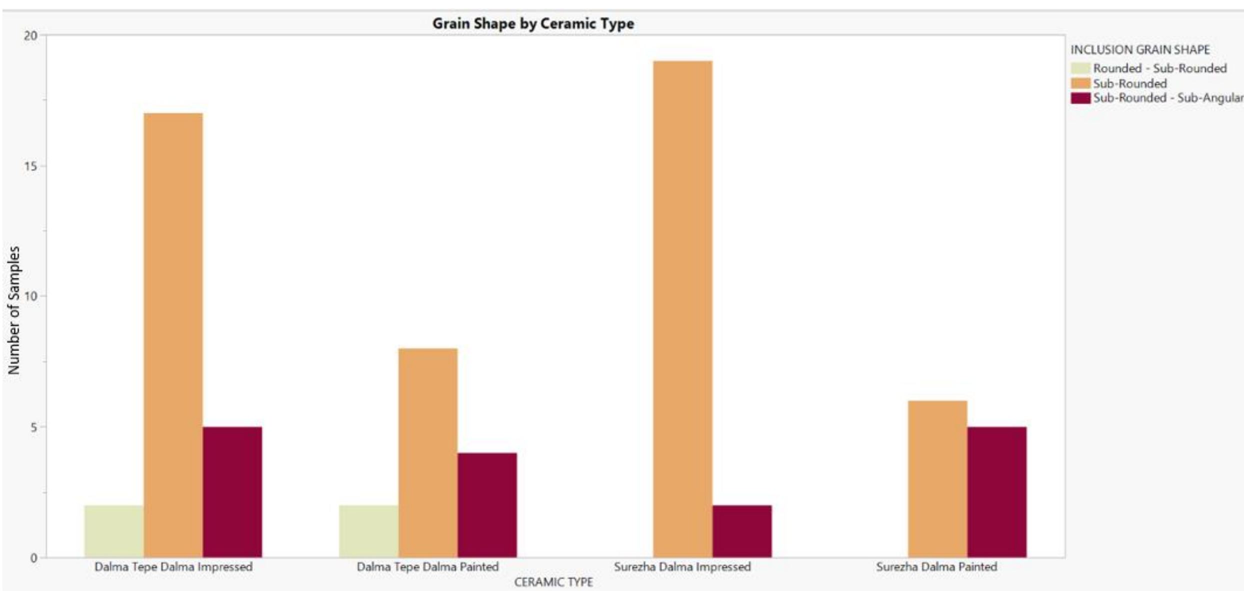
a) Inclusion sorting categories after Barraclough (1992).

Fig. 4.4: Inclusion Amount Percentage: Dalma Ware[a, b, c]



a) Percentages modelled after Matthew *et al.* (1991).
b) DT = Dalma Tepe; S = Surezha
c) (DT) Dalma Impressed average inclusion amount: 4.21±2.8; (DT) Dalma Painted average inclusion amount: 3.86±2.5; (S) Dalma Impressed average inclusion amount: 3.97±1.5; (S) Dalma Painted average inclusion amount: 4.55±1.2.

Fig. 4.5: Grain Shape: Dalma Ware[a]



a) Inclusion shape categories after Barraclough (1992).

Surezha: Paste Analysis

Paste photos of the 68 ceramic samples from Surezha were assessed for various characteristic attributes: 32 of the samples from Surezha are of Dalma Ware tradition, including 11 Dalma Painted and 21 Dalma Impressed. The Dalma Painted wares have reddish bands of color which can appear streaky or in blocky stripes; individual bands of color can measure from less than a centimeter to up to two centimeters in thickness (*Fig. 4.6*). In some cases, it seems that a white or buff stripe is purposefully kept between bands of red. It appears that all the Dalma Painted of Surezha have a white or buff slip underneath the reddish designs. Remnants of red paint on the interior of these sherds is visible on some of the samples, and all the samples appear to have a fugitive buff slip on the interior as well.

Fig. 4.6: Surezha Dalma Painted Wares

From left: SR9640, SR9635, SR9636, SR9638

The Dalma Impressed wares at Surezha appear to have a white or buff slip, and many appear to have a solid red overcoat as well, as with the Dalma Painted of Surezha, it is very poorly preserved (*Fig. 4.7*). The impressions consist of the honeycomb type, small puncture holes, and crescent moon-shaped patterns, amongst others. All of the impressed rim samples in this study included a one- or two-centimeter gap below the rim, without any impressed design. Some of these samples were blackened in some areas.

Fig. 4.7: Surezha Dalma Impressed Wares

From left: SR6156e, SR6156c, SR6156d, SR6117a

Surezha's Dalma Ware pastes were well sorted, with 56.3% of samples with sorting considered "good", 40.6% was considered "fair", and the remaining samples were interpreted to be poorly sorted. In assessing by type, 45% of Surezha's Dalma Painted samples were considered to have "good" sorting, an additional 45% were "fair", and the remainder was poor. In contrast, nearly 62% of Surezha's Dalma Impressed wares had "good" sorting, and the remaining was considered "fair" (*Fig 4.3*).

All Surezha's Dalma Ware had an inclusion amount of 10% or less. 38% of the Dalma Impressed samples had extremely low amounts of inclusions (5-8%), whereas only 9% of Dalma Painted exhibited such low inclusion amounts (*Fig. 4.4*).

Under the Keyence digital microscope, the mineral inclusions of Surezha's Dalma Ware appeared somewhat less diverse in color than those of Dalma Tepe and limited to red, black, and white, the variety of which varied per sherd. Barraclough's grain sphericity estimation chart (1992) aided in the identification of grain shape; nearly 80% of Surezha's Dalma Ware contained grains which are exclusively sub-rounded, and the remaining sherds have both sub-rounded and sub-angular grains. When assessing types, however, some clear differences begin to form.

While Surezha's Dalma Painted have comparable amounts of samples with sub-rounded grains (54.4%), and with sub-rounded to sub-angular grains (45.5%), 90.5% of Surezha's Dalma Impressed samples have sub-rounded grains alone (*Fig. 4.5*).

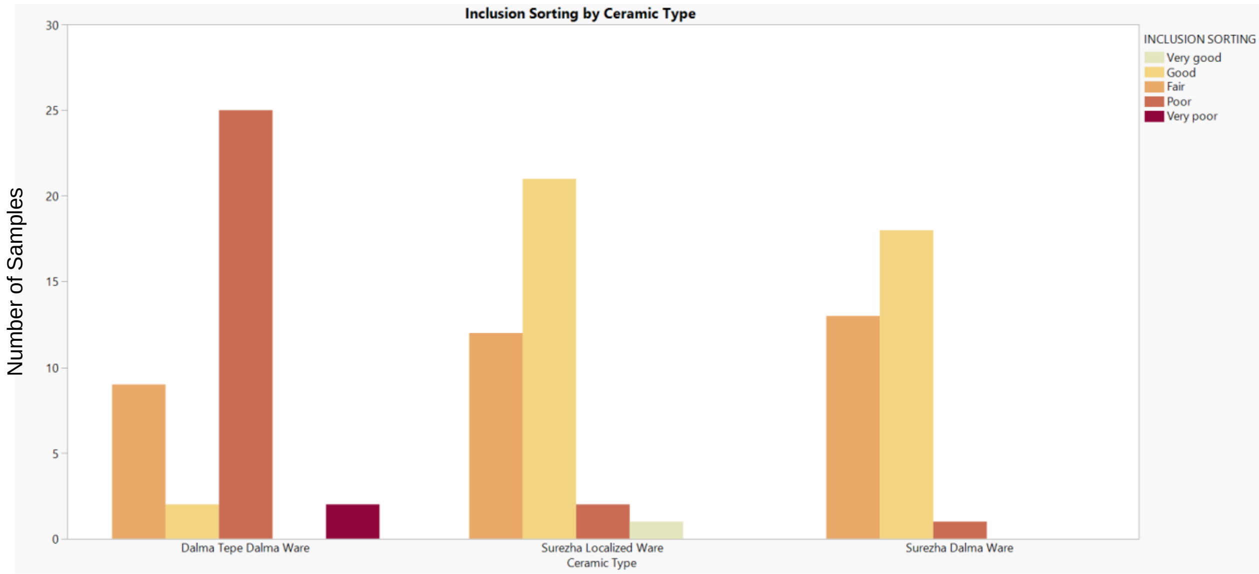
Only two samples of Surezha's Dalma Ware have dark firing cores. Both are of the Dalma Impressed type.

Fig. 4.8: Surezha Local Wares

From left: SR3276 (Fine Paste Buff), SR3281 (Grit Tempered Buff), SR6031a (waster)

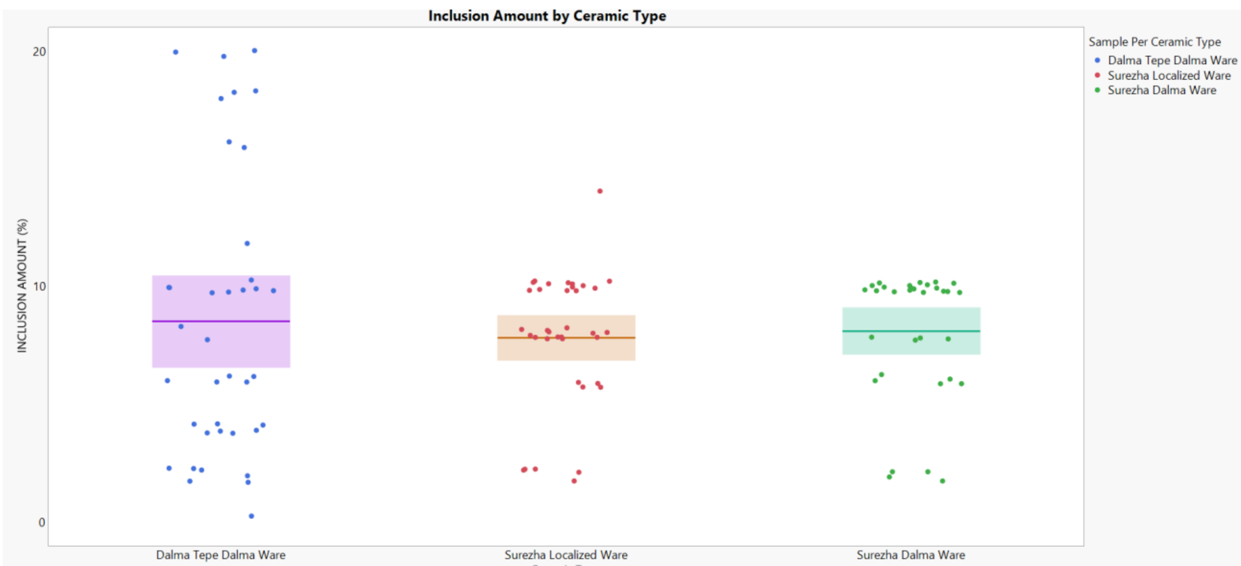
The availability at Surezha also allowed this study to assess several non-Dalma wares found at Surezha. This subset involves Fine Paste Buff Ware, Grit Tempered Ware, Chaff Tempered Ware, and wasters *(Fig. 4.8*). Overall, the inclusion sorting was considered "good" for 58% of these local, non-Dalma wares, while 32% of Surezha's local ceramic samples had "fair" sorting, and 8% had "poor" sorting (*Fig. 4.9*). All the sampled non-Dalma Ware has an inclusion amount less than 13%. Nearly 99% of these samples have an inclusion amount between 5% and 10% (*Fig. 4.10*). About 53% of the samples have grains which are exclusively sub-rounded, and 46% have grains both sub-rounded and sub-angular; only 1% had only sub-angular grains (*Fig. 4.11*). Under a Keyence digital microscope, Surezha's non-Dalma wares have grains colored black, red, and various shades of white and grey. A substantial minority of these sherds (23 or 31%) exhibited a dark core.

Fig. 4.9: Inclusion Sorting: Surezha Local Wares and Dalma Ware[a]



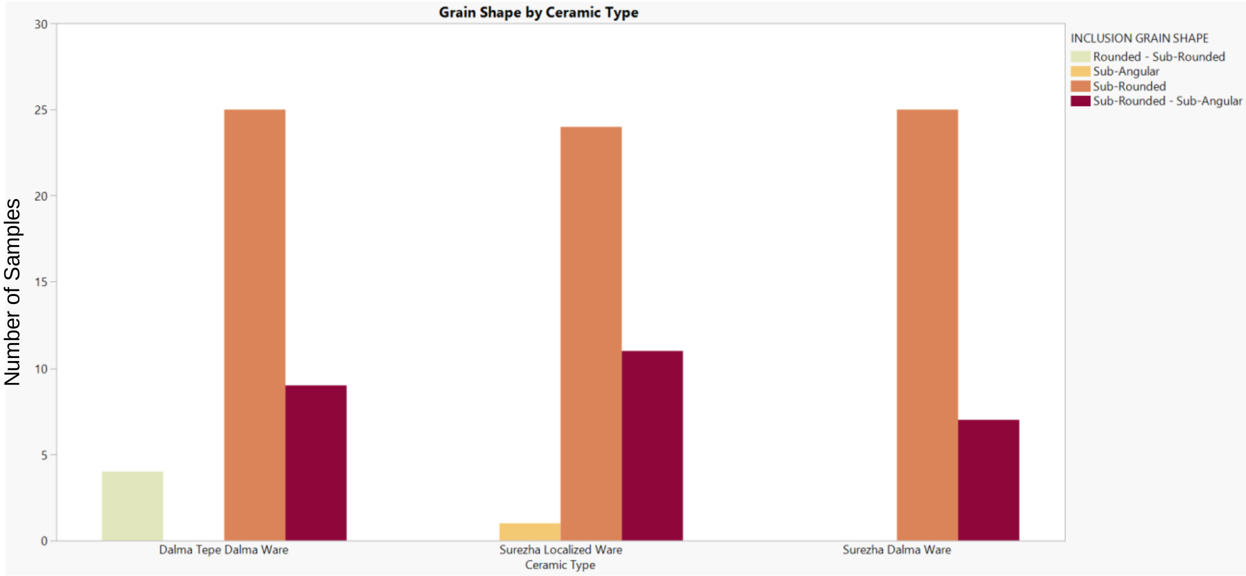
a) Inclusion sorting categories after Barraclough (1992).

Fig. 4.10: Inclusion Amount Percentage: Surezha Local Wares and Dalma Ware[a,b]



a) Percentages modelled after Matthew *et al.* (1991).
b) Dalma Tepe Dalma Ware average inclusion amount = 4.05±2.6; Surezha Local wares average inclusion amount = 3.83±1.3; Surezha Dalma Ware average inclusion amount = 4.06±1.4.

Fig. 4.11: Grain Shape: Surezha Local Wares and Dalma Ware



a) Inclusion shapes after Barraclough (1992).

Efforts to statistically characterize paste texture data was undertaken to understand ware types within and between sites. By using JMP's analytical software, a Chi-Square Test of Independence was performed in assessing the compositional attributes as discussed above: inclusion sorting, percentage inclusion amount, and grain shape. Four sets of comparisons were tested in this assessment per defined attribute: 1) Surezha local wares vs. Surezha Dalma Ware, 2) Surezha Dalma Painted vs. Surezha Dalma Impressed, 3) Surezha Dalma Ware vs. Dalma Tepe Dalma Ware, and finally, 4) Dalma Tepe Dalma Painted vs. Dalma Tepe Dalma Impressed. The test values are outlined in the table below (*Table 4.2).*

Table 4.2: Chi-Square Test of Independence as assessed by ware and type.[a,b]

Assessment Based on Type	*N*	*df*	χ^2	*p*
Surezha Local Wares vs. Surezha Dalma Ware				
Inclusion Sorting	68	3	1.374	.7117
Percentage Inclusion Amount	68	4	6.901	.1412
Inclusion Grain Shape	68	2	1.68	.4318
Inclusion Grain Size	68	6	6.206	.4005
Surezha Dalma Painted vs. Surezha Dalma Impressed				
Inclusion Sorting	32	2	2.353	.3084
Percentage Inclusion Amount	32	3	3.711	.2944
Inclusion Grain Shape	32	1	5.5453	**.0195***
Inclusion Grain Size	32	3	2.484	.4781
Surezha Dalma Ware vs. Dalma Tepe Dalma Ware				
Inclusion Sorting	70	3	37.442	**.0001***
Percentage Inclusion Amount	70	9	22.197	**.0083***
Inclusion Grain Shape	70	2	3.763	.1523
Inclusion Grain Size	70	12	38.327	**.0001***
Dalma Tepe Dalma Painted vs. Dalma Tepe Dalma Impressed				
Inclusion Sorting	38	3	5.529	.1369
Percentage Inclusion Amount	38	9	15.837	.0704
Inclusion Grain Shape	38	2	.773	.6794
Inclusion Grain Size	38	11	15.366	.1664

a) Where the null hypothesis assumes that compositional attributes (sorting, inclusion amount, and grain shape) are independent from ceramic types, and the alternative suggests that compositional attributes are not independent of ceramic types.
b) P values with an asterisk indicate values below the level of significance ($p = .05$).

Where the corresponding p-value of the statistical value is less than the significance level (0.05), the null hypothesis of "no difference" between members of the comparison may be rejected and the alternative is suggested in its place. The following key findings should be noted:

- First, when assessing Surezha's local wares vs. its Dalma Ware, the choosing of materials including grain size, shape, percentage amount, and the level of sorting is suggestive of independence. According to the data available, this implies that there is no statistically significant association between the tested inclusion attributes of two ceramic families at the site of Surezha.
- Second, when comparing Surezha's Dalma Painted wares and its Dalma Impressed, the test statistic suggests that a vessel's grain shape is not independent of ceramic tradition, that is, that there may be some association with ceramic tradition and grain shape at Surezha. This perhaps lends support for the theory that Dalma Ware production at Surezha have different modes of *chaîne opératoire* when it comes to choosing the size of the mineral inclusions per ceramic type. However, the same cannot be said for relationships between types and their inclusion sorting, inclusion percentage, or grain size.
- Third, the comparison of grain shape, sorting, size, and percentage between Surezha's Dalma Ware and Dalma Tepe's Dalma Ware suggests that inclusion sorting, size and percentage are not independent of type, thus implying that such compositional attributes have some association with that of their type. This may suggest that Dalma ceramicists at Surezha and those at Dalma Tepe were engaged in distinguishable modes of production concerning inclusion sorting and

percentage. On the other hand, there was no such association to speak of when assessing grain shape between Surezha Dalma Ware and Dalma Tepe Dalma Ware.

- Finally, statistical analysis suggests that Dalma Impressed wares and Dalma Painted wares at Dalma Tepe were independent of attributes of grain shape, inclusion sorting, and inclusion amount. This implies that there is no statistically significant association between Dalma types at Dalma Tepe and their compositional attributes.

Petrographic Analysis

Petrography uses thin sections to analyze the mineral composition and microscopic structure of a ceramic piece. Thin sections are made by first impregnating the ceramic sherd with epoxy and then cutting a small piece of the sherd to fit upon a microscope slide. Once mounted upon the slide, it is ground to 30 microns (0.03 mm) in thickness. This thin section allows the researcher to identify the minerals within each sample by observing the behavior of transmitted light through the thin section under a polarizing light microscope (Stoltman 2001). Due to their distinctive and characteristic crystalline structure, minerals exhibit known, observable traits under polarized light, which allow the researcher to accurately identify them (Nesse 1991; Perkins 1998; Miyashiro 1994; Quinn 2013).

Table 4.3: Samples thin sectioned in this study.

Sample ID	Site	Ware Type	Time Period	Chemical Group	*Analyzed By*
SR3276	Surezha	Fine Paste Buff	Ubaid	Surezha-2	Minc & Buehlman-Barbeau 2020
SR3279	Surezha	Chaff Tempered Buff	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR3281	Surezha	Grit Tempered Buff	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR3273	Surezha	Fine Paste Buff	Ubaid	Surezha-1	Minc & Buehlman-Barbeau 2020
SR3291	Surezha	Grit Tempered Buff	LC2	Surezha-2	This thesis
SR6031a	Surezha	Waster	LC1	Surezha-1	This thesis
SR6156c	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6156d	Surezha	Dalma Impressed	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR6156f	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6156g	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6194a	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6194b	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6194c	Surezha	Dalma Impressed	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR6194d	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR6281a	Surezha	Dalma Impressed	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR62931	Surezha	Dalma Impressed	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR6293a	Surezha	Dalma Impressed	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR6368c	Surezha	Waster	LC1	Low Rb:Cs*	This thesis
SR9635	Surezha	Dalma Painted	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR9636	Surezha	Dalma Painted	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR9637	Surezha	Dalma Painted	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR9638	Surezha	Dalma Painted	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR9640	Surezha	Dalma Painted	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR9641	Surezha	Dalma Painted	LC1	Surezha-1	Minc & Buehlman-Barbeau 2020
SR9644	Surezha	Dalma Painted	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
SR9645	Surezha	Dalma Painted	LC1	Surezha-2	Minc & Buehlman-Barbeau 2020
DT6127315	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-2	This thesis
DT6127322	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-2	This thesis
DT6020665	Dalma Tepe	Dalma Painted	Hasanlu IX	Dalma Tepe-1	This thesis
DT6020725	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-2	This thesis
DT6020716	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-2	This thesis
DT6020732	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-1	This thesis
DT6020703	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-1	This thesis
DT6020719	Dalma Tepe	Dalma Impressed	Hasanlu IX	Dalma Tepe-1	This thesis

Thin sections were prepared by the Vancouver Petrographics Lab. Samples were cut lengthwise to illustrate the vertical cross section of the vessel; however in the event that the sherd was simply too small to distinguish directionality, they were sectioned at the region providing the greatest surface area. For this study, I used a Nikon Eclipse E600 Polarizing Microscope, and an AmScope (x64) microscope camera system which resulted in photographs with a pixel resolution of 3584 x 2748 each. Working at 40x magnification, four photos were taken of a single location on each thin section (each photo measured three millimeters) to properly analyze the aplastic inclusions: One photo was taken under plane polarized light (PPL) to record the structure, shape, and size of the inclusions, and three more photos under cross polarized light (XPL) at rotating 30, 60, and 90 degrees to illustrate possible extinction patterns and other defining features of a given mineral, as well as the presence of any voids. These four photos are then used in the process of identifying and quantifying the sample's inclusions, which was done by loading the image sets into a pipeline using the image analysis program CellProfiler (Jones *et al.*, 2008).

CellProfiler can assist the researcher in efforts to identify, count, and measure aplastic inclusions, and can be used in place of a manual point-count (*see Appendix C for details*). In brief, a pipeline, or set of instructions, was developed first to recolor the four images into grayscale and align them to each other to correct any possible shifting seen during the photography process. When aligned, CellProfiler identifies any light objects against the matrix of each of the photos and outlines them as polygons. Because voids will appear light in PPL and dark in XPL, subtracting the identified light polygons of the XPL photos will result in a measure and count of the voids per sample, with the remaining polygons which are visibly light in PPL and light in at least one of the XPL images are designated as mineral inclusions. This approach readily identified most felsic minerals and bright mafic minerals such as epidote. However, it does not identity isotropic minerals that are dark or black under both PPL and XPL; this was particularly a problem in characterizing the abundance of opaque minerals. In addition, some samples required more specific instruction and supervision in distinguishing the matrix from mineral inclusions, as the pipeline sometimes attempted to identify light areas of the background matrix as inclusions. Thus, while CellProfiler does aid the researcher in the matter of measurement accuracy and time, some samples may require more guidance than others; this is far from being an automated system of measure and identification.

CellProfiler has an expansive suite of ways to numerically characterize and illustrate the polygon data harvested from the pipeline, such as the count and sphericity of the individual polygons, as well as the maximum length as a measure of grain size. Interpreting the data involves converting CellProfiler's measurements from pixels to millimeters, which can then be interpreted by the Wentworth scale of mineral grain sizes, when appropriate (*Table 4.4)*.

Table 4.4: Wentworth Scale of Mineral Grain Sizes (1922).[a]

Size Class	**Grain Size (*in mm)***
Coarse Sand (CS)	0.5 – 1.0
Medium Sand (MS)	0.25 - 0.5
Fine Sand (FS)	0.125 - 0.25
Very Fine Sand (VFS)	0.0625 - 0.125
Silt	<0.0625

a) Adopted to specifically illustrate the grain sizes as commonly seen in ceramic samples.

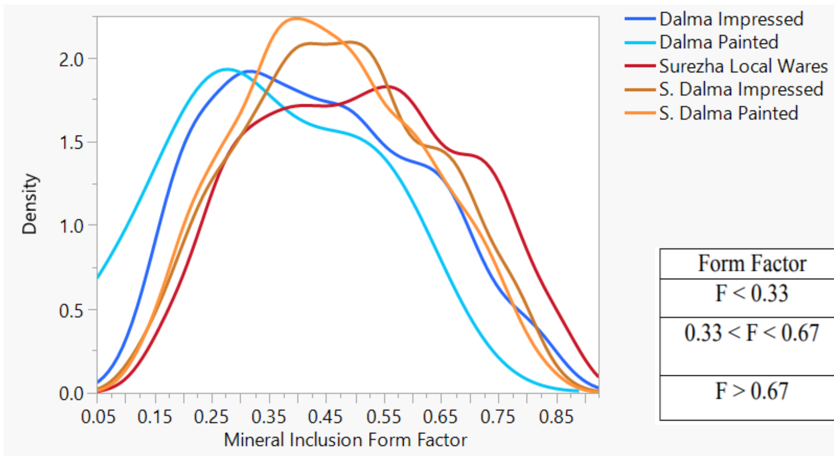
In addition, a photograph of each entire thin section was taken on a light table in order to properly assess the length and shape of a sample's voids. Many of the samples are chaff tempered and thus included voids that are larger than the region seen using the polarizing light microscope; it was important to document the most accurate depiction of voids as possible, as this attribute may impact the understanding of production decisions and the community of ceramic practice across sites and types. These photos were also fed into a CellProfiler pipeline, where the voids were individually measured, and their general shape was assessed. The amount of voids in a given thin section sample was quantified as a percentage of the entire thin section sample image.

Petrographic Analysis: Dalma Tepe

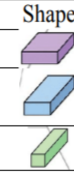
The mineral suite of Dalma Tepe's Dalma Ware predominately consists of quartz, opaque minerals, and sedimentary rock fragments (*Table 4.5*). While the quartz in these samples includes grains which are relatively small and angular, a number of thin section samples include large polycrystalline quartz fragments as well. Though the opaque minerals within the samples are variable in size; they are all generally subrounded, although some appear hexagonal in shape. Form factor measurements from CellProfiler was used to evaluate the grain inclusion as platy, bladed, or elongated in shape. At Dalma Tepe, most mineral inclusions appear to be platy, though a fair amount are bladed as well (*Fig. 4.12*).

The sedimentary rock fragments are similarly subrounded and stand out against the matrices in light grey or brown masses; some fragments are quite large (2-2.5 mm). Epidote, hornblende, and perthite are present in these samples in a trace amount. The epidote and hornblende minerals appear quite small and subrounded, and only appear in a few of the thin section samples. While it is immediately apparent that all samples included quartz, it is interesting to note that chemical group Dalma Tepe-2 appears to have more quartz present than that of chemical group Dalma Tepe-1. The chemical groups are likewise linked with the presence of opaque minerals. Overall, Dalma Ware at Dalma Tepe has a consistently minimal mineralogical composition; whether this is due to cultural editing of the clay or the naturally occurring variability of a given clay source, stands to be further examined with regional clay survey.

Fig. 4.12: Grain Form Factor of Surezha Local Wares[a,b,c,d]



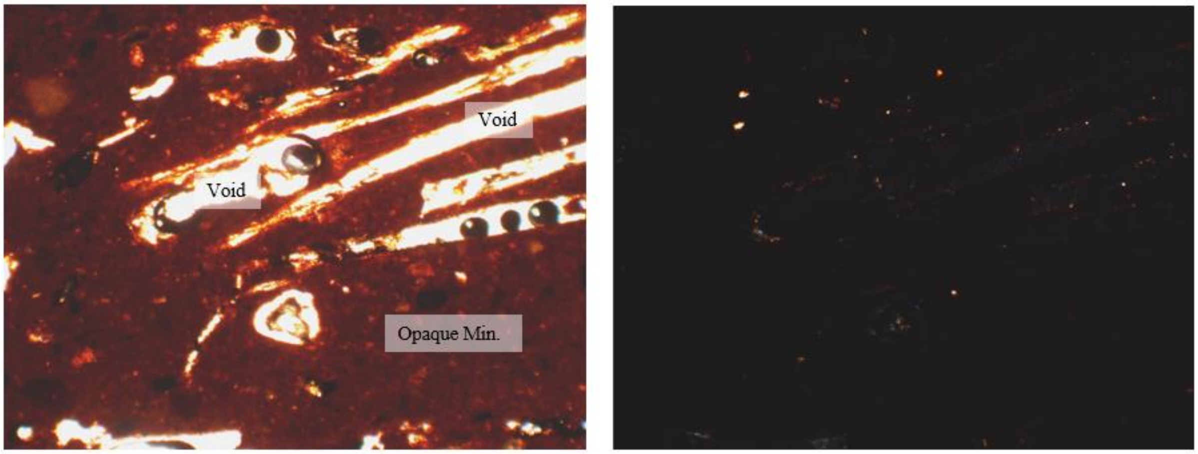
Form Factor	Classification	Shape
F < 0.33	Platy (P)	
0.33 < F < 0.67	Bladed (B)	
F > 0.67	Elongated (E)	



a) $F_{4, 5766} = 25.89$, $p = <.0001$.
b) Form factor classification chart (right) from Haron (2018), Bunte (2001).
c) Form factor is measured by the CellProfiler software (left).
d) "Dalma Painted" and "Dalma Impressed" = ceramic wares from Dalma Tepe; "S. Dalma Impressed" and "S. Dalma Painted" = ceramic wares from Surezha.

Dalma Tepe-1 is chemically defined by a higher amount of scandium and other transition metals, and a lower amount of calcium (Minc & Buehlman-Barbeau 2020). In thin section, the matrices of the Dalma Tepe-1 samples appear murky and mottled (*Fig. 4.13*); all but one (DT6020719) exhibit deep red colored matrices. In these three samples, the mineral inclusions are scarce, and instead it appears that the organic inclusions far outweighed that of the mineral material, perhaps suggesting that the mineral inclusions are naturally occurring rather than culturally added as temper. Mineralogically, this group is seen to display small amounts of quartz, as well as epidote and hornblende, along with small pieces of sedimentary rock. The quartz is small and angular, and only one sample of this group included a polycrystalline mass of quartz (DT6020703). Meanwhile, the epidote and hornblende appear in small, subrounded pieces in amounts much lesser than that of the quartz.

Fig. 4.13: Dalma Tepe-1 Petrographic Image[a]



a) Sample DT6020665 (PPL left, XPL right). Image taken at 40x.

Opaque minerals of this group appear in both rounded and elongated shapes; sedimentary rock inclusions likewise are readily present in this group, where they appear brown or tawny with subrounded edges. Voids of this type appear to be long or blocky (ca. 0.5 – 5 mm in length), indicative of chaff temper.

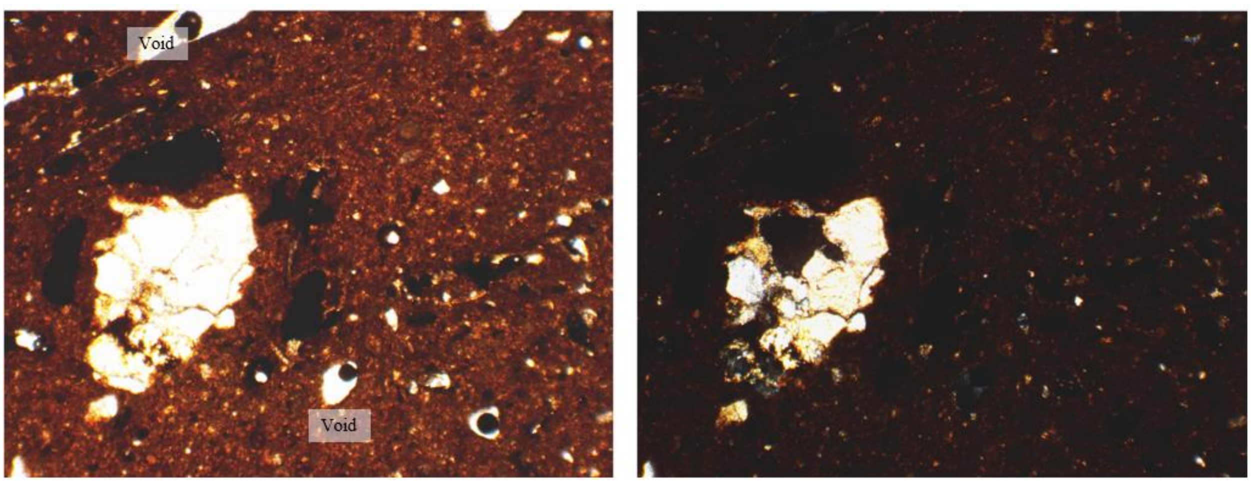
Table 4.5: Mineral composition of Dalma Tepe wares.[a,b,c]

ID	*Group*	*Type*	QUARTZ	PLAGIO-CLASE	ORTHO-CLASE	EPIDOTE	HORN-BLENDE	CALCITE	PERTHITE	OPAQUE	SEDIMEN-TARY FRAG.
DT6020665	DT-1	*D.P.*	T							X	T
DT6020732	DT-1	*D.I.*	T				T		T	T	X
DT6020703	DT-1	*D.I.*	X				T		T	X	X
DT6020719	DT-1	*D.I*	T			T	X			X	T
DT6127315	DT-2	*D.I.*	A						T	X	T
DT6127322	DT-2	*D.I.*	A		T				T	X	
DT6020725	DT-2	*D.I.*	X							X	T
DT6020716	DT-2	*D.I*	T	T	T			X	X	X	T

a) D.P. = Dalma Painted; D.I. = Dalma Impressed
b) DT-1 = Dalma Tepe-1 chemical group; DT-2 = Dalma Tepe-2 chemical group
c) A = abundant; X = present; T = trace

Dalma Tepe-2 is characterized by higher calcium content and lower amounts of scandium and other transition metals (Minc & Buehlman-Barbeau 2020). In thin section, the matrix of these samples appears tawny brown, with mineral inclusions which can be quite small and angular, and some which are large and sub-rounded (*Fig. 4.14*). Like Dalma Tepe-1, it displays a varying amount of quartz in its samples, although in a higher amount overall than in the case of Dalma Tepe-1. Three out of the four samples in this group contain large masses of polycrystalline quartz. Opaque minerals of this group are small and subangular, and most are blocky or rectangular in shape. Neither epidote nor hornblende are present in Dalma Tepe-2 thin sections, however, unlike Dalma Tepe-1, orthoclase is present in trace amounts in this group. Like those in Dalma Tepe-1, voids of this chemical group can appear to be long and blocky (0.5 – 3 mm in length), indicating chaff temper.

Fig. 4.14: Dalma Tepe-2 Petrographic Image[a]



a) Sample DT6020725 (PPL left, XPL right). Images taken at 40x.

Textural Analysis: Dalma Tepe

Data from the CellProfiler pipeline was used to assess the amount and size of mineral inclusions on each thin section; these results confirmed the patterns recorded during qualitative paste analyses. The samples from Dalma Tepe had a range of mineral sizes, with the most common size being fine and very fine sand, according to the Wentworth scale. Three out of the eight samples hosted minerals in the medium sand range, and two showed measures of coarse sand. The average amount of mineral inclusions per sample was measured as a percentage of the whole thin section image, which resulted in mineral inclusions measuring up to 10% of the given sample (*Table 4.6)*. Voids, in contrast, were characterized from a photograph of the entire thin section taken upon a light table, then measured and counted using CellProfiler.

Table 4.6: Mineral and Void Percentage of Dalma Ware at Dalma Tepe.[a,b,c]

ID	Chemical Group	Type	Total Mineral Inclusion %	Total Void %
DT6020665	DT1	DP	0.4%	2.0%
DT6020732	DT1	DI	4.0%	11.0%
DT6020703	DT1	DI	5.0%	4.0%
DT6020719	DT1	DI	8.0%	5.0%
DT6127315	DT2	DI	10.0%	7.0%
DT6127322	DT2	DI	8.0%	4.0%
DT6020725	DT2	DI	9.0%	4.0%
DT6020716	DT2	DI	9.0%	3.0%
Mean			**6.6%**	**5.0%**
Std. Dev.			**3.4%**	**2.8%**

a) Percentage calculated from image total area.
b) DT1 = Dalma Tepe-1; DT2 = Dalma Tepe-2
c) DP = Dalma Painted; DI = Dalma Impressed

Though more than half of the samples from Dalma Tepe portrayed an amount of mineral inclusions at eight percent or more of the total sample, a substantial range is yet seen within the sample population, with one sample measuring a mineral amount less than one percent of its total. Dalma Tepe-1 has a notably lesser amount, with more than half of its samples hosting amounts of mineral inclusions measuring at five percent or less, while those in the Dalma Tepe-2 chemical group appear to have a consistently greater amount of mineral inclusions per sample (8-

10%). In measuring the voids in a given sample, it appears that most Dalma Ware at Dalma Tepe has a void amount in the range of four to seven percent of its total. However, the overall range of this void percentage remains variable, from two to eleven percent. In this sampling, most voids measured less than a millimeter, however, some samples contained voids as large as four or five millimeters, and all had voids of at least one millimeter.

Petrographic Analysis: Surezha

The strong presence of chaff temper suggests that the mineral inclusions are a natural part of the clay and may help identify provenance. Based on thin section analysis, this study found that the mineral suite of Surezha's ceramic wares includes quartz, orthoclase, epidote, calcite, plagioclase, and types of opaques and iron oxides (*Table 4.7*). Though all chemical groups share a predominance of quartz and consistent epidote, it is of particular interest to note that the chemical group Surezha-2 contains high amounts of calcite in its samples, where those in Surezha-1 contain none. Surezha-2 also hosts higher amounts of orthoclase, plagioclase, and epidote. Though differences such as these act to differentiate these chemical groups, it should be noted that these mineral types are shared between ware types.

Surezha-1 is chemically defined by higher amounts of aluminum, the transition metals, and the REE than found in Surezha-2, although the distinction between the two groups is not strong (Minc & Buehlman-Barbeau 2020). The matrices of Surezha-1 thin sections are mostly a dark, brownish color, and more than half the samples appear to be made with extremely fine paste (*Fig. 4.15*).

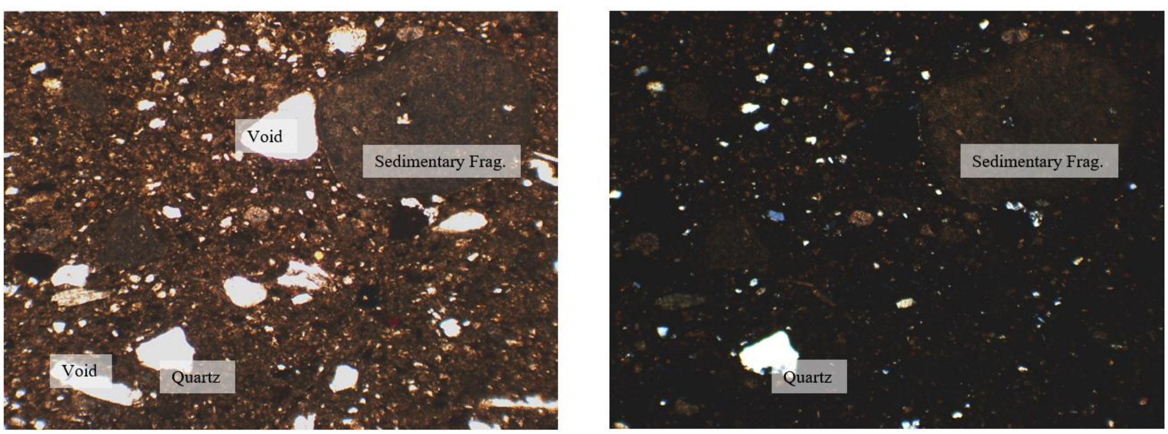
Table 4.7: Mineral composition of Surezha wares.[a,b,c,d]

ID	*Group*	*Type*	QUARTZ	EPIDOTE	PLAGIO-CLASE	ORTHO-CLASE	CAL-CITE	RUTILE	IRON OXIDE	SED. FRAG.	OPAQUE
SR9638	S1	*DP*	X					T	T	T	T
SR9640	S1	*DP*	X	T				T	X	T	T
SR9641	S1	*DP*	X					T	X	T	T
SR6293a	S1	*DI*	A	X	T	T		X	X	X	T
SR6156d	S1	*DI*	X		T			T	T		T
SR6156c	S1	*DI*	X	T				X	T	T	T
SR62931	S1	*DI*	T	T				T	T	T	T
SR6194c	S1	*DI*	T					T		T	T
SR6031a	S1	*W*	T								
SR3273	S1	*FPW*	X	T				X	T	T	T
SR6031a	S1	*W*	T								
SR9636	S2	*DP*	X		T			T	T	T	T
SR9645	S2	*DP*	X	T		X			T	T	T
SR9644	S2	*DP*	X	T	X	X		T	T	T	T
SR9635	S2	*DP*	X	T				T	T		T
SR9637	S2	*DP*	X	T				T	T		T
SR6156c	S2	*DI*	X	X	X	T	A	T	T	T	T
SR6281a	S2	*DI*	X	X	X	T	A	T	T	T	X
SR6194a	S2	*DI*	X	X	T		A		T		T
SR6194b	S2	*DI*	X	X	T	T	A	T	T	T	T
SR6194d	S2	*DI*	X	X	T	T	A	T	T	T	X
SR6156g	S2	*DI*	X	X	T		X	X	T	T	T
SR6156f	S2	*DI*	X	X	X		X	T	T	T	T
SR3276	S2	*FPB*	X	T		T	X	T	T		T
SR3279	S2	*CTB*	X					T	T		T
SR3281	S2	*GTB*	A	X		X	T	T	T	T	T
SR3291	S2	*GTB*	X	T			X		T		T
SR6368c	S*	*W*	X						T		T

a) Table adapted from Minc & Buehlman-Barbeau 2020
b) DP = Dalma Painted; DI = Dalma Impressed; FPB = Fine Paste Ware (Ubaid); CTB = Chaff Tempered Buff; GTB = Grit Tempered Buff; W = Waster
c) A = abundant; X = present; T = trace
d) S1 = Surezha-1 chemical group; S2 = Surezha-2 chemical group; S* = chemical outlier with low Rb:Cs

Mineralogically, this group is characterized by its quartz inclusions, which appear consistently present to abundant per sample, and trace amounts of epidote, which appear in most samples. Sedimentary rock fragments are also present in almost every sample in this group. Opaque minerals appear in trace amounts throughout the set as well. These minerals are small and angular, with sharp edges and distinct rectangular or triangular shapes; however, others appear subrounded as well. Form factor of the grains was measured using CellProfiler, where the measurement of form factor was used to evaluate the grain inclusion as platy, bladed, or elongated in shape. At Surezha, most mineral inclusions appear to be bladed (*Fig. 4.12*). Interestingly, there is no calcite present in any of the Surezha-1 samples, the lack of which may persist as a defining feature should future petrographic study perceive the same. Plagioclase and orthoclase appear in trace amounts in only a few of the samples. Voids appear abundantly in some samples while not in others, and may measure from 0.5 – 6 mm in length.

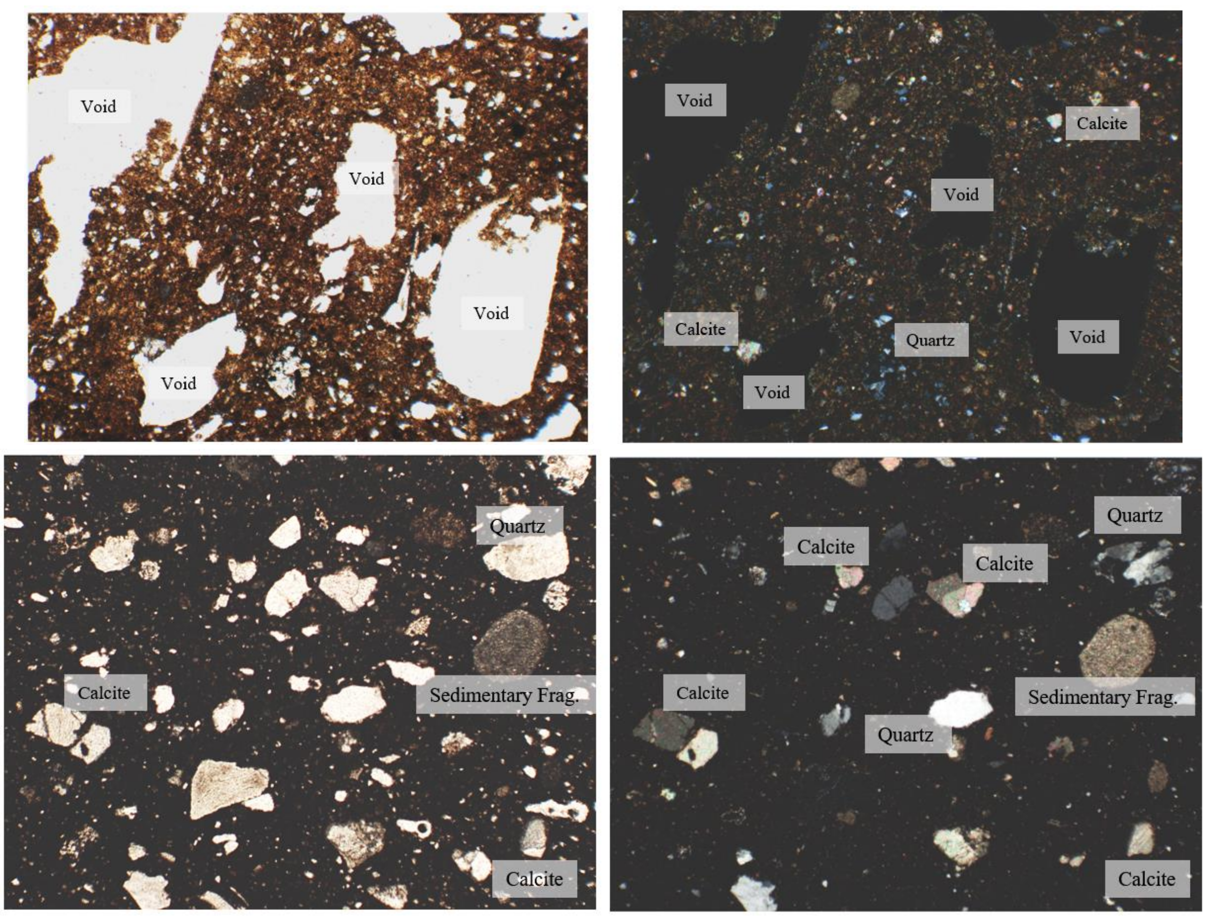
Fig. 4.15: Surezha-1 Petrographic Images[a]



a) Sample SR6293a (PPL image left, XPL right). Image taken at 40x.

Surezha-2 is chemically defined by its slightly higher average concentration of calcium and sodium, and lower amounts of aluminum and most other elements, suggesting a mild dilution effect. This dilution is perhaps due to the amount of quartz, which appears in larger quantities and grain size than the quartz present in the Surezha-1 group, as is calcite, which appears in abundance in a number of Surezha-2 samples (Minc & Buehlman-Barbeau 2020). While most of the samples' matrices appears dark or light brown in thin section (*Fig. 4.16*), a few exhibit high birefringence, especially those abundant with calcite, suggesting calcareous clays which may also support evidence of this group's high amounts of calcium as opposed to Surezha-1. Like samples of Surezha-1, Surezha-2 is predominately quartz, the amount of which is consistent across samples. Sedimentary rock fragments are present, but not as much as they are seen in the Surezha-1 group.

Fig. 4.16: Surezha-2 Petrographic Images[a]



a) Top: Sample SR6194b (PPL image left, XPL right). Bottom: Sample SR3281 (PPL left, XPL right). Images taken at 40x.

Opaque minerals are also measured in relative abundance; these minerals appear small and angular, and most are rectangular in shape. Epidote, plagioclase, and orthoclase are present in most of these samples, while plagioclase and orthoclase are seen in lesser amounts than quartz or epidote; however, this group appears to have higher amounts overall. Like that of Surezha-1, the amount of voids in this chemical group appears variable per sample. These voids can appear quite large, with the group hosting those measuring from 0.5 – 5 mm in length.

Textural Analysis: Surezha

Output from the CellProfiler pipeline was used to assess the amount and size of mineral inclusions in a three-millimeter space on each Surezha thin section (*Tables 4.8, 4.9)*. The samples from Surezha had a variety of mineral sizes, with the most common size being fine and very fine sand according to the Wentworth scale; a small amount of medium sand was found amongst both the Dalma types and Surezha's local wares. The average amount of mineral inclusions per sample was measured as a percentage of the whole thin section image, which resulted in a range of 0.7% to 14%; however, the vast majority of samples had a mineral inclusion amount at 5% or less. Like that of the Dalma Tepe voids, the size of many of the voids in Surezha's samples were well over the petrographic image of three millimeters. Thus, a photograph of the entire thin section was taken upon a light table, illuminating the voids to be measured and counted using CellProfiler.

The main chemical groups at Surezha are comparable in terms of the amount of mineral inclusions; with both averaging about 6%. Surezha-1 appears with the largest range of mineral inclusions, with one sample indicating 0.7% inclusions, and another at 14%. Dalma Impressed wares likewise seem prone to more variation in regards to mineral amount, however, the majority of the samples seem to indicate an amount of 5% or less; likewise, most of Dalma Painted wares at Surezha similarly indicate an amount of 5% or less. In total, the average mineral inclusion amount of Surezha's Dalma Ware is 4.6%. The average void amount of Surezha's Dalma ware is 4.8%. This may be compared to Surezha's local wares, which have a mineral inclusion amount averaging at 6.9%, and an average void inclusion amount of 4.2% (*Table 4.10*). Surezha's local wares have a range (3 – 13%) perhaps more comparable to that of Dalma Impressed (0.7 – 14%), as opposed to the Dalma Painted mineral range of 3 – 7%. This comparability between types is further seen in discussion of total void amounts per sample.

Where Surezha's Dalma Painted wares exhibit a range of 3 – 8% in void amount, Surezha's local and Dalma Impressed wares are seen in ranges of 0.7 – 8% and 0.2 – 8%, respectively. Most of the voids in Surezha's samples measured less than a millimeter, however, some were quite large, measuring at four, five, and six millimeters in length. Variability in void amount and size was comparable across chemical groups.

Table 4.8: Surezha-1* Mineral and Void Percentage.[a,b]

ID	**Type**	**Total Mineral Inclusion %**	**Total Void %**
SR6031a	W	11.0%	2.0%
SR3273	FPB	3.0%	2.0%
SR6156d	DI	5.0%	5.0%
SR6194c	DI	0.7%	3.0%
SR62931	DI	4.0%	0.2%
SR6293a	DI	14.0%	3.0%
SR9638	DP	3.0%	4.0%
SR9640	DP	5.0%	6.0%
SR9641	DP	7.0%	8.0%
SR6368c*	W	4.0%	8.0%
Mean		**5.7%**	**4.1%**
Std. Dev.		**4.0%**	**2.6%**

a) Table adapted from Minc & Buehlman-Barbeau 2020
b) DP = Dalma Painted; DI = Dalma Impressed; FPB = Fine Paste Ware; W = Waster
**SR6368c* is part of an outlier chemical group of low Rb:Cs

Table 4.9: Surezha-2 Mineral and Void Percentage.[a,b]

ID	Type	Total Mineral Inclusion %	Total Void %
SR3291	GTB	13.0%	8.0%
SR3276	FPB	3.0%	0.7%
SR3279	CTB	4.0%	4.0%
SR3281	GTB	10.0%	5.0%
SR6156c	DI	4.0%	8.0%
SR6156f	DI	4.0%	4.0%
SR6156g	DI	3.0%	1.0%
SR6281a	DI	6.0%	5.0%
SR6194a	DI	2.0%	8.0%
SR6194b	DI	5.0%	7.0%
SR6194d	DI	5.0%	3.0%
SR9635	DP	3.0%	5.0%
SR9636	DP	4.0%	3.0%
SR9637	DP	3.0%	6.0%
SR9644	DP	6.0%	5.0%
SR9645	DP	3.0%	6.0%
Mean		**4.9%**	**4.9%**
Std. Dev.		**2.9%**	**2.3%**

a) Table adapted from Minc & Buehlman-Barbeau 2020
b) DP = Dalma Painted; DI = Dalma Impressed; FPB = Fine Paste Ware; CTB = Chaff Tempered Buff; GTB = Grit Tempered Buff; W = Waster

Table 4.10: Average Inclusion Amounts of Surezha Dalma and Local Wares.

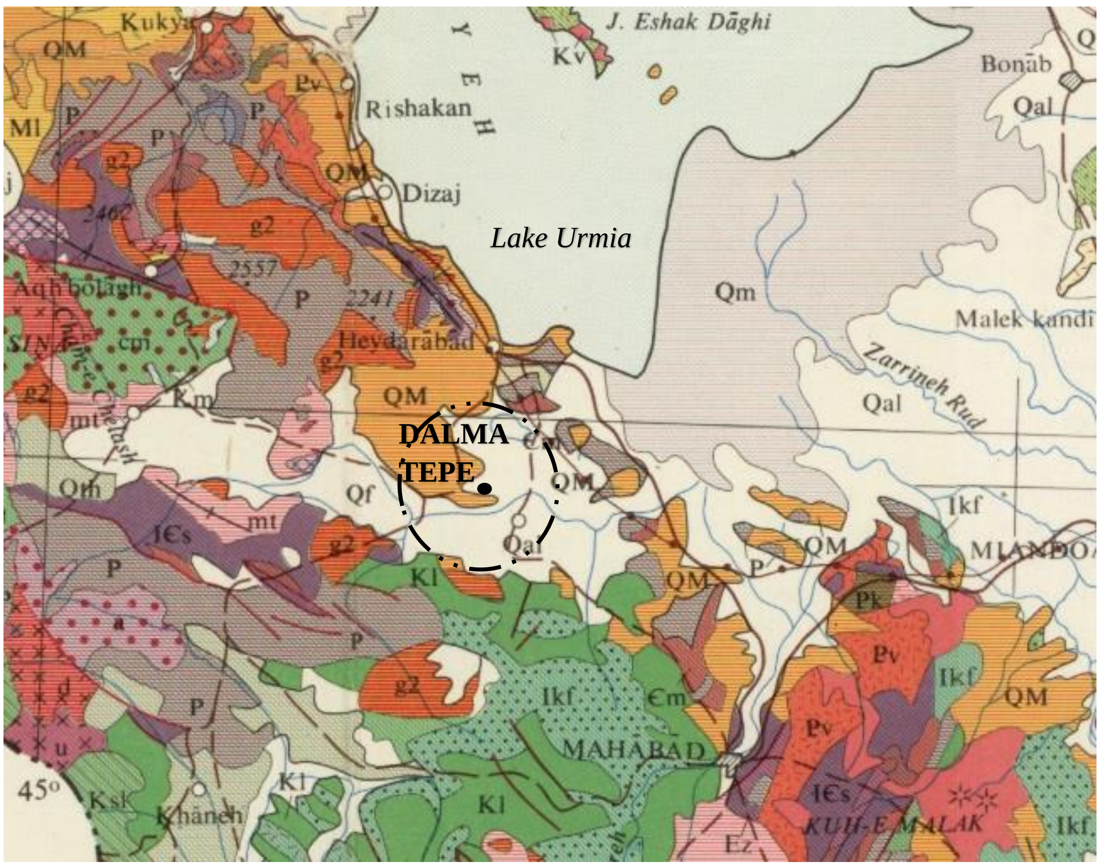
	Surezha Dalma Ware		**Surezha Local Wares**	
Measure	*Min. Inclusion Amount*	*Void Inclusion Amount*	*Min. Inclusion Amount*	*Void Inclusion Amount*
Mean	4.6%	4.8%	6.9%	4.2%
Std. Dev.	2.7%	2.2%	4.3%	2.9%

Preliminary Geologic Provenance Analysis from Dalma Tepe

Dalma Tepe is located within the west-to-east running Ushnu-Solduz Valley at the base of Lake Urmia. This region is a part of the Sanandaj-Sirjan Zone, a highly variable geologic region (*Fig. 4.17*).

In efforts to distinguish the geologic provenance of the ceramics from Dalma Tepe, discussion of the geologic formation and processes surrounding must be assessed. Under the assumption that clay procured within roughly seven kilometers of Dalma Tepe may be considered "local" (Arnold 1981), this section will first attempt to match the mineralogical and clay composition of Dalma Tepe's ceramics to the region directly encompassing the site.

Fig. 4.17: Geologic Landscape of Northwestern Iran (Huber & Eftekhar-Nezhad 1978)



A circle with a 7 km radius surrounds the site.

Qal: Alluvium.
Qf: Alluvial Fan Deposit
QM: Qom Formation
cm: Colored Melange
mt: Metamorphics, undiff, mainly Precambrian
d: Diabase
g2: Post-Cretaceous intrusive rocks
P: Upper Permian-Djulfian limestone
I€s: Soltanieh-Barut Formation
K1: Cretaceous Limestone/Dolomite

As petrographic and paste analysis showed, Dalma Tepe's ceramics are composed predominantly of quartz, some amphiboles (hornblende), and sedimentary rock fragments. Additionally, many of the ceramic samples included large grains of polycrystalline quartz, a type that has been cited to originate from low-grade metamorphism, which includes rocks such as schist and shale (Folk 1965; Basu *et al.*, 1975). A single sample includes calcite, which suggests an origin with limestone, and another sample included a mineral with an extinction pattern (Maltese Cross) known specifically to volcanic processes. Thus, when reviewing the landscape in immediate proximity to Dalma Tepe, I will look for parent materials associated with these minerals to make claim of the ceramics' "local" origin.

The Ushnu-Solduz Valley lies within a Quaternary alluvium formed by the perennial Gadar River and its surrounding geologic formations. The Gadar River runs west to east, from within the Zagros peaks to the southern basin of Lake Urmia. As seen in the geological map of the region (*Fig. 4.12*), the 7 km radius of local material around Dalma Tepe includes the alluvium and the Qom Formation, which consists mainly of limestone. It may be assumed that the alluvium consists of minerals and materials brought into the valley through fluvial activity. Carried from the Zagros Mountains, sediment loads in the Gadar River would have traveled through a number of geologic landmarks traveling from the northwest southward, near Iran's border with Turkey and Iraq, eventually changing course eastward into the valley. These formations include 1) a landmark of diabase, an igneous rock similar to gabbro or basalt, 2) formations of mélange, a type joined together by tectonic, diapiric, or sedimentary processes and known in this region to contain metabasic schists, calc-silicate minerals, amphibolites, and peridotites (Hajialioghli & Moazzen 2014), and finally, 3) a formation of metamorphic rocks. The behavior of the minerals carried by the Gadar River are expected to be rounded due to the erosional and abrasive river processes, especially due to the fact that the diabase and mélange landmarks are roughly 35 - 50 km from the Dalma Tepe site.

In summary, in the alluvium, the Gadar River is expected to have brought in mineral complexes such as diabase, schists, amphibolites, peridotites, and Precambrian metamorphics. The alluvium, and nearby alluvial fan, may be an attributable source for sedimentary rock fragments. Thus, the mineralogy of the general region does match the mineralogical assemblage of the Dalma Tepe ceramics, although, the overall lack of calcite perhaps speaks to the probability of a local match as well. Due to the limestone Qom formation which nearly encircles Dalma Tepe entirely, it may be expected that the local-based ceramics at the site would have a regular presence of calcite. The influence of limestone is expected again from fluvial processes from nearby areas such as the Permian-Djulfian formation to the west and east, and the Cretaceous limestone and dolomite formation to the south. Despite all this, there is an overall absence of calcite in the ceramic samples from Dalma Tepe.

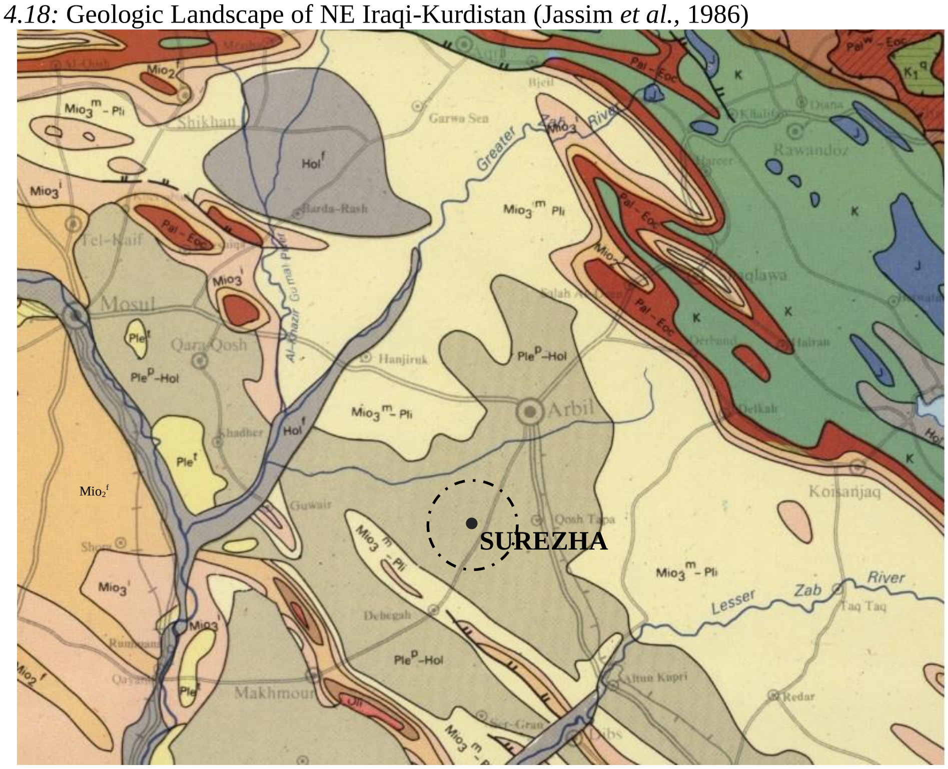
The mineral inclusions were generally in small amounts (average of 6.6% of the sampled space), and though most grains were in the “very fine sand” and “fine sand” size range, a number of samples had mineral inclusions with a measure of medium and coarse sand. Most of the mineral inclusions were platy or bladed, rather than elongated, and maintained angularity; however, some were indeed quite rounded, especially the sedimentary fragments. This poorly sorted mixture of angular and sub-rounded grains are perhaps reflective of the region’s local alluvium or alluvial fan; studies (Blair & McPherson 1994) have indeed suggested that the sudden decrease of velocity and unconfinement of a river system as it drains into an alluvial fan results in a rapid deposition of poorly sorted, angular grains.

Though the Dalma Tepe ceramics are suggestive of clay with origins non-local to the site of Dalma Tepe due to a general lack of calcite inclusions, the morphology of the grains may indeed reflect origins with an alluvial fan. Therefore, the petrographic and paste analyses of the ceramics of Dalma Tepe are not inconsistent with the local geologic terrain. Further analysis of the mineralogy and clay within the region is required for additional speculation of the provenance of Dalma Tepe ceramics.

Preliminary Geologic Provenance Analysis from Surezha

Surezha is located in the Erbil Plain (*Fig. 4.18*), which is part of a region known for its general homogeneity, making provenance analysis markedly difficult (Alavi 1994, 2004; Minc *et al.*, 2019).

Fig. 4.18: Geologic Landscape of NE Iraqi-Kurdistan (Jassim *et al.*, 1986)



A circle with a 7 km radius surrounds the site.

Ple^p-Hol: Quaternary Polygenetic Synclinal Filing
$Mio_3{}^m$-Pli: Bai Hassan Formation
$Mio_2{}^i$: Injana Formation
$Mio_2{}^f$: Fatha Formation
K: Cretaceous Shiranish Formation

The mineral composition of Surezha's ceramic assemblage is characteristic of its chemical grouping: Though both chemical groups Surezha-1 and Surezha-2 predominantly consist of quartz and epidote, Surezha-2 has abundant measures of calcite, a mineral which is entirely absent from Surezha-1 ceramic samples. Surezha-2 also has a higher amount of epidote, plagioclase, and orthoclase, all of which may help in the identification of provenance. Meanwhile, Surezha-1 has a higher amount of sedimentary rock fragments, though these are also present in the Surezha-2 wares. As proposed by the Dalma Tepe ceramics, this section will assume that clay procured within roughly seven kilometers of Surezha may be considered "local", and therefore study of provenance will begin with the area directly surrounding the site. In addition, Surezha-2 may be strongly associated with its origins with limestone, due to its abundance of calcite. Under the initial hypothesis that the ceramics at Surezha are made from locally sourced clays, this study will look specifically for geologic landmarks of granite, schist, gneiss, sandstone, and limestone within 7 km of Surezha.

Surezha is located within a region of Quaternary polygenetic synclinal filling with minerals from the surrounding geologic formations, as well as the river systems. This region is bound primarily by the Bai Hassan formation, as well as the Injana formation. The Bai Hassan formation consists mainly of claystone, sandstone, and conglomerates, and, similarly, the Injana formation is known to have claystone, sandstone, and siltstone. The Upper Zab River flows from the Lake Van region in Turkey before bending westward to meet the Tigris River; meanwhile, the Lower Zab rises in NW Iran and crosses the Zagros to also meet the Tigris near the Erbil Plain. The Upper and Lower Zab cut through the Nappe Zone of NE Iraqi-Kurdistan, a region known for its gabbro, granite, and basalt. Though the southeastern flowing Tigris is known to carry both heavy and flakey minerals including biotite, muscovite, magnetite, and spinel, the junction of the Upper Zab and Tigris mark a reportedly lesser amount micas, having been replaced by epidote and opaque minerals (Al-Juboury *et al.*, 1999; Al-Juboury 2009; Minc *et al.*, 2019).

Based on these reports, the 7 km radius of locally based clays at Surezha can be expected to be directly influenced by the colluvial deposition of eroded sediments derived from sandstones, claystone, and siltstone of the Bai Hassan and Injana formations, as well as minerals from the Nappe Zone carried by the Upper and Lower Zab Rivers, including gabbro, granite, and basalt. Finally, from the Tigris River, minerals such as epidote and various opaque minerals may be present, however, the Tigris River's influence on clays in Surezha's locality may not be as prominent or direct due to the distance between them. Notably, there is seemingly no influence of limestone in the immediate region that would dominate in the mineralogical makeup of Surezha's locality. The closest sources of limestone are within the Fatha Formation, the majority of which is ca. 60 km directly west of Surezha (Al-Juboury & McCann 2008), and the Cretaceous Shiranish Formation ca. 50 km to the northeast (Awdal *et al.*, 2013). However, this assessment is based on a map with a reasonably large scale; a more concise and regionally detailed geologic map specific to that of the Erbil Plain may better speak to the true establishment of a limestone presence proximal to the site of Surezha.

The size and shape of the mineral inclusions of the Surezha ceramics are generally uniform throughout the assemblage. Though some of the grains have generally rounded edges, most grains are angular and bladed, or elongated, based on assessments of form factor. The mineral grains also appear to be generally small (0.05 - 0.1 mm), with a few samples including grains sized as medium sand. Though colluvial environments are generally expected to be poorly sorted, with a mixture of coarse to fine sediments, the overall mineral assortment of Surezha's vessels are not inconsistent with these expectations based on grain morphology and under the consideration that ceramicists may specifically procure clay from parts of the colluvium containing predominately fine sediments formed from erosional processes (Waters 1992; Blair & McPherson 1994).

Based on the size and shape of the mineral inclusions, as well as the mineral species themselves, it may be suggested that many of the ceramics sampled from Surezha originate from clays found centered between the main rivers, subjected to colluvial processes, which subsequently suggests their locality at the site of Surezha. However, the abundance of calcite in the Surezha-2 ceramic wares suggests provenance with limestone formations to the north and southwest. The distinguishable mineralogy of Surezha-1 and Surezha-2 lends evidence towards two separate communities of ceramic practice at the same site, a proposition which will be explored in more detail in the following chapter.

Summary and Comparisons Between Sites: Dalma Ware

This study utilized over 100 ceramic samples from Surezha and Dalma Tepe in order to explore communities of practice in the Chalcolithic Near East via qualitative paste analysis and qualitative petrographic analysis. With 34 petrographic thin sections in total, Dalma and local wares were assessed in comparison of their compositional attributes. This petrographic analysis was paired with Minc & Buehlman-Barbeau's trace element data (2020) based on chemical characterization of the entire ceramic collection in order to further understand the region's communities of practice and potential modes of dispersal for the Dalma tradition.

The Dalma Ware at Dalma Tepe and Surezha are first and foremost comparable by their exterior appearances. Though the Dalma Painted at Surezha appears more worn than that at Dalma Tepe, both appear to have reddish streaky or striped designs over a white slip. Dalma

Painted at both sites appear to have the same white slip and solid red paint covering the interior of the vessels as well. Similarly, the Dalma Impressed at both sites shared a plethora of designs, all of which were treated with white slip and red paint, although like Surezha's Dalma Painted, the Dalma Impressed sherds from Surezha were also much more worn. In general, the Dalma Painted wares from Surezha had greater sherd thickness than the Dalma Painted sherds at Dalma Tepe, and the paint at Dalma Tepe appears reddish brown (with 37% a "reddish yellow" between both 5 YR 6/8 - 6/6 - and 7.5 YR 6/6; and 19% a "brownish yellow" or "light yellowish brown" with 10 YR 6/4 – 6/6; the remaining samples had Munsell colors ranging in the 10 YR, 7.5 YR, 5 YR, and 2.5 Y classifying families), whereas the paint at Surezha appears merely brownish (with 22.6% a "very pale brown" with a measure of 10 YR 7/3 – 7/4; 29% measuring "pale brown" or "light yellowish brown" with 10 YR 6/3 – 6/4; the remaining samples had Munsell colors ranging in the 10 YR, 7.5 YR, 5 YR, and 2.5 Y classifying families).

The mineral signature of Dalma Ware between Surezha and Dalma Tepe are clearly different, although both include quartz, opaque minerals, and iron oxides. Epidote and orthoclase are also shared between sites; however, both minerals are seen in much smaller quantities at Dalma Tepe. Calcite is a rather abundant addition to Surezha's mineral suite, though interestingly, it is not seen in any of Surezha's Dalma Painted wares, and only some of the Dalma Impressed. Grain size distributions in the Dalma Ware at either site also exhibits differences; the majority of mineral inclusions at Surezha, for example, are present in an amount at or less than 5% of the sample's total composition, while the majority of samples at Dalma Tepe have mineral inclusions representing between eight and ten percent of the sample's total. Grain sizes and shapes are also noticeably different at either site, with Dalma Tepe vessels including grains at a larger size than those at Surezha, and the shape of the grains at Dalma Tepe appearing more platy rather than bladed or elongated. These differences are seen in discussion of the vessels' compositional attributes as well: While the sorting of inclusions at Dalma Ware is found to be largely "poor", and sometimes "very poor", the sorting at Surezha is found overall to be "good" and "fair". Indeed, in many aspects, Surezha's Dalma Ware is more similar to its local contemporaries than the Dalma Ware at Dalma Tepe, though these similarities may be attributed to the assumption that the local and Dalma assemblages at Surezha were made of the same clay resources and materials. Dalma Ware from both sites were similar in their observed amounts of organic inclusions. While Dalma Tepe's Dalma Ware had a void percentage averaging at 5.0%, Surezha's Dalma Ware saw voids averaging in the 4.8% range. Void analysis also drew Dalma Tepe and Surezha in comparison of void measurements, the result of which was comparable across sites.

These differences are complemented with the INAA data from Minc & Buehlman-Barbeau's study on the same samples (2020), which suggest that the Dalma Ware from Dalma Tepe and the Dalma Ware from Surezha do not share the same origin. Further testing of clay from each respective region is needed to more accurately source the ceramics at Surezha and Dalma Tepe. The following chapter commences in discussion of the petrographic and paste analysis results as they relate to the theoretical modes of Dalma dispersal and communities of practice addressed in previous chapters.

Chapter V

Summary and Discussion

In efforts to further define Northern Mesopotamia's inter-regionality, this study explored the ceramic tradition of Dalma Ware as it is shared between the Chalcolithic sites of Surezha and Dalma Tepe. The results of these analyses suggest key differences and similarities between the two sites. This chapter will further assess these findings in discussion of the results, and their potential relation to the expected patterns of behavior affiliated with modes of dispersal, as outlined in Chapter III. Later, this section will also serve to address the current understanding of Dalma Ware as a community of practice as seen in previous study, and the state of Dalma study going forward.

Summary of Results

At Dalma Tepe, 38 ceramic samples of Dalma Ware were included in the analysis, including Dalma Painted and Dalma Impressed. Paste analysis has shown that these ceramics hosted a variety of mineral and chaff inclusions; the organic inclusions comprised 5% of the sample image on average, and could appear quite large, with some measuring up to 4 or 5 mm in length. The mineral inclusions made up 6.6% of the sample image on average, and were generally poorly sorted. Grain sizes ranged from the size of silt (ca. 55%) and very fine sand (ca. 37%) to coarse, medium, and fine sand (ca. 7.5%), and while some grains could be considered rounded, others were quite angular. These variations of grain attributes in the materials used to produce Dalma Tepe's Dalma Ware are consistent with an alluvial depositional environment in which changing water flows introduce a variety of grain sizes.

Petrographic analysis of Dalma Tepe's Dalma Ware revealed a mineral complex which predominately included quartz, sedimentary rock fragments (silt stone), opaque minerals, and some amphiboles, with a trace amount of epidote, perthite, and orthoclase. A single ceramic sample included calcite. Because Dalma Tepe is located in an alluvium with a perennial river, it is plausible to consider that its Dalma Ware was locally made. However, limestone formations directly surround the site, as well as the alluvium itself, and the overall lack of calcite or limestone fragments perhaps warrants a call for further study, specifically on the clay local to the site of Dalma Tepe. Future study of the regional clay resources may also prove better able to assess the potential processes within the alluvium itself, such as cyclic deposition, which may likewise influence the mineralogical makeup (Beerbower 1964).

Over 70 ceramic samples from Surezha were analyzed for this study. Like the assemblage at Dalma Tepe, both Dalma Painted and Dalma Impressed wares were studied from the site. Local wares from the site were used to compare the Dalma community of practice and local community of practice at Surezha. The average inclusion amount for the Dalma Ware at Surezha equals roughly 4.6%, meanwhile, the void amount averaged to about 4.8%. Voids of this type ranged in size, with the largest measuring up to 5 or 6 mm in length. The maximum length is comparable to Dalma Tepe's Dalma ceramics, though the voids at Surezha were slightly broader. The mineral inclusion amount of Surezha's Dalma Ware, on the other hand, was on average 2% less than the inclusion amount at Dalma Tepe. The shape of these mineral grains ranged from sub-angular to sub-rounded, and most were in the silt (ca. 63%) and very fine sand size (ca. 34%) range, while a few measured in the fine sand size (ca. 2%), and an even lesser amount in the medium sand (ca. 0.2%). This uniform sorting of grains may reflect on their geologic provenance.

The local wares from Surezha analyzed for this study are comparable to the site's Dalma Ware in many ways; first, they show similarities in grain shape and size: Most mineral grains were sub-rounded and sub-angular, and a few inclusions were specifically more angular than seen in the Dalma Ware. The size of the grains used in local wares, like the Dalma, were largely in the silt and very fine sand range, and a few measured in the fine sand size, and only a small amount measured as medium sand. The mineral and organic inclusion amounts, however, did show some difference with Surezha's Dalma Ware. While it should be noted that these inclusion amounts include a variety of different ceramic traditions (Grit and Chaff Tempered Ware, Fine Paste Buff Ware) which may strongly influence the average amount, the differences still stand with Surezha's local wares having an average mineral inclusion amount of 6.9%, and an average void inclusion amount of 4.2%. Also, form factor analysis of grain shape showed that Surezha's Dalma Ware had a rather concise measurement, where most of the grains fell into the classification of "bladed" grains; meanwhile, Surezha's local wares had a much larger range of shapes, from platy, to bladed, to elongated. Thus, while similar, there is some evidence which suggests a separate community of practice amongst Dalma ceramicists.

Petrographic analysis revealed an abundance of quartz and epidote, alongside a moderate presence of plagioclase and orthoclase in all of Surezha's sampled wares. Minc & Buehlman-Barbeau (2020) identified two main chemical groups within Surezha's assemblage, which was clarified with petrographic study. Only one chemical group (Surezha-2) included heavy amounts calcite in its mineral complex. The opposing chemical group, Surezha-1, meanwhile exhibited no measure of calcite at all in its samples. This is perhaps indicative of the geologic provenance of the sampled vessels; while both chemistry and petrography suggest a local provenance for Surezha-1 wares, the calcite inclusions in Surezha-2 wares perhaps indicate an origin some distance from the site. Interestingly, though both Dalma Painted and Dalma Impressed were attributed to both chemical groups, the Dalma Painted samples from Surezha contained no calcite. More research is necessary to further claim the provenance of these ceramic wares.

Discussion of Results

The petrographic and paste results of this study suggest that the Dalma Ware of Surezha and that of Dalma Tepe, despite mineralogical and trace element differences, do hold certain consistencies as a larger group when compared to other contemporary wares at Surezha. Its exterior motifs in both Painted and Impressed types were similar across sites, and furthermore, paste analysis showed an overall similarity of material type and amount. Most interesting, the findings of this study mirror that of Tonoike's study (2009), which suggested an overall cohesiveness within the Dalma tradition, with generalized differences per region. These differences may correlate with the variable of time, where Tonoike and this thesis found Dalma Ware of the early 5th millennium had a more variable array of mineral inclusion sizes, and moderate amounts of voids, whereas both studies also found that Dalma Ware in the later 5th millennium hosted mineral inclusions of a finer grain, and moderate to heavy void amounts (*Table 5.1*). The similarities between Surezha's Dalma Ware and its Central contemporaries suggest a consistency of change within the tradition over time that transcended regions, speaking to its existence in a broad community of practice which survived the course of a millennium.

Table 5.1: Regional Compositional Comparisons of Dalma Ware[a]

	Solduz Basin (NW Iran)	**Central Zagros (West-Central Iran)**	**Dalma Tepe (NW Iran)**	**Erbil Plain (Northern Mesopotamia)**
4500 - 4000 BCE		Moderate to heavy voids; fewer large inclusions.		Moderate to abundant voids (largest measuring 5 – 6 mm); mostly fine inclusions.
5000 - 4500 BCE	Moderate voids; more large inclusions *(in comparison to Central).*		Moderate voids (largest measuring 4 – 5 mm); more large inclusions *(in comparison to Erbil Plain).*	

a) Regional observations of the Dalma Ware from the Solduz Basin and Central Zagros from Tonoike (2009)

Table 5.2: Expectations and Observations of Communities of Ceramic Practice in Four Modes of Dispersal[a]

	Trade	**Pastoralism**	**Itinerant Specialists**	**Exogamy**	***Dalma Ware at Surezha***
Ceramic technology	Homogeneous across region, reflecting a single community of practice at place of origin.	Largely homogeneous across region; potential for slight variation due to multiple pastoral groups or familial distinctions.	Homogeneous within type and distinct to sub-region served by potter, reflecting their community of practice.	Mixture of practices; some wares reflective of place of origin, others with attributes adapted from local community of practice.	**Homogeneous within the site type; distinct from local communities of practice.**
Chemical & Mineralogical signature	Local to place of origin; distinct from local pottery.	Local to scope of pastoral route; potential for chemical/mineral signature mix if region encompasses geological diversity.	Either local or non-local to site of recovery; indistinct from local pottery.	Potential mix of chemical & mineralogical signatures in assemblage due to some transported wares while the majority would match local pottery.	**Showed two distinct mineral and chemical groups, indicative of local and non-local clay materials.**
Abundance in overall assemblage	Low	High	Low	Low	**Low**
Assemblage composition	Special forms, easily packed or transported; forms distinct from local wares.	Majority of vessels reflect a household assemblage.	Specialized forms meant for target market; distinct from local form.	Majority of vessels reflect a household assemblage distinct from local forms.	**Forms distinct from local wares.**
Presence of ceramic production facilities at site	None	Expected on-site or within scope of pastoral route.	Expected on-site; specialized toolkit also expected on-site.	Expected on-site.	**Specialized toolkit found on-site (relation to Dalma Ware TBD). Production facility TBD.**

a) Expectations of four theoretical modes of dispersal in comparison to the observed attributes of Surezha's Dalma Ware. Attributes of Surezha's Dalma Ware and the closely matched expectations highlighted in dark grey. Expectations which have potential to match with the observed attributes at Surezha but fall short of doing so in absolute are marked in a lighter grey. Expectations which bear no observable connection with the Dalma Ware at Surezha are highlighted in white.

However, Surezha's Dalma Ware also bore similarities to the local wares at the site, in both trace element and mineralogical analysis. Though the amount of Dalma Ware at Surezha is minimal in comparison to the greater assemblage, certain attributes, such as inclusion sorting, grain size and shape, and void percentage fall within the range of Surezha's local wares.

Under this paste compositional analysis it has been made possible to assess the questions initially posed by this study. In the section that follows, I will analyze each theorized mode of dispersal as discussed in Chapter III (*Table 5.2*) in order to address the question of what practices, adaptations, and behaviors may have contributed to the spread of Dalma Ware.

In Theory: Dalma Ware as a Product of Trade:

The observable expectations this project has set for recognizing behaviors of trade and exchange in the ceramic record call for a pattern involving a chemical signature that is distinct from the site's local assemblage, presumably homogenous to the traded wares' own chemical signature of origin. In linking a ceramic assemblage to behaviors of trade, this study also looked for a ceramic production or technology which is distinct from the local wares; this again would indicate an assemblage which was made under a community of practice not local to the site itself. The ceramic assemblage as a product of trade would not be in the majority of the rest of the site's ceramic assemblage, nor would its type be reflected in a local ceramic workshop, being made off-site. Lastly, traded ceramic wares would appear in specialized forms, whether they are special for forms of status or wealth, or special in that they were made to withstand a certain level of transport.

The Dalma Ware in this study from Surezha was in the minority of the site's entire collection, and some wares did indeed suggest a non-local origin. Moreover, the Dalma Ware at Surezha could have arguably been made for the likes of transport, as would be indicative of trade. However, many of the samples had a chemical signature that was not distinct from that of the local wares, which is inconsistent with the idea of trade. Surezha's Dalma Ware also largely comparable to other local wares at the site in aspects of ceramic production. Therefore, the overall similarities in ceramic production at the site are markedly inconsistent with the theory which suggests that the presence of Dalma Ware at Surezha can be attributed to behaviors of trade or exchange at this time.

However, it is worth noting that obsidian trade has proven to link multiple sites in the region to a number of obsidian sources. While this study has suggested Dalma Ware is not a direct product of trade at Surezha, it stands that the community of Dalma may have utilized routes or paths facilitated and known to traders or other participants of high mobility, as discussed below.

In Theory: Dalma Ware as a Product of Pastoralism

Pastoralism has been a consistent contender to be the theoretical driving force behind Dalma dispersal. Where Abedi *et al.* (2015) and Tonoike (2009) point to the numerous Dalma sites which reflect practices of pastoralism, this study likewise looks for certain markers of such behavior which can be linked to the likes of Dalma Ware at Surezha. In recognizing ceramic vessels as a product of pastoral tradition, one of the many expectations include potential for contrasting chemical signatures. In the event that a pastoral group is traveling to a new site, whether based on seasonal mobility or otherwise, it may be expected that they take a number of ceramic vessels with them. The mixture of chemical signatures, then, may arise from the continued production of ceramics at the new site. Thus, it is expected that the trace element analysis will exhibit data which is consistent with the generalized region in which the pastoral group resides. Next, pastoral ceramic tradition may be recognized by the ware itself: The majority of vessels are expected to have a function meant for household or pastoral activities, such as cooking or storage, in order to reflect the pastoral lifestyle. Vessels may also be made especially for travel or transport, which would be recognizable in the assessment of their production.

The Dalma Ware at Surezha may be contributed to pastoralism first in the fact that while some of the ceramic assemblage appears to be local to the site itself, many other Dalma vessels are indicative of a non-local source, perhaps with a nearby highland region. This suggests the idea of transhumant pastoralism, in which the pastoralists carry the tradition to and from Surezha, resulting a mixed chemical and mineralogical signature in the ceramic wares. Though Surezha's Dalma Painted was found in both chemical groups, no samples contained calcite. This perhaps indicates that it was made in the lowland site of Surezha, as opposed to the highlands where limestone is predominately located. This is consistent with previous studies which have likewise suggested that Dalma Painted is overwhelmingly found at lowland sites, where Dalma Impressed as a much more variable extent, due to pastoral practices (Tonoike 2009). However, it should be noted that the non-local signature is not mutually exclusive in favor of Dalma Ware: Several non-Dalma ceramic wares were also hypothesized to have a non-local signature. While it is possible that multiple communities of ceramic practice were involved in transhumant practices such as pastoralism, more research is needed on this possible line of theory.

In Theory: Dalma Ware as a Product of Itinerant Specialists

As itinerant specialists rely largely on the marketability of their craft, it is expected that the pottery of itinerant ceramicists would serve a function, whether as a symbol of status, or as a household necessity. As pottery made by itinerant ceramicists would most likely be made on-site, it would be expected that there would be evidence of a ceramic production facility relating directly to the ceramic type in question; furthermore, a specialized toolkit relating to the ceramic type may also be expected. Depending on the *chaîne opératoire* of the ceramicist's practice, the vessel's chemical signature could be local to the site of production, or it could have been brought from the specialist's own source of procurement. Regardless, the production method, identifiable in ceramic paste analysis, would be distinct from the site's local wares, as being local to the ceramicist's own community of practice.

As mentioned previously, Surezha Dalma Ware has a mixture of chemical and mineralogical signatures, which may lend support to the theory of an itinerant specialist initially bringing their own clay and materials, before using local clay due to various reasons, including the specialist settling at Surezha, or simply needing more material due to local demand. Moreover, evidence of ceramic ring scrapers found at the site may prove their functionality of part of a ceramic toolkit, as theorized by Alden (1988), and may likewise be linked to the community of Dalma practice and the idea of itinerant ceramicists; however it is important to note that ring scrapers have been found at many sites that do not contain Dalma Ware.

However, the Dalma Ware at Surezha is has some inconsistencies with itinerant practices for reasons regarding the observed community of practice. Though Surezha's Dalma type is largely distinct from its local wares, the Dalma Ware at Surezha are highly variable from sample to sample. As it is expected that an itinerant ceramicist or a group of itinerant ceramicists would produce ceramic wares that adhered to a singular, specialized community of practice, Dalma Ware's site variability does not fully align with this conjecture. A ceramic production facility connected to Dalma Ware is also yet to be recovered at Surezha, which puts an additional pause on the development of this theory of itinerant specialists.

In Theory: Dalma Ware as a Product of Individual or Community Displacement

Finally, the theory of individual or community displacement, namely that of exogamy, acting as the distributor of Dalma Ware at Surezha rests upon expectations regarding the majority, though not all, of the ceramic products having a local chemical signature and a production method which, like the chemical signature, may demonstrate both local and non-local customs. In theory, ceramic tradition as a product of exogamy relies on an individual being brought into a community as a knowledge bearer of their own community of practice. As time in the new community goes on, it may be expected that this is represented by their adaptations as learned by the local community, resulting in pottery which is made by a mixture of two communities of practice, as undoubtedly exhibited in the ceramics they produce. In measuring chemical signatures of a pottery type introduced by exogamy, it is expected that the non-local individual would bring with them a number of goods and objects, including perhaps pottery. Though the individual may continue to make pottery reminiscent of their own community, perhaps even passing it down generationally, it is expected that this pottery type would remain in the minority of the site's assemblage.

At Surezha, Dalma Ware is consistent with the fact that it is not in the majority, and it is similar yet not identical to other local wares' production attributes. Furthermore, there is some chemical variation within the Dalma assemblage at Surezha (Minc & Buehlman-Barbeau 2020), though more study needs to be done regarding the local signature in the region. However, Surezha's Dalma Ware, though found briefly in time, is found scattered throughout the site, apparently not concentrated in a single household or the like. More evidence from Surezha is needed for this claim to be properly assessed.

Summary of Dalma Ware at Surezha

The Dalma Ware at Surezha is made from local and non-local clays. It bears similarities to that of its on-site contemporaries, in both chemical and mineralogical attributes. However, it maintains a certain level of consistency with inclusion attributes and production execution when compared to Dalma Ware of Dalma Tepe. Furthermore, it is clear that the Dalma Ware at both Surezha and Dalma Tepe share a community of identity, as seen through the outward design of the Dalma style. Though Dalma Tepe's Dalma Wares are currently understood as being at least two to three hundred years older than those at Surezha, it is worth noting that the petrographic consistencies concerning community of practice echo Tonoike's (2009) own findings. This thesis suggests that the Dalma Ware at Dalma Tepe generally has moderately sized voids and a larger number of coarse inclusions, when compared to the Dalma Ware of Surezha, which has a moderate to large voids and finer grained inclusions; meanwhile, Tonoike suggests that the Dalma Ware of the Solduz Basin of NW Iran follow the same pattern of attributes, while those of the Central Zagros hold these listed consistencies with that of Surezha. Interestingly, these patterns may be suggestive as a variable of time rather than region, as Dalma Ware at Surezha in the Erbil Plain hold more similarities with its contemporaries in the Central Zagros, and the Dalma Ware at Dalma Tepe maintains its consistencies with its region and time.

When assessing the Dalma Ware at Surezha, then, it may be of immediate interest to explore its dispersal in relation to its contemporaries in the Central Zagros. Under the current understanding that Dalma Ware was absent from NW Iran since ca. 4500 BCE, interpretation of the type at Surezha may incorporate the distance from its contemporaries, and the implications which may follow. Under this study's conceptualization of Dalma Ware at Surezha, it has been found that there are considerable inconsistencies with the expectations under the theory of trade. The three remaining theories explored in this thesis likewise host varying levels of inconsistencies, but all warrant the need for further exploration following a fuller understanding of the site of Surezha, as well as the presence of Dalma Ware in the Erbil Plain and its periphery. From the expectations listed (*Table* 5.2), the data gathered in this study suggest that pastoralism is likely the most probable cause of Dalma's presence at Surezha; this is based largely on the observable ceramic technology and chemical signature of the samples, both of which variables bear the most weight in distinguishing a plausible agent of dispersal. Again, further research is required in efforts to fully evaluate the remaining theories of itinerant specialists and exogamy in order to truly comprehend Surezha's Dalma Ware.

This thesis focused on four major modes of dispersal in searching for that which was responsible for the known extent of Dalma's presence in the Erbil Plain. In characterizing these mechanisms by expectations of their material behaviors, this study offers a glimpse into the social and economic atmosphere of the Chalcolithic Near East. With the majority of the Dalma assemblage confined to the Central Zagros of Iran during the later half of the 5th millennium, as currently understood, its presence at Surezha suggests a knowledge of and connection between the people of the Central Zagros and Northern Mesopotamia. Though the closest Dalma-related site to Surezha, Yorgan (Nuzi) Tepe near the modern-day city of Kirkuk, is indeed closer than that of the Central Zagros, it is nevertheless compelling that Surezha's Dalma Ware shares much of the same compositional attributes with that of its Central neighbors (Henrickson & Vitali 1987; Tonoike 2009). This suggests a contemporary community of practice and identity which encompassed a broad region spanning various types of terrain, further instilling the inter-regional status and connectivity Surezha held in Northern Mesopotamia.

Limitations of Study

The limitations of this study stem largely from its sample selection. In future study, it would prove doubly useful to compare Dalma Ware to other pottery at the Dalma Tepe site, or in the general region. Further, additional survey and excavation is needed in Northern Mesopotamia in order to truly advance the theory surrounding Dalma's presence in the area. Moreover, this study was limited in its understanding of Dalma Ware in that it is very much a discussion of how the ceramic tradition changed over the span of at least 200 years, thus entering the potential for bias in assessing Dalma Ware's consistencies as a behavior and practice shared between two sites in absolute. However, this study nevertheless provided a much-needed insight into the Dalma tradition as it exists on the Erbil Plain, no matter the time period. It has been the consistent hope that the research done in this study may be used in future endeavors of forwarding the understanding of Dalma Ware in either region, until a time comes where a more thorough collection of data may prove adequate in speaking of Dalma Ware as a whole.

The Study of Dalma Ware Going Forward

Since its initial recovery at Dalma Tepe in 1958, scholars have been working to understand Dalma Ware as a cultural marker of identity in the Chalcolithic Near East. Previous research has suggested attributing the dispersal of Dalma Ware to that of pastoralism, as the ceramic type is found at numerous pastoral archaeological sites, such as Kul Tepe Jolfa, Dava Göz, and Godedzor (Abedi *et al.*, 2015; 2019). The kinship and economic ties pastoralists may hold with sedentary groups may further facilitate the high levels of Dalma spread as well. Pastoralism, in theory, would moreover create a community that would allow such an overall consistency in production and manufacture of Dalma ceramics while yet empowering this consistency to fluctuate, as if made on a household level, as familial or pastoral units may involve their own internalized take on a larger community of practice. However, under the current understanding of the Dalma timeline, theory now looks to identify the full story of Dalma community, as evidence suggests their leave from the Northwest Zagros by the mid-5th millennium (Abedi *et al.,* 2015). The study of Dalma Ware must now focus on its presence as a variable in both time and place, as the mechanism of its dispersal and production may be dependent on these such factors, an endeavor as taken on by Abedi in his ongoing exploration of this ceramic tradition (2015; 2019).

Exploration into the Dalma tradition may further our understanding of the Chalcolithic Near East, as mechanisms of movement tracked by the material artifacts, such as pottery, have the ability to lend discussion into the way ancient communities lived and interacted inter-regionally. This thesis provided a petrographic analysis of Dalma material culture as it exists in the Ushnu-Solduz Valley and Erbil Plain, and furthermore related this analysis to trace element data in order to refine the standing definition of Dalma Ware as it is currently understood. Dalma Ware's presence in Northern Mesopotamia offers a unique glimpse into the world as it was understood nearly seven thousand years ago by those who lived and interacted with people and individuals interconnected in knowledge, material, and tradition. This study explored theories of trade, pastoralism, itinerant specialists, and exogamy as agents of dispersal accountable for the presence of Dalma Ware at the site of Surezha. Further study is needed to expand on the understanding of this ceramic tradition west of the Zagros Mountains, as well as the specific comparison between the Dalma assemblage in Northern Mesopotamia and its contemporary Dalma neighbors in the Central Zagros, in order to assess production and manufacture within such community of practice during a set period in time.

This thesis is one of many concerning the theory and practice of the Chalcolithic Near East. As a small contribution to the larger scope of study concerning Mesopotamia and the regions surrounding, the ongoing study of Dalma Ware and its community of practitioners offers invaluable insight into the everyday connections and communications which bridge Northern Mesopotamia and beyond.

BIBLIOGRAPHY

Abdi, K. (1999). Archaeological Research in the Islamabad Plain, Central Western Zagros Mountains: Preliminary Results from the First Season, Summer 1998. *Iran*, 37(1), 33-43.

Abdi, K. (2003). The Early Development of Pastoralism in the Central Zagros Mountains. *Journal of World Prehistory*, *17*(4), 395-448.

Abedi, A. (2017). Iranian Azerbaijan Pathway from the Zagros to the Caucasus, Anatolia and Northern Mesopotamia: Dava Göz, A New Neolithic and Chalcolithic Site in NW Iran. *Mediterranean Archaeology & Archaeometry*, 17(1).

Abedi, A., Eskandari, N., Shahidi, H. K., Sharahi, I., & Shirzadeh, G. (2014). New Evidence from Dalma and Kura-Araxes Culture at Tapeh Qal 'e-ye-Sarsakhti. *Iran and the Caucasus*, *18*(2), 101-114.

Abedi, A., & Omrani, B. (2015). Kura-Araxes Culture and North-Western Iran: New Perspectives from Kul Tepe Jolfa (Hadishahr). *Paléorient*, 55-68.

Abedi, A., Omrani, B., & Karimifar, A. (2015). Fifth and Fourth Millennium BC in North-Western Iran: Dalma and Pisdeli Revisited. *Documenta Praehistorica*, *42*, 321-338.

Abedi, A., Varoutsikos, B., & Chataigner, C. (2018). Provenance of Obsidian Artifacts from the Chalcolithic Site of Dava Göz in NW Iran Using Portable XRF. *Journal of Archaeological Science: Reports*, *20*, 756-767.

عابدی, بهره مندی پورفرد, رعنا, گراوند, افراسیاب, ملک پور, & رازانی. (2019). منشأیابی ابزارهای ابسیدینی محوطه های پیش ازتاریخ دشت خوی براساس آنالیز فلورسانس اشعه ی ایکس (XRF). *پژوهش های باستان شناسی ایران*, *9*(21), 41-60. [in English]

Akkermans, P. M., Duistermaat, K. (1996). Of Storage and Nomads: The Sealings from Late Neolithic Sabi Abyad, Syria. *Paléorient*, 17-44.

Alavi, M. (1994). Tectonics of the Zagros Orogenic Belt of Iran: New Data and Interpretations. *Tectonophysics*, *229* (3-4), 211-238.

Alavi M. (2004) Regional Stratigraphy of the Zagros Fold-Thrust Belt of Iran and its Proforeland Evolution. *American Journal of Science* 304:1–20

Alden, J. R. (1988). Ceramic Ring Scrapers: An Uruk Period Pottery Production Tool. *Paléorient*, 143-150.

Alden, J. R., & Minc, L. (2016). Itinerant Potters and the Transmission of Ceramic Technologies and Styles During the Proto-Elamite Period in Iran. *Journal of Archaeological Science: Reports*, *7*, 863-876.

Algaze, G., Brenties, B., Knapp, A. B., Kohl, P. L., Kotter, W. R., Lamberg-Karlovsky, C. C., Schwartz, G.M., Weiss, H., Wenke, R.J., Wright, R.P., & Zagarell, A. (1989). The Uruk Expansion: Cross-Cultural Exchange in Early Mesopotamian Civilization. *Current Anthropology*, *30*(5), 571-608.

Algaze, G., Brentjes, B., Charvát, P., Cioffi-Revilla, C., Dittmann, R., Friedman, J., Ekholm Friedman K., Knapp A., Lamberg-Karlovsky C. C., McCorriston J., Nissen, H. J., Oates J., Stanish C., Wilkinson T. (2001). Initial Social Complexity in Southwestern Asia: The Mesopotamian Advantage. *Current Anthropology*, *42*(2), 199-233.

Alibaigi, S., Khosravi, S., & Aali, A. (2012). Early Villages and Prehistoric Sites in the Abharroud Basin, Northwest of the Iranian Central Plateau. *Documenta Praehistorica*, *39*, 459-472.

Alizadeh, A. (1988). Socio-Economic Complexity in Southwestern Iran During the Fifth and Fourth Millennia BC: The Evidence From Tall-i Bakun A. *Iran*, *26*(1), 17-34.

Alizadeh, A. A. (2004). Mobile Pastoralism and Prehistoric Exchange. *Persiens Antike Pracht. Bergbau, Handwerk, Archäologie*, 76-91.

Alizadeh, A., Alden, J. R., Danti, M. D., Garthwaite, G., & Alizadeh, A. (2010). The Rise of the Highland Elamite State in Southwestern Iran: "Enclosed" or Enclosing Nomadism? *Current Anthropology*, *51*(3), 353-383.

Alizadeh, K. and Azarnoush, M. (2003) Systematic Survey of Tepe Baruj: Sampling Method and Statistical Results (Barresi-ye Raveshmand-e Tappe-ye Baruj: Ravesh-e Numunebardari va Natayej-e Amari). *Iranian Journal of Archaeology and History* 33. pp. 4–25.

Al-Juboury, A. I., & Al-Miamary, F. A. (2009). Geochemical Variations in Heavy Minerals as Provenance Indications: Application to the Tigris River Sand, Northern Iraq. *Journal of Mediterranean Earth Sciences*, *1*, 33-45.

Al-Juboury, A. I., Ghazal, M. M., & Al-Naqib, S. Q. (2001). Development and Heavy Mineral Analysis of the Tigris River Terraces, Northern Iraq. *Dirasat, Al-Ulum Al-Asasiyyat [Dirasat, Pure Sciences]*, *28*, 245-259.

Al-Juboury A.I., Ismail S.A. and Ghazal M.M. (1999). Chromite Enrichment in the Recent Fluviatile Sediments, North Iraq. *Qatar University Science Journal* 18: 159-167.

Al-Juboury, A. I., & McCann, T. (2008). The Middle Miocene Fatha (Lower Fars) Formation, Iraq. *GeoArabia*, *13*(3), 141-174.

Al-Qayim B., Omer A., Koyi, H., Tectonostratigraphic Overview of the Zagros Suture Zone, Kurdistan Region, Northeast Iraq. *GeoArabia*; 17 (4): 109–156.

Altaweel, M., Marsh, A., Mühl, S., Nieuwenhuyse, O., Radner, K., Rasheed, K., & Saber, S. A. (2012). New Investigations in the Environment, History and Archaeology of the Iraqi Hilly Flanks. *Iraq*, 1-35.

Amanolahi-Baharvand, S. (1975). *The Baharvand, Former Pastoralists of Iran* (Doctoral Dissertation).

Ambrosiani, K. (1981). *Viking Age Combs, Comb Making and Comb Makers: In the Light of Finds from Birka and Ribe* (Doctoral Dissertation, University of Stockholm).

Arnold, D. E. (1981). A Model for the Identification of Non-Local Ceramic Distribution: A View from the Present. *Production and Distribution: A Ceramic Viewpoint*, *120*, 31-44.

Arnold, D. E. (1988). *Ceramic Theory and Cultural Process*. Cambridge University Press.

Ashby, S. P. (2015). 'With Staff in Hand, and Dog at Heel'? What Did it Mean to be an 'Itinerant' Artisan? *Everyday Products in The Middle Ages: Crafts, Consumption, and the Individual in Northern Europe C. AD 800-1600*, 11.

Awdal, A. H., Braathen, A., Wennberg, O. P., & Sherwani, G. H. (2013). The Characteristics of Fracture Networks in the Shiranish formation of the Bina Bawi Anticline; Comparison with the Taq Taq field, Zagros, Kurdistan, NE Iraq. *Petroleum Geoscience*, *19*(2), 139-155.

Bakhshaliyev, V. (2018). Archaeological Researches in the Settlement of Nakhchivan Tepe. *Amisos*, *3*(4), 40-66.

Barraclough, A. (1992). Quaternary Sediment Analysis: A Deductive Approach at A-level. *Teaching Geography*, *17*(1), 15-18.

Barth, F. (1961). *Nomads of South Persia. the Basseri Tribe of the Khamseh Confederacy*. Oslo University Press.

Basu, A., Young, S. W., Suttner, L. J., James, W. C., & Mack, G. H. (1975). Re-evaluation of the use of Undulatory Extinction and Polycrystallinity in Detrital Quartz for Provenance Interpretation. *Journal of Sedimentary Research*, *45*(4), 873-882.

Bea, F., Mazhari, A., Montero, P., Amini, S., & Ghalamghash, J. (2011). Zircon Dating, Sr And Nd Isotopes, and Element Geochemistry of the Khalifan Pluton, NW Iran: Evidence for Variscan Magmatism in a Supposedly Cimmerian Superterrane. *Journal of Asian Earth Sciences*, *40*(1), 172-179.

Beerbower, J. R. (1964). Cyclothems and Cyclic Depositional Mechanisms in Alluvial Plain Sedimentation. *Kansas Geological Survey Bulletin, 169*(1), 31-32.

Berberian, M., & King, G. (1981). Toward a Paleogeography and Tectonic Evolution of Iran. *Canadian Journal of Earth Sciences.* 18. 210-265.

Binandeh, A., Glascock, M. D., & Oga, A. (2020). Origin of Obsidian Tools from Ubaid and Rick Abad in Little Zab Basin, Northwestern Iran. *Journal of Archaeological Science: Reports*, *32*, 102395.

Blair, T. C., & McPherson, J. G. (1994). Alluvial Fans and their Natural Distinction From Rivers Based on Morphology, Hydraulic Processes, Sedimentary Processes, and Facies Assemblages. *Journal of Sedimentary Research, 64*(3a), 450-489.

Bobek, H. (1968). *History of Iran.* Cambridge University Press.

Bourdieu, P. (1990). *The Logic of Practice*. Stanford University Press.

Braidwood, R. J., Howe, B., & Reed, C. A. (1961). The Iranian Prehistoric Project: New Problems Arise as More is Learned of the First Attempts at Food Production and Settled Village Life. *Science*, 133 (3469), 2008-2010.

Bunte, K., & Abt, S. R. (2001). *Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel-and Cobble-bed Streams for Analyses in Sediment Transport,* *Hydraulics, and Streambed Monitoring*. US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Chang, C., & Koster, H. (1986). Beyond Bones: Toward an Archaeology of Pastoralism. *Advances in Archaeological Method and Theory*, *9*, 97-148.

Chataigner, C., Avetisyan, P., Palumbi, G., & Uerpmann, H. P. (2010). Godedzor, a Late Ubaid-Related Settlement in the Southern Caucasus. *Beyond the Ubaid: Transformation and Integration in the Late Prehistoric Societies of the Middle East*, 381-398.

Childe, V. G. (1957). The Bronze Age. *Past & Present*, (12), 2-15.

Costin, C. L. (1991). Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production. *Archaeological Method and Theory*, *3*, 1-56.

Dadaneh, M. Z., Ghasrian, S. M., Colantoni, C., & Skuldbøl, T. B. B. (2019). The Marivan Plain Archaeological Project: Western Iran and its Neighbours in the Chalcolithic Period. *Antiquity*, 93(372).

Danti, M. D. (2013). *Hasanlu V: The Late Bronze and Iron I Periods*. University of Pennsylvania Press.

Dietler, M., & Herbich, I. (1989). Tich Matek: The Technology of Luo Pottery Production and the Definition of Ceramic Style. *World Archaeology*, *21*(1), 148-164.

Dyson-Hudson, N. (1972). The Study of Nomads. *Journal of Asian and African Studies*, *7*(1-2), 2-29.

Dyson, R. H. (2003). Hasanlu Tepe. *Encyclopaedia Iranica.*

Dyson Jr., R.H., and Young Jr., T. C. (1960). The Solduz Valley, Iran: Pisdeli Tepe. *Antiquity* 34, 19-27.

Eckert, S. L., Schleher, K. L., & James, W. D. (2015). Communities of Identity, Communities of Practice: Understanding Santa Fe Black-on-White Pottery in the Española Basin of New Mexico. *Journal of Archaeological Science*, *63*, 1-12.

Eerkens, J. W. (2008). Nomadic Potters Relationships Between Ceramic Technologies and Mobility Strategies.

Esterhuysen, A. B. (2008). Ceramic Alliances: Pottery and the History of the Kekana Ndebele in the Old Transvaal. *Five Hundred Years Rediscovered: Southern African Precedents and Prospects*, *500*, 197-214.

Folk, Robert L. (1965). "Some Aspects of Recrystallization in Ancient Limestones", from *Dolomitization and Limestone Diagenesis*, Lloyd C. Pray, Raymond C. Murray.

Forest-Foucault, C. (1980). Rapport sur les Fouilles de Kheit Qasim III-Hamrin. *Paléorient*, 221-224.

Ghlamghash, J., Vosoughi Abedini, M., & Pourmafi, M. (2008). Geochemistry and Petrology of Co-Existing I-and S-Type Granitoids in Oshnavieh Area, NW of Iran. *Geosciences*, *17*(1).

Gibbs, K. (2012). Not Meant to Last: Mobility and Disposable Pottery. *Documenta Praehistorica*, *39*, 83-94.

Gilbert, A. S. (1983). On the Origins of Specialized Nomadic Pastoralism in Western Iran. *World Archaeology*, *15*(1), 105-119.

Glascock, M. D. (1992). Characterization of Archaeological Ceramics at MURR by Neutron Activation Analysis and Multivariate Statistics. *Chemical Characterization of Ceramic Pastes in Archaeology*, *7*, 11e26.

Gosselain, O. P. (1992). Technology and Style: Potters and Pottery Among Bafia of Cameroon. *Man*, 559-586.

Grillo, K. M. (2014). Pastoralism and Pottery Use: An Ethnoarchaeological Study in Samburu, Kenya. *African Archaeological Review*, *31*(2), 105-130.

Hajialioghli, R., & Moazzen, M. (2014). Supra-Subduction and Mid-Ocean Ridge Peridotites from the Piranshahr Area, NW Iran. *Journal of Geodynamics*, *81*, 41-55.

Hamlin, C. (1975). Dalma Tepe. *Iran*, *13*(1), 111-127.

Hammer, E. (2019). The City and Landscape of Ur: An Aerial, Satellite, and Ground Reassessment. *Iraq*, *81*, 173-206.

Haron, N. A. (2018). Sphericity and Shape Analysis for Grain Scale Organization at Sungai Hulu Langat. *Available at SSRN 3269704*.

Hegmon, M. (1998). Technology, Style, and Social Practices: Archaeological Approaches. *The Archaeology of Social Boundaries*, 264-279.

Henrickson, E. (1985). An Updated Chronology of the Early and Middle Chalcolithic of the Central Zagros Highlands, Western Iran. *Iran,* 23, 63-108.

Henrickson, E. F., & Vitali, V. (1987). The Dalma Tradition: Prehistoric Inter-Regional Cultural Integration in Highland Western Iran. *Paléorient*, 37-45.

Hole, F. (1987). Settlement and Society in the Village Period. *The Archaeology of Western Iran: Settlement and Society from Prehistory to the Islamic Conquest*, 79-106.

Huber, H., and Eftekhar-Nezhad, J. (1978). *Geological Map of Iran Sheet No. 1 North-West Iran, 1:1,000,000.* Tehran. N.C.C. Offset Press.

Jasim, S. A. (1983). Excavations at Tell Abada: A Preliminary Report. *Iraq*, *45*(2), 165-185.

Jassim S.Z., Hagopian D.H. and Al-Hashimi H.A.J. (1986). *Geological Map of Iraq (1:1,000,000).* Baghdad: Geological Survey and Mineral Investigation.

Jeffra, C. D. (2015). Experimental Approaches to Archaeological Ceramics: Unifying Disparate Methodologies With the *Chaîne Opératoire*. *Archaeological and Anthropological Sciences*, *7*(1), 141-149.

Jones T.R., Kang I.H., Wheeler D.B., Lindquist R.A., Papallo A., Sabatini D.M., Golland P., Carpenter A.E. (2008). Cellprofiler Analyst: Data Exploration and Analysis Software for Complex Image-Based Screens. *Bmc Bioinformatics* 9(1):482

Khalidi, L., Gratuze, B., Stein, G., McMahon, A., Al-Quntar, S., Carter, R., Cuttler R., Drechsler P., Healey E., Inizan M.L., Mouralis D., Pernicka E., & Robin A.K. (2016). The Growth of Early Social Networks: New Geochemical Results of Obsidian from the Ubaid to Chalcolithic Period in Syria, Iraq and the Gulf. *Journal of Archaeological Science: Reports*, *9*, 743-757.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.

Lechtman, H. (1984). Andean Value Systems and the Development of Prehistoric Metallurgy. *Technology and Culture*, *25*(1), 1-36.

Lechtman, H., & Merrill, R. S. (Eds.). (1977). *Material Culture: Styles, Organization, and Dynamics of Technology*. West Publishing Company.

Leroyer, C., Joannin, S., Aoustin, D., Ali, A. A., Peyron, O., Ollivier, V., Petros, T., Karakhanyan A., & Jude, F. (2016). Mid Holocene Vegetation Reconstruction from

Vanevan Peat (South-Eastern Shore of Lake Sevan, Armenia). *Quaternary International*, *395*, 5-18.

Levine, L. D., & McDonald, M. M. (1977). The Neolithic and Chalcolithic Periods in the Mahidasht. *Iran*, 15(1), 39-50.

MacEachern, S. (1998). Scale, Style, and Cultural Variation: Technological Traditions in the Northern Mandara Mountains. *The Archaeology of Social Boundaries*, 107-131.

Marro, C., Bakhshaliyev, V., Berthon, R., & Thomalsky, J. (2019). New Light on the Late Prehistory of the South Caucasus: Data from the Recent Excavation Campaigns at Kültepe I in Nakhchivan, Azerbaijan (2012-2018). *Paléorient*, *45*(1), 81-113.

Mason, R. B., & Cooper, L. (1999). Grog, Petrology, and Early Transcaucasians at Godin Tepe. *Iran*, 37(1), 25-31.

Matthew, A. J., Woods, A. J., & Oliver, C. (1991). Spots Before the Eyes: New Comparison Charts for Visual Percentage Estimation in Archaeological Material. *Recent Developments in Ceramic Petrology*, *81*, 211-263.

Mazhari, S. A., Amini, S., Ghalamghash, J., & Bea, F. (2011a). Petrogenesis of Granitic Unit of Naqadeh Complex, Sanandaj–Sirjan Zone, NW Iran. *Arabian Journal of Geosciences, 4*(1-2), 59-67.

Mazhari, S. A., Amini, S., Ghalamghash, J., & Bea, F. (2011b). The Origin of Mafic Rocks in the Naqadeh Intrusive Complex, Sanandaj-Sirjan Zone, NW Iran. *Arabian Journal of Geosciences, 4*(7-8), 1207-1214.

McCarthy, P. J., Martini, I. P., & Leckie, D. A. (1998). Use of Micromorphology for Palaeoenvironmental Interpretation of Complex Alluvial Palaeosols: An Example from the Mill Creek Formation (Albian), Southwestern Alberta, Canada. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *143*(1-3), 87-110.

Messager, E., Nomade, S., Wilhelm, B., Joannin, S., Scao, V., Von Grafenstein, U., Martkoplishvili I., Ollivier V., Mgeladze A., Dumoulin J.P., Mazuy A., Belmecheri S., & Lordkipanidze D. (2017). New Pollen Evidence from Nariani (Georgia) for Delayed Postglacial Forest Expansion in the South Caucasus. *Quaternary Research*, *87*(1), 121.

Minc, L. (2008) Neutron Activation Analysis. In *Encyclopedia of Archaeology*, Vol. 3, edited by Deborah M. Pearsall, pp. 1660-1683.

Minc, L., Alden J.R., & Stein G. (2019). A Preliminary Assessment of Ceramic Style and Chemical Composition During the Chalcolithic Era at Surezha, Iraqi Kurdistan. *Paléorient*, 42 (2):121-136.

Minc, L. & Buehlman-Barbeau, S. (2020). "Assessing Compositional Variation in Ubaid and LC Ceramics from Surezha, Kurdistan: An Update". (Forthcoming)

Miyashiro, A. (1994). *Metamorphic Petrology*. Crc Press.

Motarjem, A., & Sharifi, M. (2014). Cultural Development of Chalcolithic Era in the East of Central Zagros Based on Archaeological Excavations at Tepe Gheshlagh. *Iranian Journal of Archaeological Studies*, 4(1), 49-65.

Nadooshan, F. K., Abedi, A., Glascock, M. D., Eskandari, N., & Khazaee, M. (2013). Provenance of Prehistoric Obsidian Artefacts from Kul Tepe, Northwestern Iran Using X-Ray Fluorescence (XRF) Analysis. *Journal of Archaeological Science*, *40*(4), 1956-1965.

Nesse, W. D. (1991). Introduction to Optical Mineralogy. Oxford University Press.

Niknami, K. A., Amirkhiz, A. C., & Glascock, M. D. (2010). Provenance Studies of Chalcolithic Obsidian Artefacts from Near Lake Urmia, Northwestern Iran Using WDXRF Analysis. *Archaeometry*, *52*(1), 19-30.

Nobari, A. H., Binnandeh, A., Neyestani, J., & Nasab, H. V. (2012). Excavation at Lavin Tepe in Northwest Iran. *Ancient Near Eastern Studies*, 49, 95-117.

Núñez, M. (1990). On Subneolithic Pottery and its Adoption in Late Mesolithic Finland. *Fennoscandia Archaeologica*, *7*, 27-52.

Núñez, M. G. (1989). More on Finland's Settling Model. *Fennoscandia Archaeologica*, *6*, 90-98.

Oveisi, B., Lavé, J., Van Der Beek, P., Carcaillet, J., Benedetti, L., & Aubourg, C. (2009). Thick- and Thin-Skinned Deformation Rates in the Central Zagros Simple Folded Zone (Iran) Indicated by Displacement of Geomorphic Surfaces. *Geophysical Journal International*, *176*(2), 627-654.

Perkins, D. (1998). Mineralogy. *In the Beginning*, *17*(17), 38.

Quinn, P. S. (2013). Ceramic Petrography. *The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section: Oxford, Archaeopress*.

Ramón, Gabriel. (2011). The Swallow Potters: Seasonally Migratory Styles in the Andes. *Archaeological Ceramics: A Review of Current Research.* 160-175.

Reif, D., Grasemann, B., & Faber, R. H. (2011). Quantitative Structural Analysis Using Remote Sensing Data: Kurdistan, Northeast Iraq. *AAPG Bulletin*, *95*(6), 941-956.

Rice, P. M. (2015). *Pottery Analysis: A Sourcebook*. University of Chicago Press.

Rowlands, M. J. (1971). The Archaeological Interpretation of Prehistoric Metalworking. *World Archaeology*, *3*(2), 210-224.

Sackett, J. R. (1977). The Meaning of Style in Archaeology: A General Model. *American Antiquity*, *42*(3), 369-380.

Saed, M. A., Zamani, D. M., Ghasemi, M., & Karimi, Z. (2017). Stratigraphy at Tepe Namashir of the Baneh: *Western Iran*.

Sayers, R. (1987) *The Korean Onggi Potter*. Smithsonian Folklife Studies, No. 5. Smithsonian Institution Press, Washington, D. C.

Schlütz, F., & Lehmkuhl, F. (2009). Holocene Climatic Change and the Nomadic Anthropocene in Eastern Tibet: Palynological and Geomorphological Results from the Nianbaoyeze Mountains. *Quaternary Science Reviews*, *28*(15-16), 1449-1471.

Shepard, A. O. (1956). *Ceramics for the Archaeologist.* Carnegie Institution of Washington.

Solecki, R. L. (1973). Tepe Seavan, a Dalma Period site in the Margavar Valley, Azerbaijan, Iran. *Bulletin of the Asia Institute* 3, 1973, pp. 98-117.

Sorkhani, R. R., & Eslami, M. (2018). Specialized Pottery Production in Dalma Tradition; a Statistical Approach in Pottery Analysis from Soha Chay Tepe, Zanjan, Iran. *Journal of Archaeological Science*: *Reports*, 17, 220-234.

Spooner, B. (1973). *The Cultural Ecology of Pastoral Nomads* (No. 45). Addison Wesley Publishing Company.

Stein, G. J. (2002). From Passive Periphery to Active Agents: Emerging Perspectives in the Archaeology of Interregional Interaction. *American Anthropologist*, *104*(3), 903-916.

Stein, G. J. (2012a). The Development of Indigenous Social Complexity in Late Chalcolithic Upper Mesopotamia in the 5th–4th Millennia BC—An Initial Assessment. *Origini*, *34*, 125-151.

Stein, G.J. (2012b). Food Preparation, Social Context, and Ethnicity in a Prehistoric Mesopotamian Colony. *The Menial Art of Cooking: Archaeological Studies of Cooking and Food Preparation*, 47-63.

Stein, G. J. (2017). Excavations at Surezha. *Erbil Plain, Kurdistan Region, Iraq. Oriental Institute Annual Report*, *2018*, 29-43.

Stein, G. & Alizadeh, A. (2014). Surezha, Kurdistan. *Oriental Institute Annual Report 2012-2013.* Chicago, University of Chicago Oriental Institute Publications. Oriental Institute Annual Report 2013-2014. 133-146.

Stein, G. J. & Fisher M.T. (2018). Surezha Excavations 2018. *Erbil Plain, Kurdistan Region, Iraq. Oriental Institute Annual Report*, *2018-2019*, 125-138.

Stein, G. J. & Özbal, R. (2007). A Tale of Two *Oikumenai*: Variation in the Expansionary Dynamics Of ‘Ubaid And Uruk Mesopotamia. In E. C. Stone (Ed.), *Settlement and Society: Ecology, Urbanism, Trade and Technology in Mesopotamia and Beyond* (pp. 356 - 370). Cotsen Institute of Archaeology.

Stoltman, J. B. (2001). The Role of Petrography in the Study of Archaeological Ceramics. In *Earth Sciences and Archaeology* (pp. 297-326). Springer, Boston, Ma.

Tonoike, Y. (2014). Petrographic Analysis of the 6th Millennium BC Dalma Ceramics from Northwestern and Central Zagros. *Iranian Journal of Archaeological Studies, 2(2), 65-82*.

Tonoike, Y. (2009). *Beyond Style: Petrographic Analysis of Dalma Ceramics in Two Regions of Iran*. Yale University.

Ur, Jason A. (2007). Early Mesopotamian Urbanism: A New View from the North. *Antiquity* 81(313): 585-600.

Ur, J. A., Karsgaard, P., & Oates, J. (2011). The Spatial Dimensions of Early Mesopotamian Urbanism: The Tell Brak Suburban Survey, 2003-2006. *Iraq*.

Ur, J., De Jong, L., Giraud, J., Osborne, J. F., & MacGinnis, J. (2013). Ancient Cities and Landscapes in the Kurdistan Region of Iraq: The Erbil Plain Archaeological Survey 2012 Season. *Iraq*, 75, 89-117.

Vandiver, P. (1987). Sequential Slab Construction; A Conservative Southwest Asiatic Ceramic Tradition, ca. 7000-3000 B.C. *Paléorient*, 13(2), 9-35.

Van Zeist, W. (1967). Late Quaternary Vegetation History of Western Iran. *Review Of Palaeobotany And Palynology*, 2(1-4), 301-311.

Van Zeist, W., & Bottema, S. (1977). Palynological Investigations in Western Iran. *Palaeohistoria*, 19-85.

Voigt, M. M. (1983). *Hasanlu, Volume I: Hajji Firuz Tepe, Iran--the Neolithic Settlement* (Vol. 1). U-Penn Museum of Archaeology.

Waters, M. R. (1992). *Principles of Geoarchaeology: A North American Perspective*. University of Arizona Press.

Wenger, E. C., & Snyder, W. M. (2000). Communities of Practice: The Organizational Frontier. *Harvard Business Review*, *78*(1), 139-146.

Wentworth, C. K. (1922). A Scale of Grade and Class Terms for Clastic Sediments. The Journal of Geology, 30(5), 377-392.

Wilkinson, T. J., Bintliff, J., Curvers, H. H., Halstead, P., Kohl, P. L., Liverani, M., McCorriston, J., Oates, J., Schwartz G.M., Thuesen I., Weiss H., & Courty M.A. (1994). The Structure and Dynamics of Dry-Farming States in Upper Mesopotamia. *Current Anthropology*, *35*(5), 483-520.

Yacoub, S. Y., Othman, A. A., & Kadhim, T. H. (2012). Geomorphology of the Low Folded Zone. *Iraqi Bulletin of Geology and Mining*, (5), 7-37.

Young Jr., T. C. (1962). Taking the History of the Hasanlu Area Back Another Five Thousand Years: Sixth-and Fifth Millennium Settlements in Solduz Valley, Persia. *Illustrated London News* 241 (6431), 3 November 1962, pp. 707--09.

Young Jr., T. C. (1966). Survey in Western Iran, 1961. *Journal of Near Eastern Studies*, *25*(4), 228-239.

Zainy, M., Al-Ansari, N., Bauer, T., & Ask, M. (2017). The Tectonic and Structural Classifications of the Western Part of the Zagros Fold and Thrust Belt, North Iraq, Review and Discussion. *Journal of Earth Sciences and Geotechnical Engineering*, *7*(2), 71-89.

Zeynivand, M., Hariryan, H., & Heydarian, M. (2013). The Dalma Settlements of Songhor and Koliyaei Plains, Central Zagros. *Iranian Journal of Archaeological Studies*, *3*(1), 39-47.

APPENDIX A

Known Dalma Extent: Archaeological Sites

Table A.1: Archaeological sites with Dalma Ware (as of 2020; not exhaustive.)

Site	Region	Date (General)	Source
Nakhchivan Tepe	Nakhchivan Autonomous Republic	Early 5th Millennium BCE	Bakhshliyev (2018)
Qosha Tepe	Nakhchivan Autonomous Republic	Early 5th Millennium BCE	Abedi (2017)
Uçan Ağıl	Nakhchivan Autonomous Republic	Early 5th Millennium BCE	Bakhshaliyev (2018)
Uzun Oba	Nakhchivan Autonomous Republic	Early 5th Millennium BCE	Bakhshaliyev (2018)
Godedzor	Syunik Province (Armenia)	Early 5th Millennium BCE	Chataigner *et al.,* (2010)
Dalma Tepe	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Hamlin (1975)
Dava Göz	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Abedi (2017)
Haiji Firuz	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Voigt (1983)
Lavin Tepe	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Nobari (2012)
Pisdeli Tepe	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Dyson & Cuyler Young Jr. (1960)
Silveh	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Binandeh (2020)
Tepe Hasanlu	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Dyson (2003); Abedi *et al.,* (2015)
Tepe Sivan (Seavan)	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Solecki (1973)
Tepe Ubaid	West Azerbaijan Province (Iran)	Early 5th Millennium BCE	Binandeh (2020)
Baruj Tepe	East Azerbaijan Province (Iran)	Early 5th Millennium BCE	Alizadeh (2003)
Kul Tepe Jolfa	East Azerbaijan Province (Iran)	Early 5th Millennium BCE	Abedi (2015)
Idir Tepe	Ardabil Province (Iran)	*Mid 5th Millennium BCE ?*	Abedi (2017)
Kamyaran	Kurdistan Province (Iran)	*Mid 5th Millennium BCE ?*	Zeynivand *et al.,* (2013)
Karvansara	Kurdistan Province (Iran)	*Mid 5th Millennium BCE ?*	Alibaigi (2012)
Marivan Plain	Kurdistan Province (Iran)	*Mid 5th Millennium BCE ?*	Dadaneh *et al.,* (2019)
Tepe Gheshlagh	Kurdistan Province (Iran)	*Mid 5th Millennium BCE ?*	Motarjem (2014)
Tepe Namashir	Kurdistan Province (Iran)	*Mid 5th Millennium BCE ?*	Saed *et al.,* (2017)
Soha Chay	Zanjan Province (Iran)	*Mid 5th Millennium BCE ?*	Sorkhani & Eslami (2018)
Tepe Nour	Zanjan Province (Iran)	*Mid 5th Millennium BCE ?*	Alibaigi (2012)
Assadabad	Hamadan Province (Iran)	Late 5th Millennium BCE	Young Jr. (1966); Tonoike (2009)
Godin Tepe	Hamadan Province (Iran)	Late 5th Millennium BCE	Hamlin (1975)
Nehavand Valley Survey	Hamadan Province (Iran)	Late 5th Millennium BCE	Young Jr. (1966)
Seh Gabi	Hamadan Province (Iran)	Late 5th Millennium BCE	Levine & McDonald (1977)
Tepe Giyan	Hamadan Province (Iran)	Late 5th Millennium BCE	Levine & McDonald (1977)
Chogha Gavaneh	Kermanshah Province (Iran)	Late 5th Millennium BCE	Abdi (1999)
Chogha Maran	Kermanshah Province (Iran)	Late 5th Millennium BCE	Henrickson (1985)
Kangavar Valley Survey	Kermanshah Province (Iran)	Late 5th Millennium BCE	Young Jr. (1966)
Sahneh Survey	Kermanshah Province (Iran)	Late 5th Millennium BCE	Young Jr. (1966)
Sar Firouz Abad	Kermanshah Province (Iran)	Late 5th Millennium BCE	Zeynivand *et al.,* (2013)
Siahbid	Kermanshah Province (Iran)	Late 5th Millennium BCE	Henrickson (1985)
Songhor Plains	Kermanshah Province (Iran)	Late 5th Millennium BCE	Zeynivand *et al.,* (2013)
Baba Qassem	Luristan Province (Iran)	Late 5th Millennium BCE	Mason & Cooper (1999); Young (1966)
Tepe Qal'e-ye-Sarakhti	Luristan Province (Iran)	Late 5th Millennium BCE	Abedi (2014)
Kheit Qasim	Diyala Governorate	Late 5th Millennium BCE	Forest-Foucault (1980)
Tell Abada	Diyala Governorate	Late 5th Millennium BCE	Jasim (1983)
Surezha	Erbil Plain (Iraqi Kurdistan)	Late 5th Millennium BCE	Stein (2017); Stein & Fisher (2018)
Yorgan (Nuzi) Tepe	Kirkuk Governoate (Iraqi Kurdistan)	Late 5th Millennium BCE	Henrickson (1985)

APPENDIX B

Paste Analysis: Munsell Color

Table B.1: Munsell color from a clean break of each ceramic sample.

SAMPLE ID	SITE	TYPE	MATRIX MUNSELL COLOR
DT6020504a	Dalma Tepe	Dalma Painted	7.5 YR 7/4: pink
DT6020530	Dalma Tepe	Dalma Painted	5 YR 5/6: yellowish red
DT6020531	Dalma Tepe	Dalma Painted	10 YR 6/6: brownish yellow
DT6020532	Dalma Tepe	Dalma Painted	5 YR 6/6: reddish yellow
DT6020536	Dalma Tepe	Dalma Painted	7.5 YR 6/6: reddish yellow
DT6020538	Dalma Tepe	Dalma Painted	5 YR 6/6: reddish yellow
DT6020544	Dalma Tepe	Dalma Painted	10 YR 7/4: very pale brown
DT6020550	Dalma Tepe	Dalma Painted	7.5 YR 5/4: brown
DT6020585	Dalma Tepe	Dalma Painted	7.5 YR 6/6: reddish yellow
DT6020608	Dalma Tepe	Dalma Painted	5 YR 6/8: reddish yellow
DT6020625	Dalma Tepe	Dalma Painted	5 YR 6/8: reddish yellow
DT6020640	Dalma Tepe	Dalma Painted	7.5 YR 5/4: brown
DT6020665	Dalma Tepe	Dalma Painted	7.5 YR 6/6: reddish yellow
DT6020703	Dalma Tepe	Dalma Impressed	5 YR 6/8: reddish yellow
DT6020705	Dalma Tepe	Dalma Impressed	7.5 YR 6/4: light brown
DT6020709	Dalma Tepe	Dalma Impressed	5 YR 3/1: very dark grey
DT6020716	Dalma Tepe	Dalma Impressed	10 YR 7/4: very pale brown
DT6020717	Dalma Tepe	Dalma Impressed	5 YR 6/8: reddish yellow
DT6020719	Dalma Tepe	Dalma Impressed	7.5 YR 6/6: reddish yellow
DT6020720	Dalma Tepe	Dalma Impressed	7.5 YR 6/4: light brown
DT6020723	Dalma Tepe	Dalma Impressed	7.5 YR 6/6: reddish yellow
DT6020724	Dalma Tepe	Dalma Impressed	7.5 YR 6/2: pinkish grey
DT6020725	Dalma Tepe	Dalma Impressed	10 YR 6/6: brownish yellow
DT6020726	Dalma Tepe	Dalma Impressed	7.5 YR 6/6: reddish yellow
DT6020727	Dalma Tepe	Dalma Impressed	7.5 YR 4/0: dark grey
DT6020728	Dalma Tepe	Dalma Impressed	7.5 YR 6/6: reddish yellow
DT6020729	Dalma Tepe	Dalma Impressed	7.5 YR 6/6: reddish yellow
DT6020731	Dalma Tepe	Dalma Impressed	7.5 YR 6/4: light brown
DT6020732	Dalma Tepe	Dalma Impressed	10 YR 6/4: light yellowish brown
DT6020734	Dalma Tepe	Dalma Impressed	7.5 YR 7/4: pink
DT6020737	Dalma Tepe	Dalma Impressed	7.5 YR 5/6: strong brown
DT6020739	Dalma Tepe	Dalma Impressed	5 YR 2.5/1: black
DT6127117	Dalma Tepe	Dalma Painted	2.5 Y 7/4: pale yellow
DT6127314	Dalma Tepe	Dalma Impressed	10 YR 6/4: light yellowish brown
DT6127315	Dalma Tepe	Dalma Impressed	10 YR 6/3: pale brown
DT6127316	Dalma Tepe	Dalma Impressed	10 YR 6/4: light yellowish brown
DT6127322	Dalma Tepe	Dalma Impressed	10 YR 6/4: light yellowish brown
DT6127327	Dalma Tepe	Dalma Impressed	10 YR 6/4: light yellowish brown

Table B.1: Munsell color from a clean break of each ceramic sample (continued).

SAMPLE ID	SITE	TYPE	MATRIX MUNSELL COLOR
SR3267	Surezha	Fine Paste Buff	2.5 Y 7/4 (pale yellow)
SR3268	Surezha	Fine Paste Buff	2.5 Y 7/4 (pale yellow)
SR3269	Surezha	Fine Paste Buff	10 YR 7/4 (very pale brown)
SR3270	Surezha	Fine Paste Buff	2.5 Y 7/4 (pale yellow)
SR3271	Surezha	Fine Paste Buff	5 Y 8/3 (pale yellow)
SR3272	Surezha	Chaff Tempered Buff	10 YR 7/4 (very pale brown)
SR3273	Surezha	Fine Paste Buff	10 YR 6/4 (light yellowish brown)
SR3274	Surezha	Fine Paste Buff	5 Y 8/3 (pale yellow)
SR3275	Surezha	Fine Paste Buff	10 YR 5/6 (yellowish brown)
SR3276	Surezha	Fine Paste Buff	10 YR 4/3 (brown)
SR3277	Surezha	Fine Paste Buff	10YR 7/4 (very pale brown)
SR3278	Surezha	Fine Paste Buff	10 YR 7/3 (very pale brown)
SR3279	Surezha	Chaff Tempered Buff	2.5 Y 6/4 (olive yellow)
SR3280	Surezha	Chaff Tempered Buff	10 YR 7/4 (very pale brown)
SR3281	Surezha	Grit Tempered Buff	10 YR 4/6 (dark yellowish brown)
SR3282	Surezha	Chaff Tempered Buff	10 YR 6/4 (light yellowish brown)
SR3283	Surezha	Chaff Tempered Buff	5 YR 6/4 (light reddish brown)
SR3284	Surezha	Chaff Tempered Buff	10 YR 6/4 (light yellowish brown)
SR3286	Surezha	Chaff Tempered Buff	10 YR 8/3 (very pale brown)
SR3287	Surezha	Chaff Tempered Buff	10 YR 5/3 (brown)
SR3288	Surezha	Fine Paste Buff	7.5 YR 8/4 (pink)
SR3289	Surezha	Grit Tempered Buff	7.5 YR 4/6 (strong brown)
SR3290	Surezha	Chaff Tempered Buff	10 YR 7/4 (very pale brown)
SR3291	Surezha	Grit Tempered Buff	10 YR 5/2 (greyish brown)
SR3292	Surezha	Fine Paste Buff	2.5 Y 7/4 (pale yellow)
SR3292	Surezha	Fine Paste Buff	5 Y 7/3 (pale yellow)
SR3293	Surezha	Chaff Tempered Buff	10 YR 6/6 (brownish yellow)
SR3294	Surezha	Fine Paste Buff	5 Y 8/3 (pale yellow)
SR6011a	Surezha	Waster	5 Y 8/3 (pale yellow)
SR6704a	Surezha	Waster	5 Y 8/3 (pale yellow)
SR7102.a	Surezha	Waster	5 Y 6/3 (pale olive)
SR6188a	Surezha	Waster	5 Y 7/3 (pale yellow)
SR6031a	Surezha	Waster	5 Y 7/3 (pale yellow)
SR6368c	Surezha	Waster	2.5 Y 7/4 (pale yellow)
SR6420a	Surezha	Waster	5 Y 8/3 (pale yellow)
SR6524.a	Surezha	Waster	2.5 Y 7/2 (light grey)

Table B.1: Munsell color from a clean break of each ceramic sample (continued).

SAMPLE ID	SITE	TYPE	MATRIX MUNSELL COLOR
SR6117.a	Surezha	Dalma Impressed	10 YR 7/3 (very pale brown)
SR6156.a	Surezha	Dalma Impressed	10 YR 6/3 (pale brown)
SR6156.b	Surezha	Dalma Impressed	10 YR 7/3 (very pale brown)
SR6156.c	Surezha	Dalma Impressed	10 YR 6/2 (light brownish grey)
SR6156.d	Surezha	Dalma Impressed	2.5 YR 7/4 (yellow)
SR6156.e	Surezha	Dalma Impressed	10 YR 7/4 (very pale brown)
SR6156.f	Surezha	Dalma Impressed	10 YR 6/3 (pale brown)
SR6156.g	Surezha	Dalma Impressed	10 YR 7/2 (light grey)
SR6194.a	Surezha	Dalma Impressed	10 YR 6/4 (light yellowish brown)
SR6194.b	Surezha	Dalma Impressed	2.5 Y 5.2 (greyish brown)
SR6194.c	Surezha	Dalma Impressed	10 YR 7/3 (very pale brown)
SR6194.d	Surezha	Dalma Impressed	10 YR 6/2 (light brownish grey)
SR6281.a	Surezha	Dalma Impressed	10 YR 7/3 (very pale brown)
SR6293.1	Surezha	Dalma Impressed	10 YR 7/2 (light grey)
SR6293.a	Surezha	Dalma Impressed	10 YR 7/4 (very pale brown)
SR6570.a	Surezha	Dalma Impressed	10 YR 6/4 (light yellowish brown)
SR9635	Surezha	Dalma Painted	5 YR 6/4 (light reddish brown)
SR9636	Surezha	Dalma Painted	7.5 YR 6/4 (reddish yellow)
SR9637	Surezha	Dalma Painted	10 YR 7/3 (very pale brown)
SR9638	Surezha	Dalma Painted	7.5 YR 5/6 (strong brown)
SR9639	Surezha	Dalma Painted	10 YR 5/4 (yellowish brown)
SR9640	Surezha	Dalma Painted	10 YR 6/4 (light yellowish brown)
SR9641	Surezha	Dalma Painted	10 YR 6/3 (pale brown)
SR9642	Surezha	Dalma Painted	7.5 YR 7/2 (pinkish grey)
SR9643	Surezha	Dalma Painted	10 YR 6/3 (pale brown)
SR9644	Surezha	Dalma Painted	10 YR 5/3 (brown)
SR9645	Surezha	Dalma Painted	10 YR 6/2 (light brownish grey)
SR9646	Surezha	Dalma Impressed	10 YR 6/3 (pale brown)
SR9647	Surezha	Dalma Impressed	7.5 YR 6/6 (reddish yellow)
SR9648	Surezha	Dalma Impressed	10 YR 5/4 (yellowish brown)
SR9649	Surezha	Dalma Impressed	10 YR 6/4 (light yellowish brown)
SR9650	Surezha	Dalma Impressed	10 YR 7/4 (very pale brown)

APPENDIX C
CellProfiler Analysis

CellProfiler Guide and Study Analysis.

CellProfiler is an open-source digital image analysis software designed to analyze microscopic images. This analysis can involve the measurement of the shape, compactness, intensity, and angularity of objects in a given image, and can reportedly analyze millions of images at a time. For the purposes of this study, CellProfiler (version 3.1.9) was used to quantify and measure mineral inclusions and voids in a given petrographic thin section. In this analysis, CellProfiler assessed four images at the same location on a petrographic slide with varying types of light (PPL or XPL) and angles of extinction (30, 60, or 90 degrees; this ensures that all minerals are captured for analysis in lieu of losing them to angles of extinction). This allows the program to properly analyze the presence of voids and inclusions in a specific space on the thin section, a space which totals to roughly three-millimeters under a polarizing microscope magnification of 40x. Measurements taken through CellProfiler were then converted from pixels to millimeters, which were converted into the Wentworth scale to account for the further analysis of mineral inclusions in a given ceramic sample as illustrated in the thin section.

CellProfiler has a vast array of analytical tools to build and customize a pipeline to fit a set of data and per research question. What follows is a step by step guide to how I analyzed my own dataset for the purposes of this study.

Building a Pipeline

Building a pipeline in CellProfiler ensures that the set of four images are properly analyzed. The parameters listed below allow the pipeline to access the given image data. To begin, images to be analyzed are uploaded into the box provided in the "**Images**" tab. The images will be listed upon its success. It is important that the images are appropriately and uniformly named, as this is crucial in allowing the program to properly recognize them as data. 34 image groups were analyzed for this study, with four images per group to total 136 images. The four images per group represented a single view of each petrographic slide under PPL and XPL. Named accordingly, here "XY1234" is the image/slide ID, "40x" represents the power of magnification in which the picture was taken, and "ppl", "xpl1-3" indicates the light and/or angle the picture was taken with, respectively:

<u>Image 1 of 4:</u> *Petrographic Slide XY1234 under PPL*: XY1234_40x_ppl.jpg

<u>Image 2 of 4:</u> *Petrographic Slide XY1234 under XPL (angle = 30)*: XY1234_40x_xpl1.tif

<u>Image 3 of 4:</u> *Petrographic Slide XY1234 under XPL (angle = 60)*: XY1234_40x_xpl2.tif

<u>Image 4 of 4:</u> *Petrographic Slide XY1234 under XPL (angle = 90)*: XY1234_40x_xpl3.tif

Once CellProfiler has confirmed a uniformity in the image names as loaded into the pipeline, the program must then recognize them. Under "**Metadata**", a drop-down menu allows the pipeline to specify how it should identify the data. The steps are detailed as follows:

1. Selecting "yes" allows the metadata to be extracted.
2. The extraction method should "Extract from file/folder names".
3. The metadata source is the "file name".
4. CellProfiler may automatically equip the researcher with a regular expression to extract the file from. However, I have found that their expression does not always recognize the file, resulting in an error. I have found the following code to be sufficient:

```
[A-Z]{2}[0-9]{0,7}[a-z]{0,1}_[0-9]{2,3}x_[a-z]{3}[1-3]{0,1}\.tif
```

Next, the researcher must select to extract the metadata from "images matching a rule", to match "all" of the following rules: "File does contain regular expression". The researcher must type “_ppl” to follow, and add three more extraction methods to match, though with “_xpl1”, “_xpl2”, and “_xpl3” in each respective case.

The researcher should select the metadata data type “Text” and press to update at the bottom of the module.

Under “**NamesAndTypes**”, the researcher must choose what to temporarily name the images. This is used to group all the ‘ppl’ and ‘_xpl1-3’ images into similar groups so the pipeline can be written to process multiple images of similar types at once. The researcher should assign a name to “Images matching rules”, and match all the following rules: Select the rule criteria to “File does contain regular expression”, and, like the previous step, enter four total matching cases of these rules to account for “_ppl”, “_xpl1”, “_xpl2”, and _xpl3”. In addition, as prompted, the researcher should assign a temporary name to each _ppl and _xpl file. I have chosen “Temp_ppl”, “Temp_xpl1”, “Temp_xpl2”, “Temp_xpl3” accordingly.

For this particular study, color images were chosen as the image type, with the intensity range from the image metadata. Finally, following four sets of this input, the researcher should choose the image set matching method to “Order”, and press update. All _ppl images should appear under a column labeled “Temp_ppl”, and three more columns should appear designating the _xpl1-3 images into columns of “Temp_xpl1-3”.

The “Groups” section is used primarily used for subsets of data that need to process independently. For this analysis, it does not apply.

Customizing A Pipeline

After the researcher has successfully updated the Images, Metadata, NamesAndTypes, and Groups modules, the pipeline is ready to be customized. The following section lists the steps

I made in order to build a pipeline that measures the size and shape of the petrographic inclusions.

1. Color to Gray

The Temp_ppl image is set to grayscale in order to "simplify" the image into clear classes of matrix (background) and inclusions (forefront). This step is repeated for Temp_xpl1, Temp_xpl2, and Temp_xpl3 images.

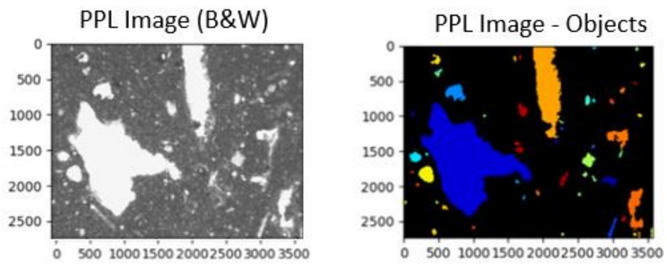
2. Align

Aligning the images is crucial for further steps involving inclusion measurement. By selecting the mutual information method, the aligned region with the grayscale _ppl image as the first output, and the grayscale _xpl1, _xpl2, and _xpl3 images as additional output images, all four images are subsequently aligned.

3. Identify Primary Objects

This step identifies all of the light (near white) objects in your 'Aligned_ppl' image from Module 2 (*Fig. C.1*). These light objects signify your inclusions and voids. Though every ceramic assemblage may vary, this study used the Global Otsu method to record the inclusions, with two threshold classes to distinguish between matrix and inclusions. Because ceramic analysis is primarily concerned with the grains ranging in size upward of the silt range, this study limited the objects to be recognized by CellProfiler to a minimum diameter of 40 pixels (ca. 0.03 mm).

Fig. C.1: Identifying Primary Objects from Image



4. Convert Objects to Image

In order to process Module 3's identified objects of LightObjects_ppl, the researcher must translate them into an image for further analysis.

5. Identify Primary Objects

This step identifies all of the light (near white) pixels in the Aligned_xpl1 image from Module 4. These light objects signify the inclusions present under cross polarized light (at 30 degrees).

6. Convert Object to Image

In order to process Module 5's identified objects of LightObjects_xpl1, the researcher must translate them into an image for further analysis.

7. Identify Primary Objects

This step identifies all of the light (near white) pixels in the 'aligned_xpl2' image from Module 6. These light objects signify the inclusions present under cross polarized light (at 60 degrees).

8. Convert Objects to Image

In order to process Module 7's identified objects of LightObjects_xpl2, the researcher must translate them into an image for further analysis.

9. Identify Primary Objects

This step identifies all of the light (near white) pixels in your 'aligned _xpl3' image from Module 8. These light objects signify the inclusions present under cross polarized light (at 90 degrees).

10. Convert Objects to Image

In order to process these identified objects of LightObjects_xpl3, the researcher must translate them into an image for further analysis.

11. Image Math

Next, the researcher must create an image that will identify the light objects--all of the mineral inclusions--in all three _xpl images. To do so, the researcher must follow the module to "add" images from modules 6, 8, 10 together. This will show all of the identified light objects on one image. As voids are not visible (bright) under cross polarized light, this step effectively identifies all of the mineral inclusions alone.

12. Identify Primary Objects

From the image produced in module 11, the researcher must identify the light objects as primary objects in order to analyze them later on.

13. Convert Objects to Image

This step converts the identified objects from module 12 into an image.

14. Edit Objects Manually*

In my experience, CellProfiler has a hard time identifying the mafic minerals in an image because of their habit of appearing not quite as dark as the matrix, or as light as the felsic minerals. Though this could be remedied through use of thresholding, I have chosen to add the objects in the image that the program failed to recognize. This is done by manually tracing the shape of the object from the chosen image and adding them to the original image produced in module 23. Details as follows.

First, the researcher must load the image to be edited. There is the option to overlaying this image on a guiding image; the researcher may choose the Grayscale _ppl (from module 1) or the original _ppl image (Temp_ppl) in order to see what inclusions the program failed to identify in module 12. CellProfiler then allows the researcher to delete, draw, or otherwise edit the identified objects (inclusions).

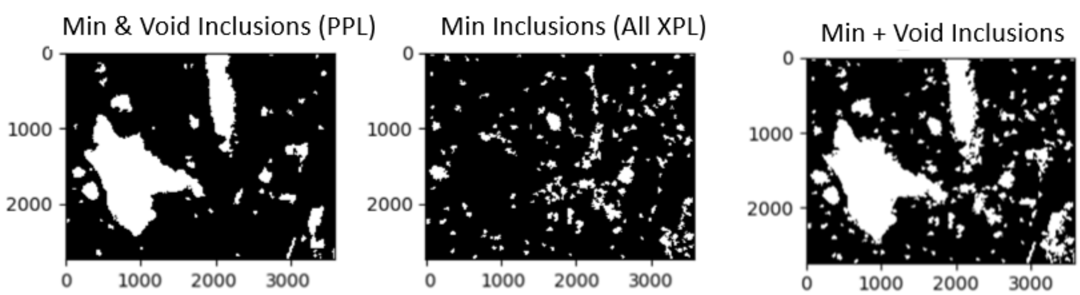
**To increase the ease and precision of tracing the needed inclusions, a drawing tablet was purchased for the purpose of this study.*

15. Convert Objects to Image

This step converts the manually added objects to an image.

16. Image Math

Fig. C.2: Image Math Example: Addition[a]



a) Addition of the void inclusions in PPL (far left) and the mineral inclusions in XPL (middle), to result in an image illustrating all of the inclusions in the given sample.

Next, the researcher must add the objects of module 14 to the rest of the identified light objects found in the _ppl image (module 4; *Fig. C.2*). This will be used later to identify voids.

17. Identify Primary Objects

After the pipeline processes the addition of module 16, the researcher must identify them all as objects.

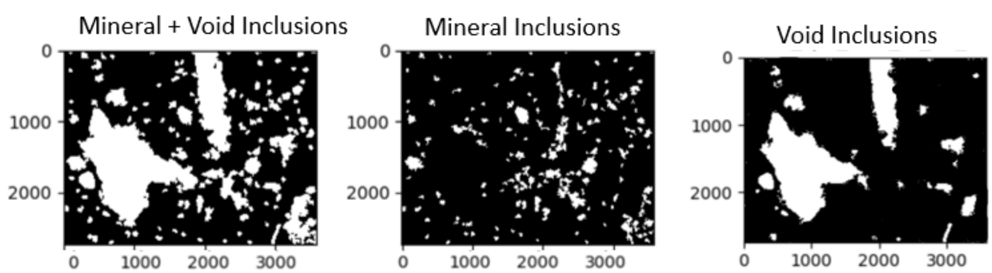
18. Convert Objects to Image

This step converts module 17's redefined objects into an image.

19. Image Math

Now, the researcher must calculate the voids present in the image (*Fig. C.3*). Because voids will be present in PPL but not all of the cross polarized images, the researcher should take the image created in module 15 (representing all of mineral inclusions) and subtract it from the image in module 18, which illustrates all of the light objects (mineral and void inclusions). The subtraction will result in the areas that are bright under PPL but not XPL, that is, the voids.

Fig. C.3: Image Math Example: Subtraction[a]



a) Subtracting the mineral inclusion (middle) from the mineral and void image (left), resulting in an image of only the voids (right).

20. Identify Primary Objects

This step identifies the voids from module 19 as objects.

21. Convert Objects to Image

This step converts module 20's objects to an image.

22. Measure Object Size Shape

This step measures the objects identified in module 17 (all mineral inclusions) and the objects in module 21 (voids) accordingly.

23. Export to Spreadsheet

Finally, the researcher must export all measurements to a spreadsheet. This step requires the researcher to choose exactly what measurements to report.

Converting Pixels to Millimeters

CellProfiler reports its findings in pixel measurements. For these measurements to be effective for the purposes of this study, I used a microscopic slide that displayed millimeter units to measure the pixels in one millimeter. Per the equipment used in this study, 1325 pixels is equal to 1 millimeter. This measurement was then used to convert the measured inclusions (size reported under Major Axis Length) to the Wentworth scale, where:

1.) Silt = 0.004 - 0.062 mm

2.) Very Fine Sand = 0.062 - 0.125 mm

3.) Fine Sand = 0.125 - 0.25 mm

4.) Medium Sand = 0.25 - 0.5 mm

5.) Coarse Sand = 0.5 - 1 mm

6.) Very Coarse Sand = 1 - 2 mm.

In Addition: Void Measure

Because the organic inclusions (voids) in this ceramic assemblage were oftentimes too large to see fully under the microscope, the thin sections were set upon a light table and photographed in full to get a more accurate measure. These images were 3008 x 2000 pixels each, with one millimeter equal to about 137 pixels. The photographs were subjected to a simplified version of a CellProfiler pipeline. This included sending one photo per sample through the pipeline as follows:

1. **Color to Gray**

   This step aids the software in identifying a light object (inclusion) in contrast to the background matrix.

2. **Identify Primary Objects**

   This step identified all voids more than 20 pixels (ca. 0.15 mm) using a Global, robust background.

3. **Edit Objects Manually**

   This is used as a failsafe to the previous step, where the researcher can manually draw, delete, or edit Module 2's identification.

4. **Convert Objects to Image**

   This step converts the objects edited in Module 3 to an image.

5. **Measure Object Size Shape**

   This step measures the objects in Module 4's image.

6. **Export to Spreadsheet**

Lastly, the researcher must choose the measurements needed for analysis to be exported to a spreadsheet.

It is after these steps where the researcher can then properly assess and classify the inclusions within a given petrographic sample.

CellProfiler is downloadable at www.cellprofiler.org.