Reconstructing diet and pottery technology of the Early Bronze Age ‘Kura-Araxes Culture’: a multi-analytical approach

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Doctor of Philosophy

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Abstract

The Kura-Araxes (KA) cultural phenomenon, dated to the Early Bronze Age (EBA, 4th and 3rd millennium, c. 3500-2500 BCE) is primarily characterised by the emergence of a homogeneous 'material culture package' in settlements across the South Caucasus (Georgia, Armenia, and Azerbaijan), as well as territories extending to the Levant and Ancient Near East. More specifically, one of the major EBA craft products associated with the KA corresponds to a homogeneous style of black-burnished pottery in the South Caucasus, known as *Early Transcaucasian Ware* and other synonymous terms in the literature.

An interdisciplinary approach is conducted on a wide selection of ceramic samples representing the KA culture, in order to reconstruct pottery technology, direct evidence of pottery use, and dietary practices. Archaeological sites and potsherd samples selected span eight coeval KA settlements across Armenia: Gegharot, Karnut-1, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs. The analysis of KA pottery is carried out using an integrated multi-analytical approach to contribute to our understanding of cultural attributes, through (1) *chaîne opératoire*, (2) pottery use and dietary inferences. Stereomicroscopy, thin-section petrography, and scanning electron microscopy-energy dispersive x-ray analysis (SEM-EDS) are employed in order to reconstruct pottery fabric pastes and the transmission of technology across coeval KA settlements. Additionally, absorbed lipid residues from pottery are analysed using gas chromatography mass spectrometry (GC-MS) and gas chromatography-compound-isotope-ratio mass spectrometry (GC-C-IRMS), to determine the organic products produced, consumed and to reconstruct pottery function and subsistence practices.

Results from petrographic analyses suggest a local household industry production, spanning diverse technological procedures in raw materials and manufacturing at each settlement (i.e., the use of volcanic ash, grog and igneous rock fragments). Results from organic residue analysis provide compelling evidence for a diversified diet across settlements, comprising plant processing, dairying, animal carcass fats and aquatic commodities. The remarkable preservation of diagnostic plant lipid biomarkers, notably long-chain fatty acids (C_{20} to C_{28}) and *n*-alkanes (C_{23} to C_{33}) in organic residues from sites in Armenia has enabled identification of the earliest processing of plants in ceramic vessels of the region. These findings expand our current interpretation regarding the nature and fabric of the prescribed EBA Kura-Araxes communities residing in Armenia, South Caucasus. It is hoped that, in the future, new evidence in pottery analyses framed with archaeological evidence will increase our current understanding of the Kura-Araxes cultural phenomenon and the overall socio-economic structure of EBA communities.

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First and foremost, I would like to thank my supervisors Prof. Mark Pollard and Dr. Chris Doherty, for their guidance, mentorship and kindness. I am deeply indebted to Prof. Mark Pollard for always having the time to discuss ongoing ideas and interpretations regarding this project.

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The Earth Sciences Department (Oxford) was extremely helpful throughout this period of time, in particular Jonathan Wells and Owen Green, who provided me with facility access and equipment to undertake thin-section preparation and analyses. The exposure to various scientific fields allowed me to examine archaeological materials from a multi-disciplinary angle. I am also thankful to Dr. Mona Edwards and Dr. Hong Zhang for the access to the Geography Department microscopes and facilities.

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Statement of COVID-19 Disruption

This D.Phil thesis was written over the course of the COVID-19 pandemic in 2020. Upon completing all laboratory work for organic residue analyses (in March 2020), the plan was to conduct additional work on selected potsherd samples for SEM-EDS work in Trinity Term 2020. However, due to the closure of labs and time constraints, this is a future research task. Additional thin-sections will be produced, in the Earth Sciences Department (Oxford), as this work was funded by Gerald Averay Wainwright Fund. These results will provide additional data for the overall research paper on the technology and analyses of Kura-Araxes pottery across Armenia.

Additional samples of charred plants were selected from Margahovit for radiocarbon dating. One of the dates is included in this thesis and published in Gevorgyan *et al*., (2021), funded by FLAME. Additional funding (NERC) was received to expand the sample size (eight samples). However, results were provided in March 2021 and will be processed and written-up as a paper on the chronology of Margahovit.

List of Abbreviations

AMS	Accelerator mass spectrometry
APAA	*ω*-(o-alkylphenyl) alkanoic acid
BCE	Before Common Era
BP	Before present
BSTFA	*N,O*-bis(trimethylsilyl)trifluoroacetamide
C	Carbon
$C_{x:y}$	Fatty acid with carbon chain length X and number of double bonds Y
$\delta^{13}C$	Ratio of the stable isotopes of carbon ($^{13}C/^{12}C$)
$\Delta^{13}C$	$\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$
C_3	Plants that fix 3-carbon compounds
C_4	Plants that fix 4-carbon compounds
CO_2	Carbon dioxide
Cal	Calibrated
CE	Common Era
DAG	Diacylglycerols
DCM	Dichloromethane
DHA	Docosahexanoic acid ($C_{22:6}$ n-3)
DHYA	Dihydroxy acid
EBA	Early Bronze Age
EPA	Eicosapentaenoic acid ($C_{20:5}$ n-3)
ETC	Early Transcaucasian Culture
FAME	Fatty acid methyl ester
FID	Flame ionisation detector
GC	Gas chromatography
GC-MS	Gas chromatography/mass spectrometry
GC-C-IRMS	Gas chromatography/combustion/isotope ratio mass spectrometry
IFA	Isoprenoid fatty acid
IR	Isotope ratio
IS	Internal standard
KA	Kura-Araxes Culture
LBA	Late Bronze Age
MAG	Monoacylglycerol
MBA	Middle Bronze Age
NISP	Number of identified species
MeOH	Methanol
MNI	Minimum number of individuals
MS	Mass spectrometry
ND	Below detection limit
NISP	Number of identified specimens
ORA	Organic residue analysis
PPL	Plane polarised light
PUFA	Polyunsaturated fatty acid
SEM-EDS	Scanning electron microscopy-energy dispersive spectrometry
SIM	Selected ion monitoring
TAG	Triacylglycerol
TLE	Total lipid extract
TMS	Trimethylsilyl
TMTD	4,8,12-Trimethyltridecanoic acid

VPDB	Vienna Pee Dee Belemnite
‰	Per mill, parts per thousand
XP	Cross polarised light

List of Archaeological Site Codes

SH	Shengavit
G	Gegharot
MG	Margahovit
KRT	Karnut-1
T	Talin Tombs
SK	Sotk-2
NB	Norabak-1
MB	Mokhra-Blur

CHAPTER 1

Introduction – Archaeological Background and the 'Kura-Araxes' Culture

1.1 Archaeological research in the South Caucasus and its context

The South Caucasus has long been a pivot for cultural interaction between Europe, Eurasia and the Ancient East (Smith, 2005; Sagona, 2018). This region comprises modern territories including Armenia, Georgia, Azerbaijan, and other autonomous zones. During the 1950s and 1970s, Soviet archaeologists embarked on numerous excavations across this region exploiting the possibilities of archaeological science and integrated analytical techniques, such as metallography, material analyses, etc., in the development of Caucasus archaeological research (Bulkin *et al.*, 1982). Most of the archaeological research during this period was relatively unknown to Western scholars due to language barriers and prolonged political unrest between the borders of the Southern Caucasus (Bulkin *et al.*, 1982: 272; Smith, 2005).

B. A. Kuftin and Henry Field (1946) labelled a remarkable Bronze Age homogeneous cultural horizon, called the Kura-Araxes cultural tradition in the late 1930s and early 1940s (Kuftin, 1946; Kohl, 2007; Burney and Lang, 1971: 44). Kuftin and Field (1946) described the ceramic materials associated with this culture as stylistically homogeneous, found in between the Kura and Araxes river basins of South Caucasus, denoting its name (Figure 1.1). Furthermore, Burney and Lang (1971: 44) described the pottery assemblage as a homogeneous pottery tradition. The Kura-Araxes (KA) cultural phenomenon, roughly dated to ca. 3500-2500 BC (Badalyan, 2014; Manning *et al.*, 2018; Passerini *et al.*, 2016), has long been recognised as one of the most extensive examples of cultural expansion and transmission in the Bronze Age (Batiuk, 2013). As such, its archaeological importance to the field is profound.

Situated in a vast mountainous zone, Armenia is relatively understudied and underexplored, both archaeologically and anthropologically. In the past decade, archaeological research grew in this region (Lindsay and Smith, 2006). Given the mounting interest in this region, international scientists are now exploring the archaeological record comprising Palaeolithic, Neolithic, Chalcolithic, Bronze, and Iron Age periods. The region of Armenia has provided scholars with salient opportunities in examining prehistoric assemblages and settlements in relation to neighbouring cultures of the Eurasian steppes and the Ancient Near East. For instance, scholars excavating at Areni-1, a Chalcolithic 4th millennium BC dwelling, have unearthed remarkably well-preserved evidence of the oldest shoe and wineries (Areshian *et al.*, 2012). As such, the archaeological importance of this region, and its interconnections with neighbouring contexts, are imperative to note in understanding the socio-economic world of prehistoric cultures.

Regarding the Bronze Age, the Kura-Araxes culture and its predominant material, pottery, are investigated in this thesis. Essentially, the main goal is to provide a holistic view of craft production and culinary practices of the Kura-Araxes culture. As Sagona (2014: 24) states, "the greater Caucasus cannot be understood in isolation. We owe much of the current re-assessment to nuanced sequences, a growing body of scientific data and the ever-increasing quantity of reliable radiocarbon evidence." Much of the investigations in the Caucasus focused on the interconnections and situating the context with Near Eastern archaeology and, more recently, Eurasian and Eastern European civilisations (Smith *et al.*, 2012). Towards this goal, as archaeologists, we still have not grasped a holistic view of the social, economic and cultural developments of the Kura-Araxes communities of the South Caucasus and the overall wider cultural context. However, due to recent international collaborations and research into the region over the past few decades, our understanding of this cultural phenomenon has increased.

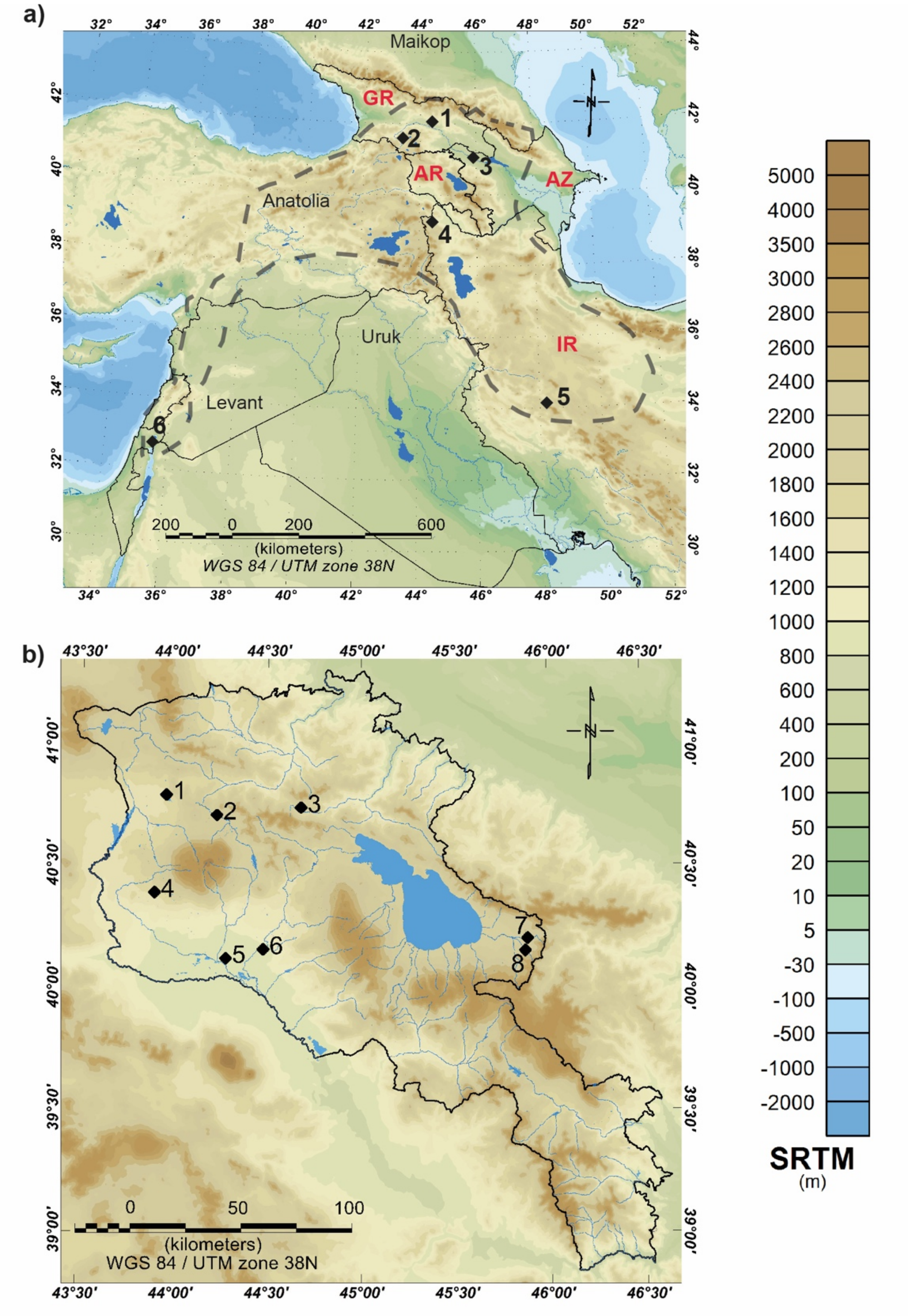


Figure 1. 1. (a) Topographic map of the Caucasus and Ancient Near East displaying the extent of the Kura-Araxes cultural phenomenon in dashed lines, approximated (AR is Armenia, GR is Georgia, AZ is Azerbaijan and IR is Iran), representing sites mentioned in text (1) Natsargora and (2) Chobareti in Georgia, (3) Mentesh Tepe in Azerbaijan, (4) Köhneh Shahar and (5) Godin Tepe in Iran and (6) Beth Shean in Israel. (b) Topographic map of Armenia, including rivers and one of the major freshwater lakes in the region, Lake Sevan. Sites: (1) Karnut-1, (2) Gegharot, (3) Margahovit (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1. These settlements are distanced between 17

and 176 km, where Shengavit and Mokhra-Blur are 17 km apart. Settlements are roughly 50-80 km apart. Maps modified using Adobe Illustrator. Maps produced by L. Manoukian using Oasis Montaj Software (www.seequent.com); SRTM 1, Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global.

1.2 Geological framework of the South Caucasus

The Caucasus isthmus is situated in between the contrastive worlds of the steppes and the Ancient Near East, lying between the Black Sea and the Caspian Sea (Figure 1.1a). The South Caucasus region is largely defined by its mountainous ranges, diverse climatic conditions, and natural resources, which provide the essential 'toolkit' for prehistoric societies to settle, develop and build urban centres (Kushnareva, 1997). Some of the rich deposits include ores and obsidian outcrops (Karapetian *et al.*, 2001). The landscape of the South Caucasus underwent ecological, environmental, and geological transformations during the Holocene and clearly defined topographical features within the region (Figure 1.1). The Armenian highlands were formed by the collision of the Arabian and Eurasian continental plates during the Neogene, part of the Alpine-Himalayan mountainous belt (Volodicheva, 2002; Galoyan *et al.*, 2009). The chain of the Lesser Caucasus and plateaus that border it to the south are regions that are strongly seismic and volcanic (Chataigner, 2016), where the Caucasus is famous for its large earthquakes as one of the most seismically active regions in the world (Korzhenkov *et al.*, 2014: 46). The significant portion of this region is mountainous, characteristic of the Caucasus (Kushnareva, 1997). Armenia consists of mountain ranges with altitudes between 2000 and 2800 m above sea level in the west and 2500 and 3300 m above sea level in the east (Pinhasi *et al.*, 2011). The tallest peaks include Mount Ararat (5156 m) in eastern Anatolia, and Mount Aragats (4090 m) in central Armenia (Karakhanian *et al.*, 2002).

This region's mountainous landscape and elevations define the formation of the overall landscape, environment and climatic features. The vast heterogeneous landscape of Armenia, such as the physical-geographic conditions, played a major role in the formation of the earliest cultures of the Caucasus (Kushnareva, 1997). Occupation of KA settlements range between

500 and 2200 masl in altitude (Haroutunian, 2016). A detailed overview of the geology of Armenia is discussed in Chapter 3 – Section 3.1.3 (see Figure 3.3 for the geological map of Armenia).

1.3 Chronology of the study region

The chronological framework of the South Caucasus is largely based on typology of artefacts and prehistoric cultures residing in the region (Figure 1.2). This section will discuss the Chalcolithic through Bronze Ages, covering pre-KA and post-KA.

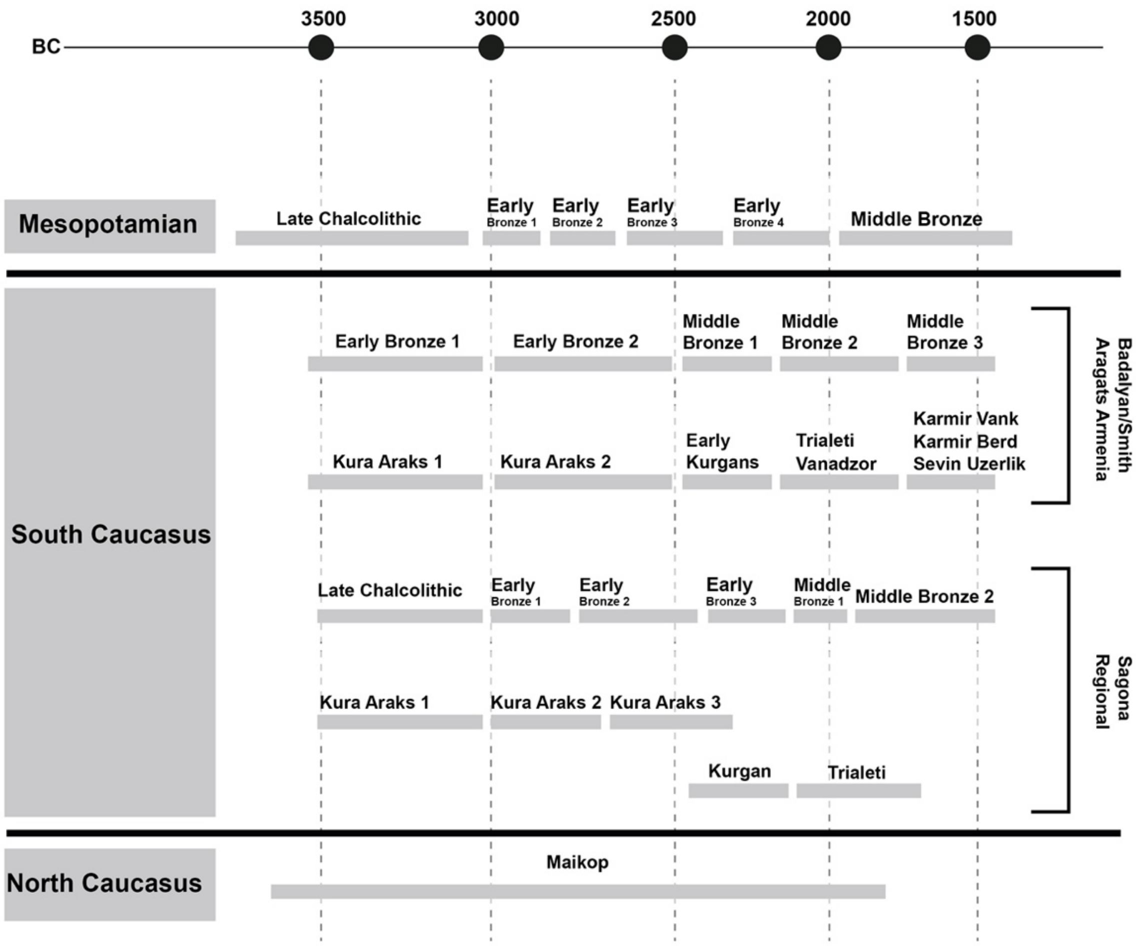


Figure 1. 2. Synoptic chronological table of archaeological periods and cultural phases relevant to the Kura-Araxes Culture of southern Caucasus in relation to neighbouring regions devised by Ruben Badalyan, Adam T. Smith and Antonio Sagona. Adapted from Palumbi and Chataigner (2014: 248).

1.3.1 Chalcolithic

Prior to the Kura-Araxes culture, the Chalcolithic period (c. 4,800 – 3,400 cal BC) is marked by diverse pottery, lithic industries, metallurgy and bead technology (Gasparyan and Arimura, 2014). Settlements of the Chalcolithic tend to be semi-nomadic and semi-sedentary, with temporary occupations in caves and shelters (i.e., the archaeological site of Areni-1 in Armenia) (Areshian *et al.*, 2012; Lyonnet, 2008; McGovern *et al.*, 2017). Other major archaeological sites include Teghut, Aknashen and Aratashen in Armenia (Badalyan *et al.*, 2004); Sioni in central Georgia; Kyul Tepe I in Nakhichevan; Alikemek tepesi in the Mughan steppe; Chalagan-depe and Leila-depe in Azerbaijan (Marro *et al.*, 2014). Pottery technology is mainly associated with chaff- and grit-temper, parallel to the ceramic traditions across the Ancient Near East. However, according to Badalyan *et al.*, (2010), organic-tempered ceramics emerged during the Neolithic period, and decreased in quantity at the end of the Chalcolithic period. Significantly, Halaf ceramics from the Near East appear in the archaeological record at a few Caucasian and eastern Anatolian sites, such as Godedzor in Armenia suggesting contact and interaction (Avetisyan and Bobokhyan, 2012).

Significantly, Marro *et al.*, (2014) studied a late Chalcolithic settlement in Nakhichevan called Ovçular Tepesi. They concluded that the presence of buff/black-coloured chaff-faced wares provides evidence of a Kura-Araxes occupation layer, implying to push the date of the KA phenomenon to the last quarter of the 5th millennium BCE. This has been debated quite extensively, as further chronometric analyses are required to provide a strict periodisation of the earliest date of the KA and the end of the Chalcolithic. The time stretching between 5000 and 4500 BC is poorly documented in the archaeological record (Palumbi, 2015: 5).

The end of the Chalcolithic period marks a ‘grey’ phase and a shift in the quantitative increase of metal artefacts in arsenical copper, specialised subsistence and craft production (Lyonnet, 2007; Courcier, 2014). There is evidence of salt mining at Duzdagi in Nakhichevan

(Marro, 2010), which marks an increase in raw material extraction techniques towards the Bronze Age. In terms of developments in metallurgy, there is evidence of slags, prills and crucibles at Mentesh Tepe and Leila Tepe in Azerbaijan and at Areni-1 in Armenia regarding copper-smelting advancements (Courcier, 2014; Bobokhyan *et al.*, 2014). Areni-1 in Armenia has been described as one of the most important multi-layer archaeological sites of the region (Areshian *et al.*, 2012). The final phase of the Chalcolithic (4,300-3,400 cal BCE) is marked by the presence of dated perishable organic materials (archaeobotanical remains, textile and basketry, leather, bone and wooden artefacts). This site also dates well into the EBA, attested by the presence of Kura-Araxes-style pottery. Furthermore, other continuity of sites and occupations include Godedzor in Armenia, Ovçular Tepesi in Nakhichevan, Soyuq Bulaq in Azerbaijan, and Berikldeebi in Georgia (Figure 1.1a) (Chataigner *et al.*, 2010; Palumbi and Chataigner, 2014). Palumbi (2015: 6) states that technological advancement in metalwork and long-distance trade could have been the cause for the development of elites in Southern Caucasian communities, which is quite similar to the social structure of Northern Caucasian cultures (i.e., Maikop) (Kohl, 2007).

1.3.2 Early Bronze Age (EBA)

The 4th and 3rd millennium BCE (c. 3500-2500 BCE) corresponds to the Early Bronze Age and is characterised by the Kura-Araxes (KA) Cultural Phenomenon, a homogenous pottery complex, defined by its surface finishing techniques and style, specifically black-burnished. This period was marked by cultural interplay and hybridity (Schwartz *et al.*, 2009; Sagona, 2014), as new technological traditions emerged (Smith *et al.*, 2009), including architectural and metallurgical traditions, funerary customs, and settlements primarily in mountainous zones.

In terms of craft production, the increase in a homogenous pottery style is significant, as well as other material industries, such as metal workshops at the site of Shengavit in Armenia (Simonyan and Rothman, 2015) (Figure 1.1b). Palumbi (2015: 9) claims that we do not understand the social lives of the producers/consumers of the EBA Kura-Araxes ceramic industry. Recently, social inequality has been documented at the Kura-Araxes settlement of Köhneh Shahar in north-western Iran, due to an increase in craft production (Alizadeh *et al.*, 2018); however, overall and comparatively, the structure of these communities is rather unknown and most likely heterarchical (non-hierarchical) (Alizadeh *et al.*, 2018).

There are complex issues in synthesising regional chronologies according to Smith (2012: 676), Marro and Hauptmann (2000) and Rubinson and Sagona (2008). The date and location of the initial appearance of this cultural phenomenon is under debate (Smith, 2012), especially when considering the presence of KA ceramics at Areni-1 (Areshian *et al.*, 2012) and Ovçular Tepesi in Nakhichevan (Marro *et al.*, 2014). There are over hundreds of Kura-Araxes sites recorded in Armenia (Haroutunian, 2016). Chronometric dates are currently under investigation at various archaeological sites to address pre-KA and post-KA levels (Manning et al., 2018; Passerini *et al.*, 2016; Gevorgyan *et al.*, 2021). Prior to 1990, only four radiocarbon dates had been published for the EBA, two from Shengavit and two from Mokhra-Blur (Lindsay, 2006: 85). In terms of neighbouring sites with KA occupation levels, Summers (2014: 159) states that radiocarbon dates from Yanik Tepe (northwestern Iran; Figure 1.1) are so few in number and have such large margins of error. In terms of relative dating, Badalyan (2014) has postulated a chronology based on ceramics, style and design. He labels two Kura-Araxes periods: KA I (c. 3600/3500-2900 BCE) and KA II (c. 2900-2600/2500 BCE).

Near the end of the Early Bronze Age, KA villages were abandoned (Greene, 2013: 60). It is postulated that climate and environmental episodes dictated the abandonment of ephemeral sites, as discussed in section 1.4. Archaeological sites post-EBA seem to be populated with the replacement of culturally distinct groups featured as “early Kurgan” material culture, specifically at the end of the Kura-Araxes cultural phenomenon (Smith, 2012). This area of research requires more synthesis and analytical research to understand transformations that took place at the end of the EBA.

1.3.3 Middle to Late Bronze Ages (MBA to LBA)

The Middle Bronze Age spans ca. 2400-1500 BCE and is normally described as the *Dark Age* (Greene, 2013: 61), and settlements are recognised by the appearance of *kurgans*. Kurgans are large mound structures that are prevalent across the Caucasus region (Smith, 2012). The MBA corresponds to the transition from agropastoral life to mobile pastoralist lifeways, social inequality and militarism (Oganesian, 1992; Smith, 2012: 679; Greene, 2013; Nugent, 2019). Smith (2012) describes this period as "the time of fragmentation and fission." Settlements include Uzerlik-Tepe in western Azerbaijan, Kul Tepe II in Nakhichevan, and Metsamor in Armenia, along with other ephemeral occupations. According to Kohl and Trifonov (2014), the MBA resembles a period with inter-regional contacts between Northern and Southern Caucasus (Kohl and Trifonov, 2014; Kohl, 2007). This is based on the clear definitive evidence of kurgan-style tumuli and burials, associated with northern and Eurasian cultures (Smith, 2012: 680). These burials are pit- and stone-cist tombs covered by tumuli of earth and/or stone cobbles (i.e., Kirovakan in northern Armenia and Trialeti region of Georgia) (Piotrovksy, 1973). Moreover, KA pottery seems to be deposited in layers with these kurgan-style tombs. However, data concerning this chronological period is lacking, and we still do not understand what led to the collapse of the KA (Palumbi and Chataigner, 2014). Divination and shrines (represented by ceramic hearths or andirons; see Figure 1.3) from the EBA extended to the LBA (Smith and Leon, 2014). These ceramic hearths or andirons have been argued as indicators of ritual activities, as part of a shrine or temple (Simonyan and Rothman, 2015; Smith and Leon, 2014). The material cultures of the MBA include Karmir-Berd, Karmir-Bank, and Sevan-Uzerlik ceramics (Smith, 2012). The latter ceramic technology is similar to KA, in terms of the surface feature as back-polished vessels with incised and punctate decoration.

Figure 1. 3. Kura-Araxes zoomorphic and anthropomorphic ceramic fireplace/andiron from Shengavit. Reproduced from Palumbi (2015: 21).

The last stage of the Bronze Age is the Late Bronze Age (LBA), which spans roughly ca. 1500-1150 BC (Greene, 2013). Late Bronze changes in Southern Caucasus are associated with substantial metallurgical practices and pottery traditions (Erb-Satullo *et al.*, 2017; Smith *et al.*, 2009). By this period, the Caucasus was producing and utilizing metals on a large scale (Kohl and Trifonov, 2014). This is based on archaeological evidence corresponding to such processes: (1) exploitation of sulphide copper mines, (2) the dramatic increase in the frequency and variety of bronze objects, and (3) the use of lost-wax casting techniques (Greene, 2013: 65). The historical connections and evolution of cultural complexity during the late stages of the Bronze Age period remain topics for future research and investigation (Greene, 2013). In fact, there is a clear indication that the LBA was a period of dramatic political shifts (Smith *et al.*, 2009; Greene, 2013: 233; Smith, 2015). This is due to the fact that the Southern Caucasus appears more densely settled than in EBA times and inhabitants of settlements were mobile. Mobility in the LBA is attested by recent stable isotopic results from LBA levels at Gegharot (Chazin, 2016; Chazin *et al.*, 2019).

Furthermore, there is evidence of trade and foreign elements at Southern Caucasian sites. At Metsamor (a Late Bronze Age settlement in Armenia), tin-bronze weapons and tools increasingly supplant arsenical copper/bronzes (Kohl and Trifonov, 2014). Specialised craft production dramatically increased in the archaeological record. In summation, the chronological framework of the South Caucasus, particularly in Armenia, requires more investigations to synthesise and devise a proper chronological resolution.

1.4 Environmental setting in the EBA

In order to understand the archaeological sequences of this region, it is imperative to define the natural environment in relation to the structure of communities. In the past decade, modern and palaeoclimatic investigations of the Caucasus region have flourished, specifically from the South Caucasus. Palaeoecological records indicate a mosaic of environments, primarily forest-steppic vegetation and semi-desert shrub species, where the north-eastern part of Armenia is dominated by forests (Gulisashvili, 1964; Volodicheva, 2002; Connor and Kvavadze, 2014; Joannin *et al*., 2014; Jude *et al*., 2016; Leroyer *et al.,* 2016; Messager *et al.,* 2013; Messager *et al*., 2017; Messager *et al*., 2020). Published palaeoecological studies provide an analytical proxy to frame archaeological data (Cromatrie *et al*., 2020). Vegetation, fauna and terrestrial sources are largely explored by zooarchaeologists and archaeobotanists, where the KA have been termed as transhumant pastoralists, based on recent research in Georgia and Azerbaijan (Herrscher *et al.,* 2018). The wealth of the environment likely influenced cultures residing in various topographical zones in the South Caucasus, where EBA inhabitants settled in both mountainous and lowland areas (Figure 1.1).

Paleoclimatic reconstructions for this period suggest that the highlands were warmer and drier than the present, while the lowlands were warmer and wetter (Wick *et al*., 2003; Connor, 2011; Connor and Kvavadze, 2014: 19). The eastern Caucasus and southern Caspian are wet and moist in the summer season and dry and cool in the winter season (Figure 1.4) (Staubwasser and Weiss, 2006: 374). Armenia has a continental climate with hot summers and cold winters. The temperature is extremely diverse, resulting in precipitation contrast between the highlands and lowlands (Figure 1.5). This is based on the data published by Messager *et al*. (2013: 125), where the western part of the Caucasus consists of subtropical forests, characterised by a high annual rainfall (up to 2800 mm/yr) (Lominadze and Chirakadze, 1971; Denk *et al*., 2001), while the eastern part includes steppes and semi-desert formations with low rainfall (400 mm/yr or less). The highlands of the Lesser Caucasus range are characterised by sharp temperature contrasts between the summer and winter months due to a more continental climate (Ryabogina *et al*., 2019; Chataigner, 2016: 1). The Eastern Caucasus (Dagestan—Russian Federation) experienced cooling and humidification oscillations with the constant rise of pine forests in 5000 BP, associated with the Bronze, Iron and Middle Ages (Ryabogina *et al.,* 2019). These results show "significant discrepancies in the timing and sequence of the expansion of tree species in the Holocene in comparison with Transcaucasia and the Western Caucasus" (Ryabogina *et al*., 2019: 111).

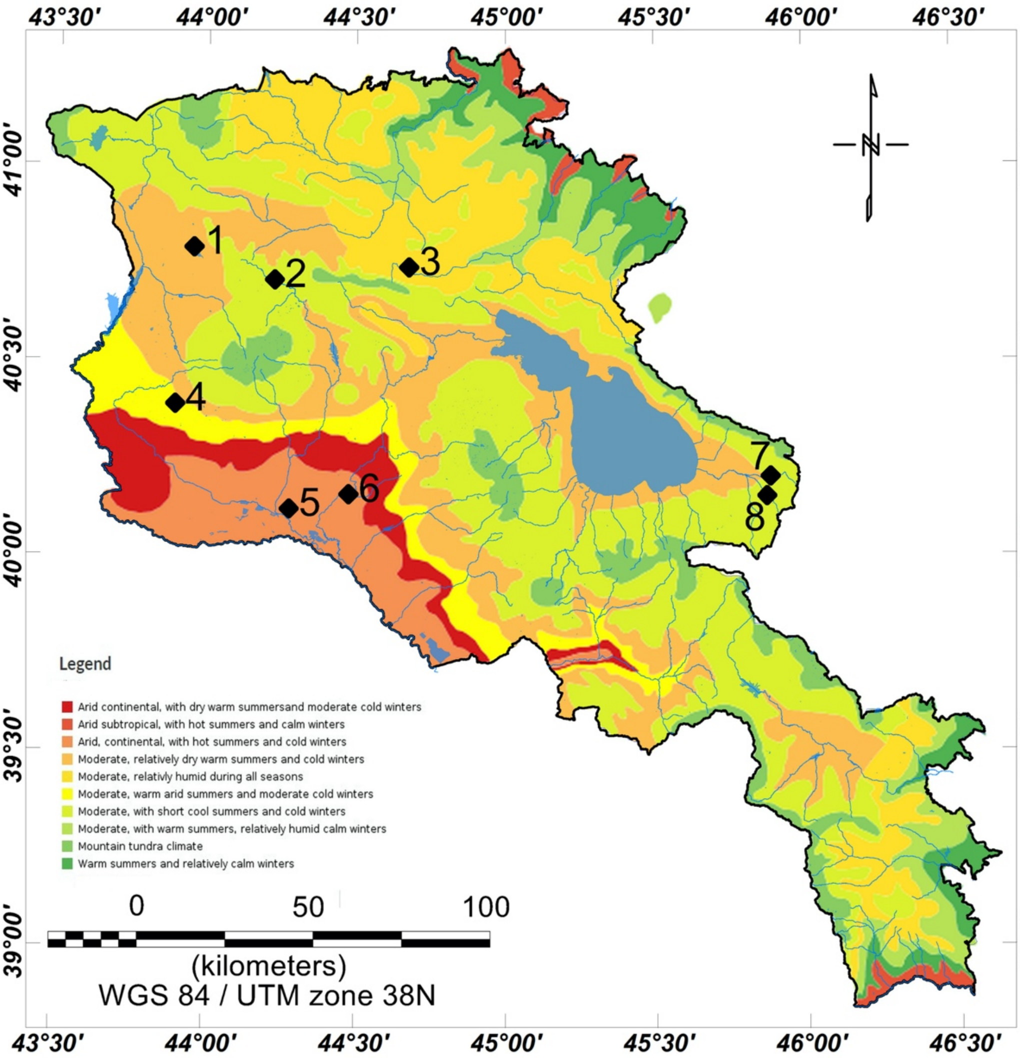


Figure 1. 4. Climatic zones map of Armenia, including rivers and one of the major freshwater lakes in the region, Lake Sevan. Sites: (1) Karnut-1, (2) Gegharot, (3) Margahovit (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1. Maps modified using Adobe Illustrator. Maps produced by L. Manoukian using Oasis Montaj Software (www.seequent.com); Climatic zones layer GIS base map source: https://sustainable-caucasus.unepgrid.ch (Suren Arakelyan; GEORISK Scientific Research Company).

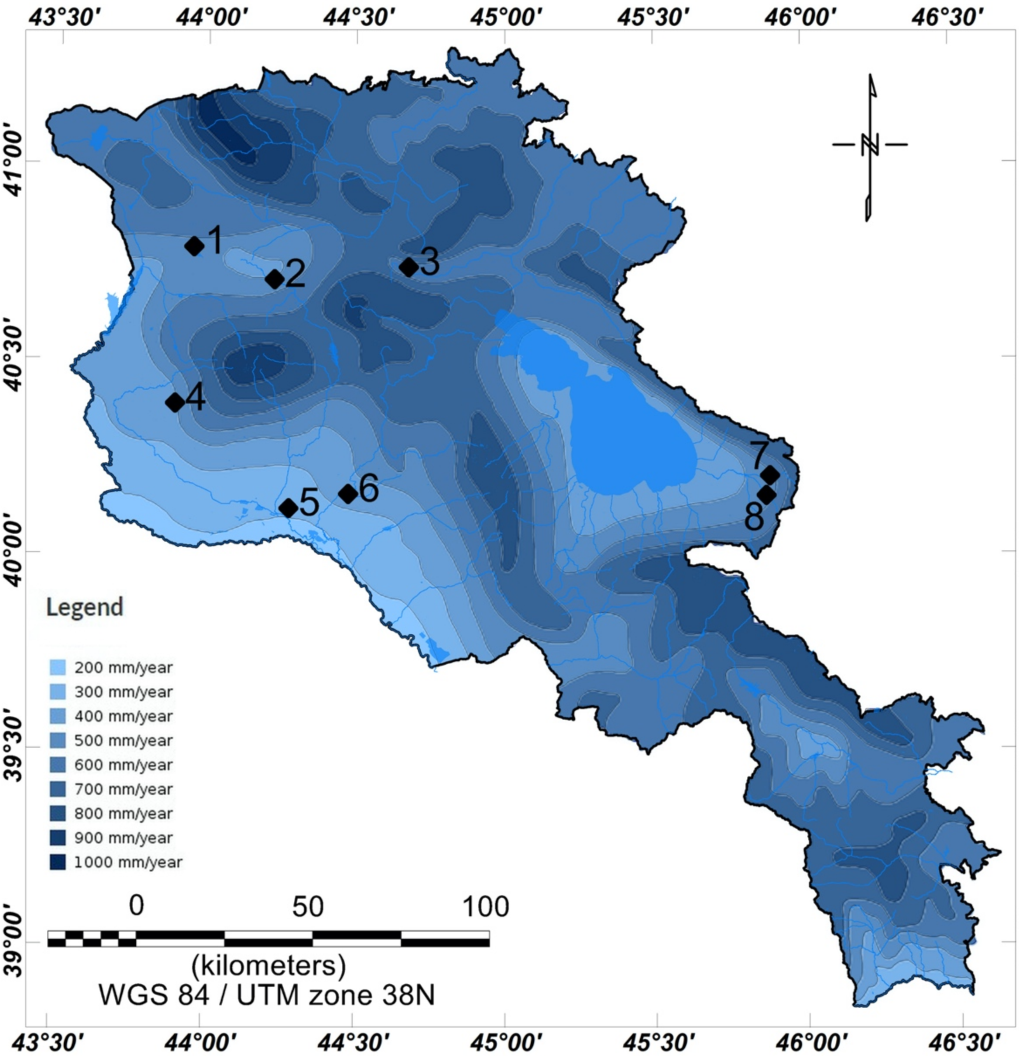


Figure 1. 5. Annual precipitation map of Armenia, including rivers and one of the major freshwater lakes in the region, Lake Sevan. Sites: (1) Karnut-1, (2) Gegharot, (3) Margahovit (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1. Maps modified using Adobe Illustrator. Maps produced by L. Manoukian using Oasis Montaj Software (www.seequent.com); Precipitation layer GIS base map source: https://sustainable-caucasus.unepgrid.ch (Suren Arakelyan; GEORISK Scientific Research Company).

Around the EBA period, rapid environmental changes occurred, which in turn affected the settlement dynamics of the KA people. Climatic factors might be one of the reasons why people settled in high- and low-land ranges in the South Caucasus ranges. Around 8200, 5200 and 4200 cal yr BP, widespread droughts altered environmental conditions (Table 1.1) (Staubwasser and Weiss, 2006). The drought of 4200 cal BP coincides with the onset and collapse of the EBA period. Climatic factors significantly alter the fundamental conditions for agriculture. Despite the fact that this abrupt climate change radically altered precipitation for cereal agriculture, the archaeobotanical evidence corresponding to the KA culture is heavily reliant on cereals and absence of pulses (Hovsepyan, 2015; Staubwasser and Weiss, 2006: 372). Significantly, Staubwasser and Weiss (2006: 372) state that the "synchronous changes among Early Bronze Age societies suggest a causal link between the event's precipitation diminution and collapse of the politico-economic superstructures dependent upon cereal agriculture" (Weiss *et al*., 1993; Cullen *et al*., 2000; Staubwasser *et al*., 2003; Drysdale *et al*., 2006; Arz *et al*., 2006).

Table 1. 1. Cultural periods associated with Holocene abrupt climate changes. Adapted from Staubwasser and Weiss (2006: 379).

BP	BC	Cultural period and event
4200	2200	4.2 kaBP arid/cooling event
	2300	Akkadian Empire First palaces in south Mesopotamia Collapse of the Kura-Araxes culture (chronological framework requires further research)
	3000	Early Dynastic Sumerian cities Sumerian Isolation Collapse of Late Uruk society, north and south Mesopotamia
	3200	5.2 kaBP arid/cooling event
	3500	Beginning of Kura-Araxes Cultural communities
	4000	Beginning of Uruk period cities Ubaid period villages in south Mesopotamia

The timing of environmental impact is significant to note, as neighbouring cultures, such as the Uruk society collapsed due to environmental reasons (Postgate, 1986; Weiss, 2003; Staubwasser and Weiss, 2006: 372). As scholars continuously debate the question of KA's collapse (i.e., Simonyan and Rothman, 2015; Smith 2005), it is possible that environmental factors played a large role. The extent of impact on food and agricultural traditions is rather unknown. The paleoclimate and archaeological record for the 5.2 ka event is well known at Soreq Cave, Lave Van (Lemcke and Sturm, 1997; Staubwasser and Weiss, 2006: 379) and Lateglacial Holocene climatic records in eastern Anatolia (Wick *et al*., 2003). Furthermore, the climate change at the 4.2 ka event is observed on a global scale (Staubwasser and Weiss, 2006, 383; Gasse, 2000; Weiss, 2000; Booth *et al*., 2005; Alexandrovskiy *et al.*, 2001). Chrono-sequences of paleosols, dating to 2600-2450 BCE, have been studied at Ipatovo Kurgan in northern Caucasus, Russia. This Kurgan is dated to Early-Middle Bronze Age, contemporary to the Maikop and KA archaeological cultures. Chataigner (2016) states that modelling variations in climate has been the objective in Georgia, through pollen data (Connor, 2006; Messager *et al.*, 2013), however it is only beginning to develop in Azerbaijan and Armenia (Joannin *et al.*, 2014; Cromatrie *et al*., 2020). Climatic changes reveal relatively humid and dry periods that lasted a few centuries (Shishlina *et al.*, 2009). Thus, humidity increased in North Caucasus and the climate relatively cooled in South Caucasus.

In terms of vegetation, the Caucasus ecoregion is characterised by an open oak forest (*Quercus*) and open woodland with heliophile[1] shrubs, and vegetation consists predominantly C_3 plants[2] (Shishlina *et al*., 2009; Chataigner, 2016; Bliedtner *et al.,* 2018). Several deciduous species exist in the Caucasus: *Pistacia atlantica* and *P. khinjuk, Acer cinarescens, Juniperus oxycedrus, Pyrus syriaca, Crataegus* spp. and *Prunus/Amygdalus* spp. (Wick *et al*., 2003: 666).

[1] Heliophile plants: attracted or adapted to sunlight.
[2] C_3 plants are predominantly trees, herbs and shrubs.

The beginning of the 2nd millennium was marked by a colder and drier climate, which could have been the cause of the disappearance of the ash trees, no longer evident in the LBA, as well as the appearance of oak/pine forests and the reduction of the tree-ring width (Jude *et al.*, 2016). The abundance of pine is not detected in Armenia up to 5000 cal BP (Leroyer *et al.*, 2016; Ryabogina *et al*., 2019). Based on Jude *et al.*'s (2016) data, it is significant to note some clear patterns: appearance of oak forests, followed by the disappearance of ash trees, as well as the appearance of oak/pine forests, over time.

The analysis of environmental and geological factors contributes to the development of ancient societies and is imperative in understanding cultural and spatio-temporal settlement patterns. Furthermore, it is clear that our view is incomplete without chronological refinement required to build a robust picture of the southern Caucasus. Environmental conditions are deeply rooted in understanding human migration, mobility, and subsistence practices (Ethier *et al.*, 2017). For instance, sheep, goat, pigs and cattle can colonise a variety of environments. It is vital to study environmental and geological zones, as seasonal mobility patterns, economy, social factors, settlement dynamics, materials and technology are connected to such ecoregions in the Bronze and further Iron Ages.

1.5 Defining the Kura-Araxes Cultural Phenomenon in the EBA

As mentioned briefly, the KA cultural phenomenon covered a vast area between the Near East and the Eurasian Steppes, including northern Israel, central Iran and the Black Sea region, in the EBA period spanning c. 3500-2500 BCE (Figure 1.1 and 1.6) (Badalyan, 2014; Manning *et al*., 2018; Passerini *et al*., 2016). Currently, some scholars suggest the KA extended to reach areas as far west as Cyprus (Alizadeh *et al*., 2018; Kohl, 2009). However, the proposed homeland or 'core' area of this culture is the Southern Caucasus (Simonyan and Rothman, 2015), in particular the mountainous zones between the Kura and Araxes Rivers, comprising

Armenia, Georgia and Azerbaijan. The cultural tradition, which emerged and developed in a much larger inter-connected world, was contemporary to the Uruk expansion in southern Mesopotamia and the Maikop culture in northern Caucasus (Figure 1.1a). The KA is one of the most prominent civilisations of the EBA in the Ancient Near East and the Caucasus (Figure 1.1 and 1.6) (Algaze, 2008; Smith, 2005). This cultural phenomenon is characterised by the presence of burnished grey-black-buff hand-made pottery and cooking hearth features, termed *andirons* (Figure 1.3). The remarkable extent of this cultural phenomenon is attested primarily by its pottery typology and style defined as black-burnished pottery. The KA ceramic tradition has often been termed *Early Transcaucasian ware, Yanik, Karz, Khirbet Kerak,* etc. (Burney and Lang, 1971; Roaf, 1990; Batiuk, 2013), but for the purpose of this thesis, it will be labelled as Kura-Araxes (KA) pottery ware, as terms are synonymous. Explaining the KA, in terms of its socio-economic structure has been heavily debated among the archaeological community through the years. As such, very few studies have scientifically analysed the material remains of this cultural phenomenon, including its cooking and subsistence practices, and technological characterisation of its predominant material culture—pottery.

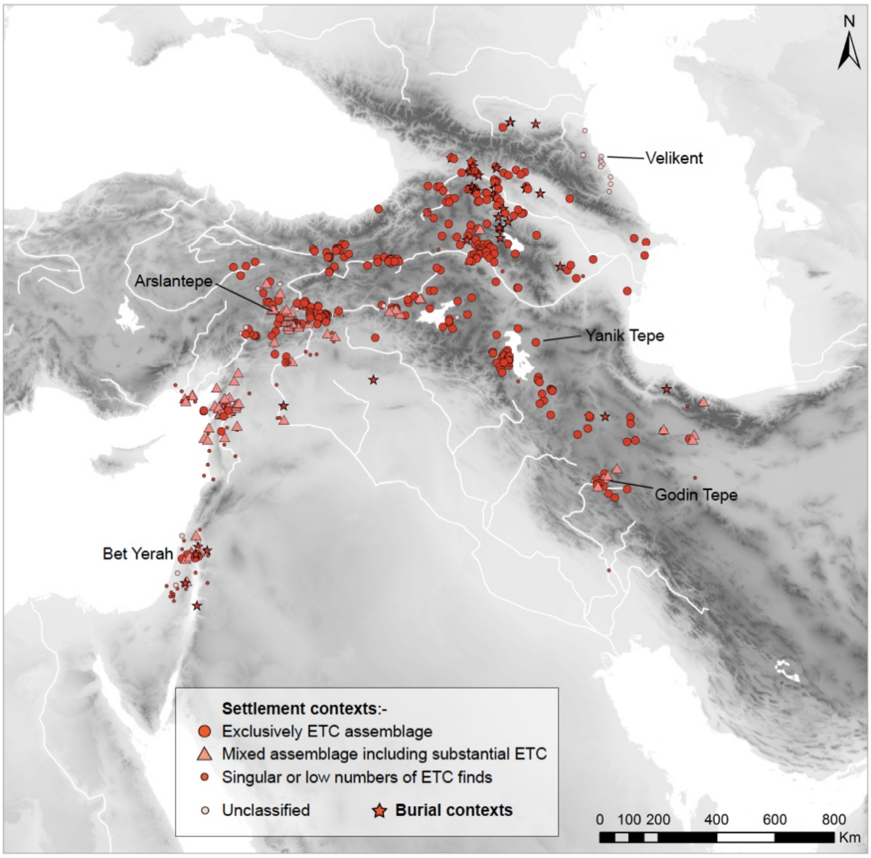


Figure 1. 6. Kura-Araxes settlements mapped in red symbols (Ancient Near East and Greater Caucasus); ETC acronym corresponds to the *Early Transcaucasian Culture* pottery assemblage, synonymous with KA pottery. Map reproduced from Wilkinson (2014a: 205).

Each different geographical area around the Ancient Near East has a distinctively different ceramic style in relation to the KA culture (Badalyan, 2014). Rothman (2014: 41) claims, "we who are studying the Kura-Araxes need to be clear to discuss each culture area separately, and not assume that every occurrence of hand-made, black-burnished ware represents a single migration event from the South Caucasus." The cultural significance of this widespread pottery type and the interconnections that it implies are not well known or thoroughly investigated. How were the KA sites organised? Were they pastoral, mobile or sedentary? How was the main product (pottery) produced and consumed? Questions pertaining to this culture's social implications, economic planning, pottery production, and reasons for its wide distribution are still widely discussed and debated (Batiuk, 2005; 2013; Kohl, 2007; Palumbi, 2008; 2015; Marro *et al.*, 2014; Smith, 2005; Summers, 2013; Wilkinson, 2014a;

2014b; Iserlis *et al.*, 2015; Sagona, 2014; 2018). However, new studies investigating questions of material analyses can improve our understanding of the EBA cultural layers of the South Caucasus, as well as how KA societies were organised (Samei *et al.*, 2019; Samei *et al.*, 2020; Samei and Alizadeh, 2020; Decaix *et al.*, 2019; Herrscher *et al*., 2018a; 2018b).

1.5.1 Subsistence practices and overall economy

The investigation of human and animal relationships using stable isotopic analysis (Chazin, 2016; Chazin *et al*., 2019) can enhance our understanding of social and cultural behaviour. In particular, archaeologists have debated whether the KA communities were structured as pastoralists and/or nomadic people, agro-pastoral, or sedentary-based (Wilkinson, 2014b; Herrscher *et al.*, 2018a; 2018b; Decaix *et al*., 2019). In terms of social complexity in the EBA, archaeologists have discussed whether Kura-Araxes occupation sites are cities or fortified settlements (Simonyan and Rothman, 2015). For instance, a wall and/or fortified section has been identified at Shengavit (Simonyan and Rothman, 2015). Based on these architectural findings, archaeologists question whether the KA were, in fact, sedentary or pastoral. Most Kura-Araxes settlements are small in size, and can be classified as villages (Iserlis *et al.*, 2015). Subsistence was mainly based on agriculture and animal husbandry (mainly sheep, goat and cattle), through farming and livestock raising (Iserlis *et al*., 2015: 10; Rothman, 2015; Samei *et al*., 2019). Moreover, expanding on the material culture and subsistence practices can shed light on the dynamics of each Kura-Araxes settlement to further understand this cultural social unity (Sagona, 2018).

Recent genetic studies point to gene flow into the South Caucasus region from neighbouring populations in northern Levant during the 3rd millennium BCE (Abranat-Tamir *et al*., 2020). However, in Anatolia and the Southern Caucasus, results suggest genetic continuity, with only transient gene flow (Margaryan *et al*., 2017; Wang *et al*., 2019;

Skourtanioti *et al.*, 2020). Movement of communities and groups suggests that subsistence practices appear to be based on nomadic and/or transhumant pastoralism (Piro and Crabtree, 2017; Hammer and Arbuckle, 2017; Arbuckle and Hammer, 2018) although a dearth of archaeozoological data has precluded direct isotope analysis of animal bones (Chazin *et al.*, 2019; Herrscher *et al*., 2018a).

1.5.1.1 Archaeobotanical evidence

Cereal-based agricultural practices dominate across EBA settlements in the South Caucasus region (Badalyan *et al.*, 2008; Hovsepyan, 2015). Distinguishing between cereals used for human consumption versus fodder is difficult (Whelton *et al.*, 2018). Cultivars include barley (*Hordeum vulgare*), naked wheat (*Triticum aestivum/turgidum*), emmer (*Triticum turgidum* subsp. *dicoccon*), and einkorn (*Triticum monococcum*) (Badalyan *et al.*, 2008; Herrscher *et al.*, 2018; Decaix *et al.*, 2019). Plants and leafy vegetables are prevalent in the South Caucasus; for instance, Rosaceae trees, grapevine (*Vitis vinifera*), and wild forms of fig tree (*Ficus carica*) (Zohary and Hopf, 2000; Nussinovitch, 2010; Decaix *et al.*, 2019). Charred nutlets of *Rosa* sp. (rose hip) and *Rubus* sp. are the most frequent remains of arboreal plants fruit at KA settlements of the South Caucasus (i.e., at archaeological sites of Chobareti, Gegharot, Sotk-2, Shengavit, etc.) (Hovsepyan, 2015: 76; Messager *et al.*, 2015). However, very few fruits were found in the botanical record, according to Decaix *et al*., (2016), apart from grape, caper and hackberry identified at Mentesh Tepe, Azerbaijan. Nutlets of *Lithosperumum arvense* were found at the site of Mokhra-Blur (Kushnareva, 1997), and *Rubus* sp. and *Rosa* sp. (rose hip) are frequent remains of arboreal plants at Sotk-2, Gegharot, and Shengavit (Hovsepyan, 2015) (Appendix D, Table 1). It is interesting to note that lentil and pea, having been the most common cultivated pulses, are non-existent in the EBA KA sites.

Major climatic events could have influenced KA inhabitants to settle in mountainous areas, alongside *Vitis vinifera* vegetation, as proposed by Batiuk (2013). Batiuk (2013) claims that KA vessels could have been used for wine production and fermented products. Based on these assumptions, archaeologists have not been able to conclusively suggest wine-related products, as scholars are refining methodologies to investigate fermented products (Whelton *et al.*, 2021; Drieu *et al.*, 2020).

Archaeobotanical remains were preserved *in situ* within ceramic vessels, often hypothesised as storage grain vessels (i.e., at the archaeological settlements of Gegharot, Aparan, Lorut, Aygevan, etc.) (Hovsepyan, 2015: 72). Evidence for agricultural pursuits includes silos, sickle blades, grinding stones, cereal grains, cereal chaff and coprolites of small rodents (Hovsepyan, 2011). The Southern Caucasus is also home to a variety of wild cereals, legumes, grape vines and fruit trees, predecessors of today's staple crops (Ketskhoveli, 1959; Bardsley and Thomas, 2005; Connor and Kvavadze, 2014: 14; Batiuk, 2013). Compared to the KA culture, agricultural played a far less significant role in the subsistence economy of the Maikop culture to the north, as Maikop focused on animal husbandry of sheep, goat and cattle (Kohl and Trifonov, 2014).

Environmental changes at the beginning of the EBA may have contributed to transforming the agriculture into cultivation of a few hardy cereals, according to Hovsepyan (2015). Scholars also note that the 4.2 ka event changed and altered the politico-economic cultures of the time during the EBA; this event collapsed the societies dependent upon cereal agriculture (Weiss *et al*., 1993; Cullen *et al*., 2000; Staubwasser *et al*., 2003; Drysdale *et al*., 2006; Arz *et al*., 2006). Comparative archaeozoological and archaeobotanical data alongside lipid residue results provide an imperative lens into the socio-economic lifestyle of prehistoric populations attested in various studies (Evershed, 2008; Craig *et al*., 2011; 2013; Roffet-Salque *et al*., 2017).

1.5.1.2 Faunal evidence

It is postulated that KA communities were agro-pastoral with (sheep/goat) livestock farming, where secondary products (i.e., milk and dairy production) were more important than primary products (Wilkinson, 2014b; Summers, 2014; Hovsepyan, 2015). This is attested by archaeozoological evidence indicating a dominance of domestic species of cattle (*Bos taurus*), sheep (*Ovis aries*) and goat (*Capra hircus*) across KA settlements (Appendix D, Table 1), including neighbouring regions such as Godin Tepe in northwestern Iran (Piro and Crabtree, 2017) and EBA Anatolian sites (Irvine *et al*., 2019), where kill-off patterns indicate a dominance of secondary products across the region (Piro and Crabtree, 2017; Siracusano and Bartosiewicz, 2012; Badalyan *et al.*, 2014; Samei *et al.*, 2019). Other domestic species include pig (*Sus scrofa*), horse (*Equus* sp.), and dog (*Canis* sp.). The extent of agricultural consumption, ruminant, non-ruminant meat, and dairy production in the context of KA communities, is not known to date (Wilkinson, 2014b). Significantly, the structure of KA societies described as mobile, pastoral, agro-pastoral and/or sedentary-based is currently in discussion. Arbuckle and Hammer (2018: 3) state that "pastoralism encompasses a broad range of animal husbandry practices that may or may not include mobility and some amount of agriculture, as well as a broad range of variation in community size and social organisation." Paz (2009) describes the KA culture as temporary, as if they were not fully settled and ready to move, implying mobility, ephemeral settlements and/or transhumance.

Scholars have hypothesised that secondary products formed a major part of the KA economy (Wilkinson, 2014b; Summers, 2014). Riehl (2009) and Hovsepyan (2015: 79) state that cloth-making (wool) could have been replaced by animal products, such as, meat, milk and wool. Scholars think that ruminants at Godin Level IV (Kura-Araxes stratum) (Figure 1.1) were killed at 4-6 years of age, old for their use as primarily meat sources, but acceptable for wool or milk production (Rothman, 2011; Summers, 2014: 165). Rothman (2015) describes the KA migratory event across the Ancient Near East as emigration (pull rather than a push) due to three activities: animal meat, by-products (wool), metals and metallurgical skills, or viniculture.

The current view of subsistence practices for the KA consists of a meat-based diet, predominantly sheep/goat and cattle husbandry (Piro, 2009). However, the percentage of other animal remains is significant to note. For instance, at Gegharot, there is evidence of pig faunal remains recorded at the end of the KA (i.e., KA II) (Badalyan *et al*., 2014). Pig faunal remains, while low in NISP (Number of Identified Specimens), are present in the archaeological record of the EBA KA layers, specifically at some settlements in Armenia (i.e., Margahovit in northern Armenia, Figure 1.1; Gevorgyan *et al.,* 2021). Scholars suggest that the KA is structured as a transhumant pastoral society, primarily reliant on cattle breeding and secondary products (Arbuckle and Hammer, 2019; Summers, 2014; Sherratt, 1983).

Due to the fact that KA people produced vessels of burnished and non-burnished, varying all sorts of typology, it is possible that people were cooking, storing and roasting different commodities, as opposed to pit-based bonfire roasting (Miller, 2002). Archaeologists do not have a clear picture of how KA societies were structured in terms of their subsistence practices and what sources they exploited and/or stored in pottery.

1.5.2 Characteristics and Material Culture

Some scholars have rejected the term 'culture' or 'culture-historical-community' as overly passive[3] (Wilkinson, 2014a; Sagona, 2014). Wilkinson (2014a: 209) asks, "what mechanisms or system lie behind the deposition of the remains that archaeologists identify as ETC or Kura-Araxes?" If the culture is based on ceramic style, Munchaev (1975) described

[3] See Wilkinson (2014a) for a general overview in defining the culture; Sagona (2014: 24) claims that we are "witnessing a sea change in the archaeology of the Caucasus, now an arena of intense international dialogue and collaboration." Archaeologists are attempting to re-evaluate the unified conception of the origin of the KA complex through new results from current and ongoing excavations, in greater Caucasus to the Syro-Mesopotamian foothills and beyond.

Kura-Araxes typological styles evident in eastern Anatolia. According to Summers (2014), much of the ETC/KA pottery has not been thoroughly explored in Iran, aside from Godin Tepe and Yanik Tepe (Mason and Cooper, 1999; Amiran, 1965; Summers, 2013; Heydarian *et al*., 2020). In fact, one of the problems is that there are many unknown sub-regions in the Kura-Araxes geographical extent (Isikli, 2015). If cultural extent is based on architectural styles, KA sites are recognized structurally by rounded and rectangular architecture including the presence of dedicated ritual buildings and distinctive clay fireplaces called 'andirons' (Simonyan and Rothman, 2015; Smith *et al.*, 2009) (Figure 1.3).

Various scholars state that the EBA presents the first archaeological evidence for a religious cult, primarily due to the andirons found at KA settlement contexts (Smith and Leon, 2014; Greene, 2013; Simonyan and Rothman, 2015). Technological traditions and assemblages associated with the KA include andirons/ceramic hearths, animal figurines, an array of tools, such as bone implements, awls, bronze ornaments and weapons, and lithic toolkits of flint or obsidian (Smith *et al*., 2009). Ivanova (2012) claims that archaeologists must consider other regions besides Mesopotamia as sources of technological innovation for the western parts of Eurasia. Thus, it is essential to study technological advancements pertaining to cultures in Southern Caucasus, as it is an interregional crossroad connecting major technological industries. We need to examine fresh explanatory paradigms regarding the Kura-Araxes, as we have struggled with making sense of this cultural phenomenon thus far (Wilkinson, 2014b: 204). Thus, characterising ceramic technology and production can provide an outlook on how societies were organised economically and socially.

Communities were not urban-based, and production technologies seem to have been tied to local resources, such as obsidian and flint, copper ores, semiprecious stones like carnelian, and exploitation of indigenous plants, such as grapes (*Vitis vinifera*) (Rothman, 2015; Batiuk, 2013). Although there are theories concerning metal circulation through Kura-

Araxes networks, the lack of metal hoards or richly furnished graves nonetheless requires some explanation (Wilkinson, 2014a: 206). The Kura-Araxes Culture has been described as a heterarchical system, where communities are organised as non-hierarchical units (Alizadeh *et al*., 2018). According to Smith (2005), there is no evidence of inequality within KA communities in the EBA. However, new research at Köhneh Shahar in north-western Iran indicates otherwise, where evidence of variable craft production reveals social complexity (Alizadeh *et al*., 2018).

There have been speculations about diet and inhumation practices regarding the Kura-Araxes culture, as well as 'ritual' structures as communal spaces, marking some social complexity. Palumbi (2015: 6) claims that prior to the EBA, large funerary tumuli appear in the Southern Caucasus (i.e, Kavtiskhevi in Georgia, Akhnalitch in Armenia, and Soyuq Bulaq in Azerbaijan) (Makharadze, 2007; Muradyan, 2014). These burials carry contemporary Maikop traditions, in terms of construction of material and style of tomb (stone-cist). However, regarding the KA burials, there were no temples and no individuals who amassed great wealth. Burial rituals were simple and modest, in contrast to the increasingly complex Mesopotamian and Maikop grave sites (Kohl, 2007; Smith, 2005).

Poulmarc'h *et al.* (2014) analysed dog molars in an unusual Kura-Araxes child burial from the site of Kalavan-1 in Armenia. They state that its use in a KA burial is interpreted as an active modification of the funerary symbolism during this period. They observed five burial types commonly associated with KA sites: cists, tombs built in various forms, horseshoe-shaped tombs, pit tombs without surface evidence, and tombs indicated on the surface by small stones often termed 'kurgans' (Poulmarc'h *et al.*, 2014; Aghikyan, 2020). Data is based on four sites, Kalavan-1 and Karnut-1 (Armenia), Ovçular Tepesi (Nakhichevan), and Mentesh Tepe (Azerbaijan) (Poulmarc'h *et al*., 2014; Aghikyan, 2020). In general, a group of mounds have been unearthed during the 3rd millennium BC. Furthermore, scholars analysed the material culture of the tomb of Arslantepe in Anatolia (Frangipane, 2014). Its material culture is associated with a wealth of cultural diversity: KA ceramics, Maikop metal objects, and Syro-Mesopotamian material culture, implying inter-regional trade and/or contact (Smith, 2012: 578; Palumbi, 2008: 111-112).

1.5.3 Kura-Araxes pottery

One of the key and predominant materials associated with the Kura-Araxes cultural phenomenon is pottery (Figure 1.7). As mentioned, pottery from KA contexts is burnished buff to black. In terms of its visual characteristics, KA pottery is found at numerous sites across the proposed extent of the cultural expansion, extending from the South Caucasus to north-western Iran and the Levant (Figure 1.1). While most quote Carol Kramer's (1985) dictum, 'pots are not people', scholars tend to debate that pottery style and manufacturing techniques are closely related to cultural groups. Thus, whether this pottery type represents a distinct population group remains to be established. The consensus is that this cultural tradition is associated with domestic pottery production and that each household made its own pottery (Rothman, 2014). Pottery technology can be analysed using various scientific methods. *Chaîne opératoires* of pottery can provide information on how vessels were made, shaped, and further used for, primarily focusing on the reconstruction of technology and paste preparation (Leroi-Gourhan, 1964: 164; Cresswell, 1976: 13; Chapter 3).

The 'epiaesthetics', referring to the surface characteristics and colouring of KA pottery, reflects an emulation of a two-colour metal aesthetic through differential surface treatment (Wilkinson, 2014b: 206). As such, the KA repertoire includes mostly black-burnished wares as its main stylistic feature, but bichrome patterns (i.e., red and black or orange/buff and black) have been noted as well (Simonyan and Rothman, 2015). Similar to Greek Attic wares, the surface treatment can be analysed using advanced microscopic techniques (i.e., SEM-EDS).

Greek black-figure ware pottery has an illite-rich slip, which allows burnish (Tite *et al*., 1982). The surface finish of Greek black-figure ware pottery was coated with spinel in the series magnetite-hercynite, Fe_3O_4 – $FeAl_2O_4$ (Tite *et al*., 1982: 122). Greek Attic ware was produced through a single firing cycle: oxidising-reducing-oxidising. Additionally, some scholars state that KA surface technology resembles graphite-burnished wares (Edens, 1995). Scientific analyses can provide information on whether the KA potters treated the pottery with either inorganic or organic coatings, as microscopy analyses and SEM-EDS can provide a quick snapshot of the surface of potsherds in high magnification (Froh, 2004; Hunt, 2016). Kreiter *et al.*, (2014) identified the differences in coating pottery with graphite, producing comparative SEM micrographs of the surface layer. They conducted a range of experiments to improve our understanding of graphite-coated ceramics in terms of graphite preparation, graphite coating, surface treatments prior to or after graphite coating, firing temperatures and atmospheres (Kreiter *et al.*, 2014: 140).

Figure 1. 7. Kura-Araxes ceramics of the phase Kura Araxes II. Take note of the extreme quality of burnish/metallic shine. 1: Aragats (Shresh-Mokhra Blur style); 2: Lorut (Ayrum-Teghut style); 3: Shengavit (Karnut-Shengavit style). Credit: Ruben Badalyan, reproduced from Palumbi (2015: 14).

The most difficult aspect of scientific analyses on ceramics is the determination of surface treatment (Ionescu *et al.*, 2015). Burnishing and smoothing of vessels result in distinctive physical appearances. Ionescu *et al*. (2015: 23) claim that, smoothing makes ceramics appear matte, while burnishing gives ceramic an appearance that may be described as lustrous or gloss. Through SEM, they conclude that both smoothing and burnishing significantly change the surface and subsurface microfabric. Cédric Lepère (2014) studied ceramic surface treatments resulting in polished surfaces, particularly noted in the Neolithic period (4300 and 3300 BC) located in France, corresponding to the Chassey culture. He experimented with tools (pebbles, sticks, etc.), movement and active part of the tool, paste water content, hydration process and superimposition of the various treatments. His methodological procedures can be applied to KA pottery in terms of understanding the technological framework of obtaining a metallic smooth surface and/or burnish/gloss. For instance, a soft leather-hard vessel produces cracks when burnished and smoothed, as opposed to a stiff leather-hard paste.

Lepère conducted surface experiments (striations and crests, microtopography and sheen, and non-plastic particles), which broadens our perspective into prehistoric technologies (2014: 144). Replication and experimental analyses seem to be very effective in understanding surface technology, due to the fact that SEM, thin-section petrography, and other bulk-geochemical methods (i.e., XRF, XRD, etc.) do not necessarily offer a conclusive approach in understanding the potter's choices in surface treatment. In essence, reconstruction of technical choices during the manufacturing process is an essential component in understanding human behaviour and cognition.

Surface treatment on KA ceramics portrays significant variability, corresponding to 'technological styles.' Thus, a valuable approach in analysing the KA pottery repertoire from various sites is *chaîne opératoire* (Arnold, 1985; Gosselain, 1992; 2002; Roux, 1994; Roux and Courty, 2019). It is vital to note that there is a distinction between polishing and burnishing (Rice, 1987: 138), and most KA pottery-related studies do not address this dichotomy (Iserlis, 2009; Iserlis *et al*., 2010; 2015). Although previous archaeometric work on KA pottery contribute towards the understanding of technological treatment, only some aspects, such as 'slipped' or 'glossed' terms are applied. However, studies have not directly addressed a conclusive *chaîne opératoire* to unequivocally explain technical processes conducted by potters. If we conclude that a hard rock pebble treatment was applied to burnishing and polishing, the clay paste alters the effect (i.e., friction based on leather-hard or humidified bone-dry pastes) (Lepère, 2014: 149). Thus, these experiments elucidate a baseline for determining surface treatments, which will be applied to this thesis.

The KA horizon is defined by the morphological and decorative criteria of KA pottery (Heinsch and Vandiver, 2002: 382) (Figure 1.7). The surface technological features of KA pottery are quite distinct compared to Eastern European black-burnished pottery (Spataro, 2017; Amicone *et al.*, 2021). The exterior of KA pottery is mostly black-burnished, but whether the finishing technique is gloss, burnish, polish, or a metallic-lustre, requires further analysis (Lepère, 2014). Greenberg and Goren (2009: 129), who studied Kura-Araxes pottery (Early Transcaucasian Ware) from Tel Beth Shen and Tel Bet Yerah (Khibet el-Kerak) in Israel, ask whether the appearance of this ceramic type represents the arrival of migrants or the adoption of migrant technologies, i.e., whether the KA culture represents a distinct population group or a shared tradition of pottery making across different cultural groups. The detailed study of KA ceramic production and its comparison between different sites is likely to shed light on the meaning of this important EBA cultural tradition.

1.5.3.1 Style and typology

The ceramic classification associated with KA is black-red-buff burnished/polished pottery, variable by type and typology (Greenberg, 2007). Quantitatively, it is mostly black-burnished. For the purposes of this thesis, *burnished* is a description based on previous research, but the surface technique varies technologically. Designs associated with KA pottery include spirals, geometric lines, zigzag lines, and stylized animals (Figure 1.7; Iserlis *et al.*, 2015). Summers (2014: 163) describes the decoration in a relatively limited repertoire of KA forms.

1.5.3.2 Pottery technology

Recent technological and compositional studies of KA ware have remarkably contributed to our understanding of the Kura-Araxes culture in terms of production techniques, experimental reconstruction, raw material acquisition and socio-cultural interconnections (Amiran, 1965; Mason and Cooper, 1999; Batiuk, 2005; Palumbi, 2008; Iserlis, 2009; Iserlis *et al.*, 2015; Smith, 2005). However, such studies have yet to unequivocally build a clear picture of EBA craft production in the South Caucasus. It is suggested that the KA people constructed ceramics with specific temper agents, such as grog (Mason and Cooper, 1999; Hovsepyan and Mnatsakanyan, 2011), volcanic ash, tuff, or obsidian (Palumbi *et al.*, 2014; Iserlis *et al.*, 2015; Hovsepyan and Mnatsakanyan, 2011). There is no evidence to suggest that KA people produced pottery using a slow wheel (Iserlis *et al.*, 2015; Kibaroglu *et al.,* 2011; Mason and Cooper, 1999).

Material analysis studies in characterising Kura-Araxes ceramics from the homeland region, pertaining to a *chaîne opératoire* approach, are few in numbers. New analytical and interpretive studies have been published recently (Mason and Cooper, 1999; Palumbi, 2008; Kibaroglu, 2007; Greenberg, 2007; Kibaroglu *et al.*, 2011; Batiuk, 2013; Palumbi *et al.*, 2014; Heydarian *et al.*, 2020; Babetto *et al.*, 2021). These studies characterise KA ware from other peripheral regions (i.e., Iran, Georgia, and Anatolia). Each site is characterised separately using thin-section petrography and other methods (i.e., X-Ray Diffraction). Despite pottery being the main cultural marker for the KA cultural phenomenon, there are few studies approaching ceramic production and use holistically, in terms of following established methodologies (Sillar and Tite, 2000). Geochemical and residue studies remain to be investigated.

Prior to the KA cultural phenomenon, material data from the Chalcolithic period suggests that there was a close connection to chaff-faced pottery from Northern Mesopotamia, and even the earliest black-burnished wares in the Upper Euphrates may have been related more closely to the central Anatolian highlands than to the South Caucasus. The earlier 5th and 4th millennium at Areni and Godedzor in Armenia are related at least by pottery style and manufacture to the Zagreb and the north Mesopotamian ‘Ubaid styles and Late Chalcolithic material (Smith, 2005). According to this, it seems that in the Chalcolithic sites of the Caucasus, the chaff-tempered pottery is much more common than the obsidian-tempered pottery, while the quantitative occurrence of the grit-tempered ceramics remains to be evaluated (Palumbi, 2008). It is interesting that the Chalcolithic pottery pastes are characterised as chaff-faced but coexist with KA pottery at some sites in Georgia (Berikldeebi V, Treli, Samshvilde I and Grmakhevistavi) (Palumbi, 2008: 309). Consequently, Lyonnet *et al*., (2008) studied ceramics from a site in Azerbaijan called Soyuq Bulaq, dating to the Late Chalcolithic. They confirmed that the ceramic material shows affiliations with Late Chalcolithic pottery from northern Mesopotamia, while one bowl seems foreign due to the surface finish: black slip on its exterior. Furthermore, an obsidian-tempered sherd with a combed pattern corresponds to the Sioni culture (Lyonnet *et al*., 2008). This culture refers to the site of Sioni in Georgia, where archaeologists unearthed a large amount of dark-coloured and obsidian-tempered ceramics.

Geographical and geological factors appear to have played a key role in the potting communities of the KA, in terms of selecting settlements (Greene, 2013). In comparison to earlier periods, EBA KA pottery is defined by homogenous style, but the technological and manufacturing connections across settlements are unknown. Rothman (2014) and Kibaroglu *et al*., (2011) state that visual analysis and petrographic analyses suggest local hand-made production of KA pottery. Wilkinson (2014b: 204) claims that petrographic investigations so far confirm the local sourcing of clays and additives, and therefore the local production of vessels (e.g., Batiuk, 2000; Iserlis *et al*., 2010; Kibaroglu *et al.*, 2011). Ceramics from the site of Köhneh Shahar in north-western Iran (Figure 1.1a) appear to be stylistically and typologically similar to KA pottery from the South Caucasus region (Alizadeh *et al.*, 2018). Alizadeh (2015: 110) claims that these potsherds are "handmade, grit-tempered, mica, with occasional chaff inclusions, and well-fired; in addition, the paste colour varies from a predominant grey and dark grey with sometimes orange and brown, and rare buff ceramics." Painted and slipped ceramics have been recorded at various sites, including Köhne Shahar in Iran, Kvatskhelebi, Beshtasheni, and Ozni in Georgia (Alizadeh, 2015; Dzhavakhishvili and

Glonti, 1962; Kuftin, 1946; Sagona, 1984; Zhorzhikashvili and Gogadze, 1974), and Sotk-2 in Armenia (Bobokhyan, 2017; personal communication).

Ceramics from Sos Höyük in Anatolia were studied by Kibaroglu *et al.*, (2011) using petrographic and X-ray fluorescence (XRF) analyses to determine clay groups and suggest provenance and manufacturing technology. They claim that KA pottery was built by hand and locally produced (Kibaroglu *et al*., 2011). Kibaroglu *et al.* (2011: 3081) claim "the predominantly volcanic affinity of the inclusions in the selected sherds from Sos Höyük, whether they occur as coarse grain or fine clasts in the matrix, indicates that the clay deposits used for production of the ceramics mainly originated from volcanic rocks." Coarse fabrics were predominant in their KA ceramic assemblage. They suggest that the characteristic of black paste colour of KA is based on firing conditions in a reducing environment. However, they conclude that the red-black wares were achieved under low-to medium temperature (700 to 800 ^{o}C). Overall, Kibaroglu *et al*. (2011: 3082) claim that KA pottery is largely based on hand-made coil or slab production, using coarse clay and a wide typological repertoire. This sequence of construction is comparable with the KA assemblage from Malatya-Elazig in Anatolia, confirmed by Schwartz *et al*. (2009). However, paste preparation is slightly different in other regions, such as Godin Tepe in northwestern Iran, where Mason and Cooper (1999) claim that potters used grog as a temper additive. Grog tempering seems to have been a widespread technique in paste preparation, also noted by Batiuk (2000), who reported grog-tempered KA ware from Gümüshane in Anatolia. Furthermore, Iserlis (2009) and Iserlis *et al*. (2010) also confirm various temper additives in KA ceramics present at the archaeological site of Bet Yerah in the Levant. Examination of production techniques reveals an extremely similar *chaîne opératoire* between very distant assemblages (Iserlis, 2009; Iserlis *et al.*, 2010). At these sites, technological traditions are consistent, comprising local hand-made pottery, and specific tempering agents. How do we explain the transmission of a manufacturing tradition over such large distances? The gap in devising a *chaîne opératoire* of the KA is integral to reconstructing the socio-economic organisation of potting communities within the 'core' homeland area (South Caucasus) as well as other neighbouring sites in the Ancient Near East (Figure 1.1).

Iserlis (2009) and Iserlis *et al*. (2015) have conducted various petrographic analyses to test for paste preparation, raw materials through experimental reconstruction, and potential provenance. Iserlis *et al.*, (2010) studied Kura-Araxes ceramics from Bet Yerah, Aparan III and Karnut-1 and confirmed that the petrographic pastes varied for cooking wares. Significantly, the slight variation in paste preparation points to some level of ceramic standardisation. However, according to Rothman (2014), KA communities employed a household industry with variable standardisation (i.e., at Shengavit). Furthermore, Iserlis *et al*. (2015) studied 27 KA potsherds from the EBA site called Tsaghkasar located in Armenia. Tsaghkasar ceramic industry is contemporary with other KA sites, such as Aparan and Karnut-1 in Armenia, in terms of coarseness, manipulation of the surface, lack of consistency in raw materials, and non-essential tempers, such as obsidian (Iserlis *et al*., 2015: 14 and 21). Consistency of raw materials, thinner slips, and degree of control over firing is observed in later periods, according to Iserlis *et al*. (2010). The simplicity of vessels suggests a "labour-intensive, slow-working, potting technique, producing highly individualized pieces." (Iserlis *et al*., 2015: 14). Similar to Iserlis *et al*.'s (2010) findings from Bet Yerah, Aparan III and Karnut-1, the cooking wares appear to be constructed differently, as the fabrics differ by type. They conclude that adding obsidian or volcanic ash as temper aids the firing regimen. Tsaghkasar clay at the site does not contain obsidian and/or volcanic ash; Iserlis *et al*. (2015: 20) identified the soil at some distance from the site, where beds of Middle Pleistocene unconsolidated volcanic ash covered by ignimbrites are located at a distance of about 1 km from the site (Shirinyan, 1958 and 1961; Chernyshev e*t al*., 2002). This is not the first case of volcanic ash used as temper (i.e., Barone *et al*., 2010 studied potsherds from various archaeological sites in

Sicily); but requires further investigation into its use and perhaps more samples will provide a pattern in determining how such raw materials add a technical advantage. Iserlis *et al*., (2015) suggest that the KA ceramics tradition is based on the use of ready-to-hand clay that underwent considerable manipulation. These studies can be used to compare signatures throughout archaeological sites in the Southern Caucasus. Contrary to previous studies, grog does not seem to be a common temper additive for Tsaghkasar KA pottery. Due to the poor plasticity of the clay, Iserlis *et al*. (2015: 20) also claim that potters levigated the clay, based on the amount of silt and temper sorting, referring to the coarse inclusions within raw materials. Levigation is a process of the paste preparation, in terms of refining the clay and removing impurities and large inclusions (Rice, 2015). Hovsepyan and Mnatsakanyan (2011) published a petrography report on EBA KA potsherds from the archaeological sites of Tsaghkasar and Talin Tombs in Armenia. Hovsepyan and Mnatsakanyan (2011) noted grog, obsidian, 'sandy' and tuff/pumice temper. The main observation was that potters at Tsaghkasar and Talin Tombs produced hand-made pottery, following a coiling technique, or pressed into moulds. The diverse petrographic descriptions reported in published data will aid in the interpretation of the KA assemblage examined in this thesis.

The use of volcanic ash as temper is an interesting phenomenon, but further samples are required to investigate whether clay was pre-treated with volcanic ash and/or obsidian. For instance, Palumbi *et al*. (2014) conducted geochemical analyses on Chalcolithic obsidian-tempered pottery from the Southern Caucasus, in order to assess their viability for provenance studies (Figure 1.8). While these potsherds do not resemble the KA assemblage, they claim that obsidian as an intentional temper rarely occurs outside of the Caucasus, with the exception of rare samples from the Aegean (Katsarou *et al.*, 2002; Palumbi *et al.*, 2014: 43). The studied ceramics correspond to the Chalcolithic period from two neighbouring sites, called Aratashen and Geghakar. Samples from these site were analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) to determine provenance and correlate the composition of obsidian inclusions with geological deposits. Their results confirm that provenance is not only feasible, but also a unique approach in studying cross-craft production, since geochemistry data regarding the obsidian deposits is available.

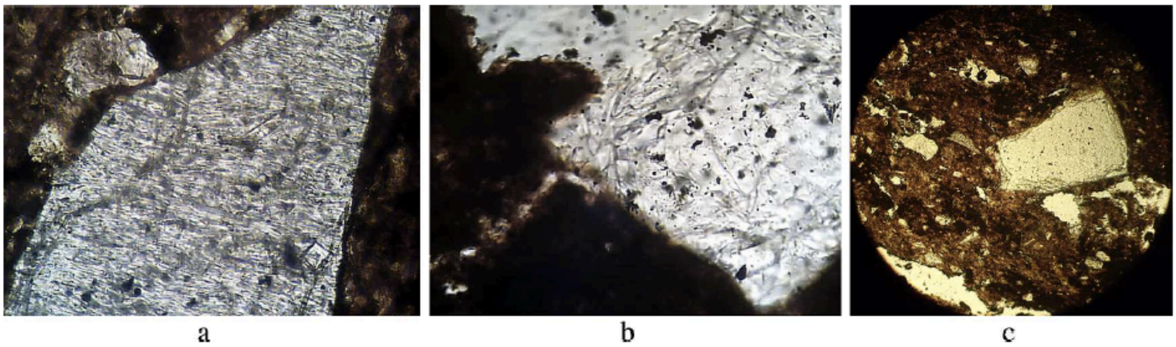


Figure 1. 8. Photomicrographs showing different types of obsidian inclusions; a) Fine-fluid transparent obsidian, magnification 20x, "parallel Nicols;" b) Fragment of transparent obsidian showing radial cracks produced by the firing of the vessel, magnification 20, "parallel Nicols;" c) Large fragment of obsidian in a fine-flaked hydromica, magnification 9x, "parallel Nicols." Obtained from Palumbi *et al*. (2014: 47, Figure 3).

In terms of thin-section petrographic work from other KA settlements, Mark Iserlis, Raffi Greenberg, and their colleagues have studied Kura-Araxes pottery from archaeological sites in the Levant extensively. Mark Iserlis and Raffi Greenberg have conducted comprehensive and comparative studies on Khirbet Kerak ware pottery production in Israel with the KA intrusive EBA layers within sites, associated with KA pottery (Greenberg, 2007; Greenberg, 2014; Greenberg *et al*., 2014; Greenberg and Iserlis, 2012; Iserlis *et al.*, 2010; Iserlis *et al.*, 2012; Iserlis, 2009). Khirbet Kerak ware potters from Tel Bet Shean and Tel Bet Yerah (Khirbet el-Kerak) constructed pottery that was technologically different from the traditional local wares, implying some indication that these potters were migrants and/or represent the adoption of migrant technologies (Greenberg and Goren, 2009: 129). Results from Iserlis *et al.*, (2010) conclude that there are three characteristics of the KA pottery tradition: (1) technological conservatism, (2) priority of surface treatment, and (3) non-correlation of form to fabric (i.e., variation). The published studies from neighbouring regions comprising KA settlements (i.e., Georgia, Azerbaijan, north-western Iran and the Levant) will provide comparative data to further reassess KA potting traditions within the 'core' KA area, specifically from the perspective of archaeological sites in Armenia.

Based on these observations, it is clear that KA pottery must be examined in a multi-analytical approach to unequivocally present a picture of the potting communities associated with social and economic factors. The identification and analysis of its *chaîne opératoire* can help archaeologists make inferences on local traditions and compare social organisation between settlements, as pottery resonates important values in their society (Rice, 1987; Iserlis *et al*., 2015: 11). The *chaîne opératoire* process concerns the procurement of raw materials, exploitation of such materials, vessel formation, surface treatment, use, discard, and firing regimen (Velde and Druc, 1999; Rice, 1987; 2015; Sillar and Tite, 2000). In terms of technological production, we have yet to find evidence of kilns associated with KA sites (Marro *et al*., 2014), in order interpret the firing regimen of KA vessels. Most archaeological sites contain a large number of pits (Simonyan and Rothman, 2015), which could have been areas of bonfire/pit-firing. Based on published petrographic studies, there seems to be a fair degree of technological heterogeneity between regional KA pottery assemblages (Wilkinson, 2014b: 204; Summers, 2004; Rothman, 2003; Greenberg, 2007; Palumbi and Chataigner, 2014). The degree of heterogeneity and to what extent pottery production varies, can be explored to understand this culture's extent and characteristics of transmission of technology across settlements. Technological analyses that are lacking currently for KA pottery research concern the synthesis of exploring paste preparation techniques and manufacturing technology (i.e., *chaîne opératoire*), vessel formation, surface treatment, firing techniques and other aspects of provenance and/or clay sourcing.

1.5.3.3 Pottery use

Pottery production and use are often not discussed together (Sillar and Tite, 2000; Hommel *et al.*, 2017; Spataro *et al.*, 2019; Skibo and Schiffer, 2008). In such cases, it is difficult to identify organic materials that might have aided technological production and/or use of vessels. For instance, through macroscopic and microscopic studies, Iserlis *et al.*, (2015: 13) point that in rare cases, bitumen was used to seal joins between slabs or coils and to repair cracked pots in KA pottery. It would be essential to investigate how widespread bitumen application was during the EBA, and whether it represents a KA 'cultural' characteristic. Moreover, residue analyses of KA pottery have not been conducted to date. As discussed in Section 1.5.1, KA subsistence practices comprise a mixed economy, based on the archaeobotanical and archaeozoological data. The direct analysis of organics within KA potsherds can provide archaeologists with information regarding the KA socio-economic structure. For instance, (1) the identification of organics used in repairing and/or technological applications, (2) the direct analysis of foodways and diet, and (3) the culinary practices employed; these lines of inquiry are imperative in reconstructing the KA culture's economy and in defining its domestic practices. Wilkinson (2014b: 210) claims that "the origin of any economy must be food production and, too-often forgotten, food consumption." Consumption and cuisine are not only part of daily life, but also factors considered during technological production of pottery.

There are various theories as to why KA pots were produced and what they were used for. For instance, Batiuk (2013) suggests KA pottery was constructed as a 'wine-kit' and interpreted the spread of pottery due to the natural distribution of the grape-vine, *Vitis vinifera,* to the 'fertile crescent' and the Eastern Mediterranean. Kohl and Trifonov (2014: 1581) claim that KA people collected grapes. Based on palaeobotanical and trace studies (Zohary and Hopf, 2000: 156-158), there is evidence of grape exploitation from the Neolithic onwards (McGovern *et al.*, 2017).

In order to determine the substances being consumed and produced, residue analysis can be conducted and tested on potsherds from KA settlements. As such, ceramic vessels offer a lens into production, storage transport and processing of food (Colonese *et al.,* 2017: 179). If ceramic vessels are unglazed, lipids (i.e., fats, oils and waxes) can be absorbed in porous vessels, providing direct evidence of pottery use (Evershed *et al.*, 1999; Evershed *et al.*, 1997; Craig *et al.*, 2013). Organic compounds can be identified within the clay mineral matrix (Grim, 1968; Sposito *et al.*, 1999). Residue analyses can confirm other technological features, such as slab building and joining through the exploitation of bitumen (Iserlis *et al.*, 2015) or surface treatment. Iserlis *et al.*, (2015) identified black glue-like substances on pottery fragments, suggesting the joining of vessels using bitumen; however, this interpretation highlights the importance of investigating pottery use and function using the archaeological biomarker approach through lipid residue analysis (Evershed, 2008), as such hypotheses can be confirmed using this approach. The fabric and temper will likely influence the absorption of organic compounds into the matrix (Rice, 2015; Roffet-Salque *et al.*, 2017; Evershed, 2008; Hamman *et al.*, 2018). Various commodities can be detected with organic residue analysis, and this area is discussed in Chapter 2.

1.6 Research framework and aims

In the past few decades, extensive archaeological research in the South Caucasus region has increased scientific studies with the aims of reconstructing past societies and cultures. Recent technological studies on KA pottery (Section 1.5.3) have remarkably contributed to our understanding of the cultural phenomenon, in terms of reconstructing potting communities, production techniques, experimental reconstruction, raw material acquisition and socio-cultural interconnections (Amiran, 1965; Mason and Cooper, 1999; Batiuk, 2005; Smith, 2005; Palumbi, 2008; Iserlis, 2009; Iserlis *et al*., 2010; Palumbi *et al*., 2014; Iserlis *et al*., 2015; Babetto *et al*., 2021). In studying KA pottery, archaeologists can shed light on many spatiotemporal characteristics and the overall development of technological practices (Hovsepyan and Mnatsakanyan, 2011). Thus, this thesis focuses on synthesising the ceramic industry located in the homeland/core area of the KA culture. The main goal is to contribute to the ongoing research in reconstructing the socio-economic structure of KA communities in Armenia (one of the core homeland areas of the culture). The thesis is divided into two main themes in reconstructing the socio-economic structure of KA settlements in Armenia: (1) pottery production and *chaîne opératoire*, and (2) the cuisine economy comprising diet, pottery use, and exploitation of local sources.

The reconstruction of KA pottery technology, in terms of characterisation of manufacturing technology, function and use, will aid in our understanding of the structure of potting communities. Furthermore, the reconstruction of cuisine-based practices and dietary inferences will shed light on the use of Kura-Araxes pottery, adding another step to the *chaîne opératoire* and define food practices, which are culturally intrinsic (Kerner *et al*., 2015; Hastorf, 2017). Ceramic vessels are one of the most commonly found technologies and/or tools across archaeological sites in antiquity. As a material, ceramics are virtually indestructible and present a palimpsest and snapshot of the time of construction, as well as the time of use (Tite, 2008). In the past decades, developments in archaeological science have focused on the molecular level. Compound-specific stable isotope analysis is used to assess lipid residues absorbed in archaeological pottery vessels, in order to investigate the contents of the vessel cooked and/or used (Evershed *et al.*, 1997; Copley *et al.*, 2003; Evershed, 2008). The comparison of various sites through South Caucasus allows us to observe change or continuity in food, cuisine, and technological traditions associated with a uniform cultural phenomenon.

The detailed study of Kura-Araxes pottery use/production and its comparison between different sites is likely to shed light on the meaning of this important EBA cultural tradition, which marks the advent of social complexity (Sagona, 2018; Irvine *et al.*, 2019). By investigating this culture's predominant craft, this project seeks to unravel archaeological themes in reconstructing social behaviour: how were KA inhabitants producing this pottery product? How was it made? What were they using this specific technology for? Are culinary traditions and production of pottery similar at various KA settlements? What were the main commodities processed, cooked and consumed? In short, how was Kura-Araxes pottery produced and what was it subsequently used for? As Skibo (2015: 189) states, "any analysis of pottery should start with the notion that all pots are designed to be used—that is to perform some function." The comparison of pottery technology and use (including culinary and dietary practices) from various settlements throughout the core region of the Kura-Araxes allows archaeologists to observe change or continuity in food and pottery traditions associated with a uniform cultural phenomenon.

1.6.1 Research questions

The main overarching archaeological research question is:

- How do culinary traditions and pottery production reflect the socio-economic organisation of Kura-Araxes communities?

Within this major question are two significant dimensions:

Transformation

- *Chaîne opératoire:* how was Kura-Araxes pottery made and is there evidence of technological change and/or continuity among coeval Kura-Araxes settlement sites in the homeland 'core' region, South Caucasus?
- Is there evidence of technological uniformity/standardisation or mass production of ceramics associated with Kura-Araxes settlements (i.e., methods of paste preparation, raw materials, production techniques, etc.)?
- Based on the food traditions, what are KA people cooking in the vessels and what are the main resources exploited across settlements in Armenia? Is it possible to reconstruct the structure of these settlements as mobile, pastoral, agro-pastoral, or sedentary? As hypothesised, are secondary products the main source of the economy?

Transmission

- What were the main raw materials that formed Kura-Araxes pottery traditions across settlements in Armenia and is there a technological signature (i.e., volcanic ash and/or obsidian) that can be traced throughout archaeological sites in the South Caucasus (Hovsepyan and Mnatsakanyan, 2011; Palumbi *et al.*, 2014; Iserlis *et al.*, 2015)? Is there a particular use for such high-quality ceramic production?
- Are potters producing Kura-Araxes pottery in order to serve specific functions? What are Kura-Araxes vessels primarily used for? Given the cultural and social unity (Sagona, 2018), what are the main commodities processed across coeval settlements?
- Through this investigation, is it possible to reconstruct subsistence practices and the overall economy across coeval settlements in Armenia?

Primary aims:

- To discuss craft production and specialisation at each separate community/settlement and assess the *chaîne opératoire* of Kura-Araxes pottery.
- To reconstruct the socio-economic structure of the Kura-Araxes cultural phenomenon by investigating the organic products processed and consumed.

This material study can fill a void in our knowledge of an inter-connected world between Europe and the Ancient Near East. The aim of this thesis, as stated at the end of this chapter, is to reconstruct the social and economic structure of the Kura-Araxes craft economy, through pottery production, culinary practices and use; in essence, devising a coherent organisation of production, including the direct use of a craft product (Sillar and Tite, 2000; Skibo, 2013). The adoption of pottery making traditions remarkably enhanced both craft production and food preparing techniques in societies, as seen through anthropological and archaeological case studies (Lévi-Strauss, 1966; Skibo, 2013; 2015). Moreover, the act of craft production and commensality is socially-embedded in prehistoric societies (Kerner *et al*., 2015).

These questions are largely based on current archaeological debates and long-standing questions regarding this cultural phenomenon (Sagona, 2018). In studying Kura-Araxes ceramics, this thesis can provide knowledge pertaining to the socio-economic world of the KA people, through the lens of ceramic production and organic residue analyses. This project will use an integrated microscopy/petrographic, molecular, isotopic, and archaeological approach applied to Kura-Araxes potsherds excavated from Armenian archaeological sites (Figure 1.1b), to reconstruct its socio-economic framework through technological analyses (*chaîne opératoire*) and residue analysis of absorbed lipids. The latter methodology will determine whether secondary products played a major role in Kura-Araxes society, or whether other commodities were favoured. This will help elucidate the development of pastoralism and/or agro-pastoralism/sedentary-based communities, adding to our corpus of knowledge on dairying practices in the Ancient Near East. This area has great relevance for research, especially in refining our understanding of EBA communities in the South Caucasus and placing the KA in its global context with contrastive societies in the Ancient Near East and Eurasian steppes (Wilkin *et al*., 2020; 2021).

1.6.2 Outcomes and summation

This chapter presents the archaeology of the South Caucasus region, including its landmark features comprising geological formations, chronological framework, and focusing on the EBA. The literature review discusses the EBA and Kura-Araxes, including the outlook on the complexity of defining the Kura-Araxes 'culture-historical community,' and its key industry, a ceramic tradition. We still have not grasped a holistic view of the social, economic and cultural developments of the Kura-Araxes communities of the South Caucasus and the overall wider cultural context. By exploring themes in transformation and transmission of culinary practices and production of pottery technology, and the cultural behaviour (i.e., through cooking and/or processing organic products), we can interpret the socio-economic structure of this culture, and whether these communities exploited their local environment and/or influenced one another. Without the application of scientific techniques in investigating technological, use and culinary practices, it is difficult to confirm theories and debates of various case studies presented in this chapter. These studies show that the combination of macro- and micro-techniques on potsherds can be tools for archaeologists in interpreting past human behaviour and cultural formation. While it is a challenge to carefully classify and characterise this culture's prevalence across a wide landscape, this thesis attempts to build its socio-economic structure within the 'core' (homeland) region in the EBA through a multi-analytical approach, which has not been conducted thus far in the region. This is significant, as it will shed light on numerous archaeological interpretations and theoretical questions archaeologists have debated and discussed over the last 70-80 years.

1.7 Structure of D.Phil Thesis

This thesis is divided into six chapters. Chapter 1 provides a broad overview of the archaeology of the region, specific characteristics of the culture in question, and the main material of the study. Furthermore, this chapter introduces the research questions, framework and aims of the thesis. Through this chapter, published studies are introduced to highlight the importance of investigation pottery technology using the *chaîne opératoire* approach. Other areas explored in Chapter 1 include the socio-economic structure of this cultural phenomenon, in order to identify the gaps in literature, specifically in terms of the technological reconstruction of this particular pottery, as well as its potential use in culinary practices.

Chapter 2 introduces the materials, sites and methodological framework of the thesis through two research themes: microscopy and organic residue analyses. Chapter 3 discusses the overview of stereomicroscopy and compares KA pottery across coeval settlements in Armenia. Based on these results, potsherds are selected for further analyses using two major methodological frameworks, (1) thin-section petrography and SEM-EDS analysis of KA pottery, and (2) pottery use and culinary practices to define food traditions. Chapter 3 primarily focuses on results from SEM-EDS and thin-section petrographic analyses, in order to reconstruct the *chaîne opératoire*. Chapter 3 – Section 3.5 provides a short discussion of a hypothetical *chaîne opératoire* of KA pottery. Chapter 4 covers the results from lipid residue analysis of KA pottery, including the compound-specific stable isotopic results to determine the taxonomic classification of the animal fats. Furthermore, results from plant lipids, terpenoids and aquatic fats are discussed across various KA settlements examined.

Chapter 5 synthesises and discusses the overall thesis results and places the Kura-Araxes culture in its wider prehistoric context. Chapter 6 concludes the thesis and suggests areas that require further research.

This thesis uses archaeological, material science and biomolecular analyses to investigate the lives of people living in the Bronze Age South Caucasus, specifically within the mountainous zones of Armenia. In summary, this thesis will explore the following themes: (1) the technology of pottery making and the organisation of potting industries, (2) ways of utilisation and consumption of such pottery; and (3) compare/contrast pottery assemblages across Kura-Araxes sites within the region of South Caucasus and beyond, in order to address social practices of pottery production and use. These questions are largely based on current archaeological debates and long-standing questions regarding this cultural phenomenon (Smith *et al*., 2012; Badalyan *et al*., 2014; Palumbi and Chataigner, 2014).

CHAPTER 2

Materials and Methodology

2.1 Introduction

This chapter introduces the following points investigated in this thesis through (1) the sampling of artefacts and archaeological sites selected; (2) the methodology and methods used to investigate pottery manufacturing technology, raw material acquisition and direct use of pottery, in order to reconstruct production, culinary, and dietary practices (Figure 2.1). The suite of methods selected provides a holistic view of the research questions pertaining to this thesis. The research questions are focused on Kura-Araxes ceramics, in order to characterise the technological framework of the core-area of this cultural phenomenon and its communities. Groupings and classifications of KA pottery from various sites will feed into wider interpretations about the cultural phenomenon, due to the fact that pottery is a traditional craft and manufacture is socially embedded (Rice, 1987: 25). Around 420 pottery fragments were screened using macroscopic methods. Through this, 140 potsherds were selected for thin-section petrographic analysis and 17 potsherds for SEM-EDS. The latter technique was applied mainly on fine-ware potsherds, as thin-walled sherds are rather difficult to analyse via thin-section petrography (Quinn, 2013: 4). Based on sample availability and preservation, 164 potsherds were selected for organic residue analysis to answer research questions pertaining to pottery use and culinary practices. Evershed's (2008a) methodology can be applied to unglazed ceramics as a source of organic residues to detect processing of different commodities, as current theories for KA ceramic use suggest wine production and/or secondary products (i.e., milk and dairy products) (Summers, 2014; Batiuk, 2013). Ceramic technology cannot be determined by the bulk chemical analysis of archaeological ceramics. Homogenised samples are not suitable for understanding composition and microstructure (i.e., the texture and the way inclusions are combined) (Quinn, 2013: 7). As Tite claims (2016: 13), "the emphasis will continue to be the employment of an holistic approach in which, as far as possible, production, provenance, and the use of a complete ceramic assemblage are investigated." This integrative approach provides a synthesis of Kura-Araxes potting traditions, as well as the possibility to compare social and economic traditions with contemporary and coeval sites throughout the Ancient Near East. The following potsherd samples listed below (Table 2.1) were obtained directly from Armenia (during excavation and post-excavation, field-seasons 2017 and 2019).

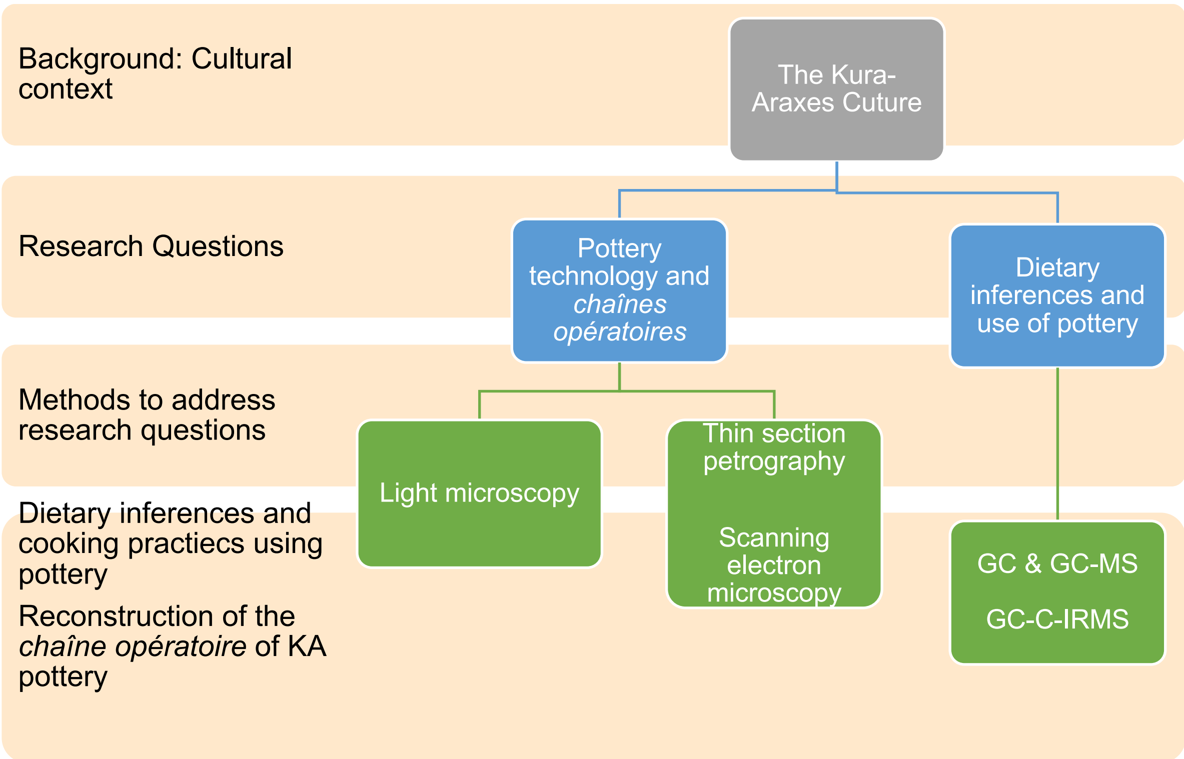


Figure 2. 1. A succinct diagram portraying the purpose of this thesis and outcomes using various scientific methods.

Table 2. 1. Data concerning the cultural horizon and periods corresponding to Armenia are obtained from Badalyan (2014), comprising Early Bronze KA I (3500/3350-2900 BCE) and Early Bronze KA II (2900-2600/2500 BCE). Key: scanning electron microscopy energy dispersive spectroscopy (SEM-EDS), gas chromatography-mass spectrometry (GC-MS), and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS).

Archaeological site		**Total samples**	**Stereomicroscopy**	**SEM -EDS**	**Thin-section petrography**	**GC-MS**	**GC-C-IRMS**
1	Norabak	11	11	11	0	0	0
2	Margahovit	46	46	0	30	30	22
3	Sotk-2	80	80	0	4	4	4
4	Gegharot	59	59	0	36	35	22
5	Talin Tombs	10	10	0	10	4	4
6	Mokhra-Blur	13	13	3	11	13	13
7	Shengavit	135	135	3	35	48	32
8	Karnut-1	66	66	0	14	30	18
Total		**420**	**420**	**17**	**140**	**164**	**115**

2.2 Sample selection and rationale

Samples were selected to serve the research questions outlined in Chapter 1. Stereomicroscopy was used as a screening tool, to define common features (surface features, colour through Munsell, aspects on firing, and the general fabric, including visible inclusions). Potsherd samples selected for thin-section petrography comprise fine-, medium-, and coarse-grained potsherds. Potsherds selected for SEM-EDS were based on the rationale that fine-wares are difficult to analyse via stereomicroscopy and thin-section petrography (Montana, 2020). Furthermore, potsherds selected for GC-MS (and further GC-C-IRMS) were based on preservation factors, and rim-to-body sherds, as published studies demonstrate higher lipid concentration near the rims (Charters *et al*., 1993).

2.2 Archaeological sites

The archaeological sites selected for this thesis are located in the Republic of Armenia region, spatially located in different ecotones, and chronologically spanning the Kura-Araxes period, ca. 3500-2500 BCE. In addition, the ecotones differ in geographical environments and terrains from mountainous localities to sites near rivers and the major lake in Armenia, Lake Sevan (Chapter 1; Figure 1.1). These distinctions provide an attempt to spatially assess differences and similarities across the landscape in pottery technology, as well as the exploitation of environment and terrestrial resources for dietary and culinary practices. Eight archaeological sites are selected for this thesis: Shengavit, Gegharot, Margahovit, Sotk-2, Norabak-1, Talin Tombs, Karnut-1, and Mokhra-Blur from Armenia (Chapter 1 – Figure 1.1b). All samples correspond to the Kura-Araxes period layers I-II, ca. 3500-2500 BCE (Badalyan, 2014; Manning *et al*., 2018). This sample set represents sherds that have not been investigated before and can provide an additional background to previously published datasets (i.e., Iserlis *et al*., 2015; Mnatsakanyan and Hovsepyan, 2011). The selection of samples was based on a number of factors: the contextual information of each sample, radiocarbon dates available from stratigraphic layers and archaeological sites, as well as storage conditions (where applicable). This is the first detailed analysis through petrography, as previous studies have focused on singular sites (or compared 2-3 sites). Moreover, this thesis investigates the first organic residue analysis of KA pottery, as well as the period and the region of South Caucasus.

2.2.1 Shengavit

Shengavit is one of the most important Kura-Araxes urban sites in the region, due to its size, preservation, and long-standing excavations (Simonyan and Rothman, 2015). It is situated in a lowland zone with an altitude of 923 masl, near the modern-day capital of Yerevan, Armenia. Shengavit is located between the Kotayk plateau and the Ararat Plain on the left bank of the Hrazdan River. The settlement size of Shengavit is 6ha and consists of a massive wall 4m wide and/or fortified structure with large basalt blocks (Simonyan and Rothman, 2015). In general, Kura-Araxes occupations are normally 1-2 ha in size (Rothman, 2014). The assemblage for this study is from a few well-contextualized excavated squares: M5, J5, and

K6. Primarily, potsherds were selected from one 10x10 m square (K6), located in the central section excavated at Shengavit. This section has been excavated to the main floor level, providing a long sequence of occupation. Radiocarbon dates have been provided and range from 3702-2270 BC (Simonyan and Rothman, 2015). Material culture from this settlement represents EB I and II. The excavated squares suggest various functional dwellings (i.e., K6 appears to be a domestic house, while M5 resembles a 'ritual shrine'). Large storage jars, called *karas*, were found in the floor of one of the round buildings in square K6. This jar was analysed for residue analysis, specifically investigating whether it contained grape wine, and results suggest resinous material (i.e., pine resin) (Simonyan and Rothman, 2015). According to Mitchel S. Rothman, Shengavit is structured as an agricultural town, due to the archaeobotanical evidence and toolkit of flint sickles across the site (Simonyan and Rothman, 2015; Hovsepyan, 2015). Consequently, ritual behaviour at Kura-Araxes settlements has been debated extensively, as to whether rooms (M5 and K6 excavated squares) with andirons represent a shrine and/or temple (Bayburtian, 1938; Sagona, 1998; Simonyan and Rothman, 2015). However, it is possible that andirons were used for cooking purposes due to its design, as pots can be placed within the structure (Simonyan and Rothman, 2015).

The general food economy of the site includes C_3-based terrestrial plants (Hovsepyan, 2015), domestic and wild species (Chahoud *et al.*, 2015). Simonyan and Rothman (2015: 34, Table 4) confirm the following: domestic cattle (*Bos taurus*), sheep (*Ovis aries*), goat (*Capra hircus*), pig (*Sus scrofa*), dog (*Canis familiaris*), red deer (*Cervus elaphus*), large ungulates, undetermined mammals, and unidentified fish. The main domesticates are sheep/goat and cattle. In general, pig remains are rare (Piro and Crabtree, 2017). Shengavit appears to be a town, which expanded near the end of the EBA period. The general food economy most likely dictated its importance as a site, due to various commodities exploited such as salt mining, grains, and broader material networks (Simonyan and Rothman, 2015: 22).

The pottery repertoire consists of typical Kura-Araxes type sherds, comprising buff to black-burnished pottery and bichrome (red/black burnished) wares. Preliminary reports of petrographic analysis on 26 potsherd samples indicate a wide variation focused on hand-made burnished wares, and structured as a household industry (Manoukian, 2015). Additional analyses of potsherds from this site will likely shed more light on the structure of potting communities, as well as whether potters adopted standardised production (i.e., specific tempers for production). Furthermore, based on other material culture, food processing tools were commonly associated with the toolkit of Shengavit inhabitants (grinders, pounders, harrowers, etc.) (Simonyan and Rothman, 2015).

Pottery is labelled as utilitarian, rather than decorative, despite the typological designs associated with KA vessels (see Figure 2.2 for potsherds selected from square M5, Shengavit). Vessels include cups, bowls, beakers, jars, and storage jars (termed *karas*). Fine-wares are thin-bodied, finely levigated and well-burnished (Simonyan and Rothman, 2015: 36). Cooking wares are classified due to their coarse-grained tempers and/or inclusions, often associated with sooting (Velde and Druc, 1999; Rice, 1987). This category includes thicker bodies, often classified with basalt grit-tempering (Simonyan and Rothman, 2015: 36) based on visual classification.

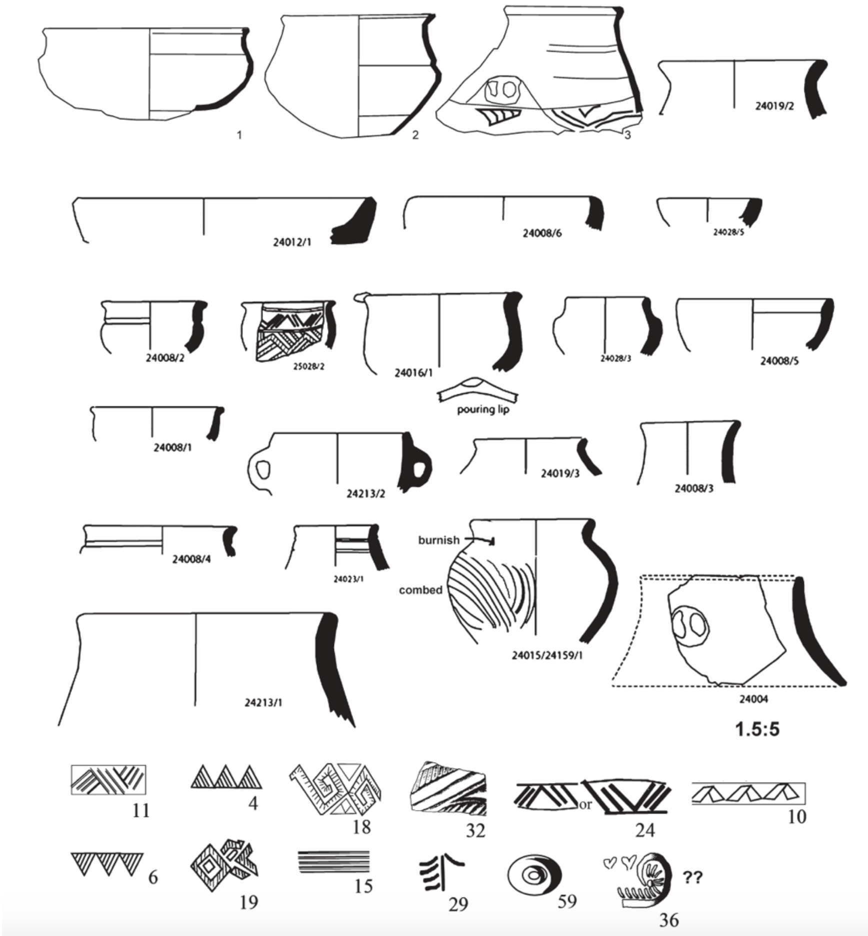


Figure 2. 2. Pottery from Shengavit M5 (drawing by Mitchell S. Rothman), reproduced from Simonyan and Rothman (2015: 35).

2.2.2 Gegharot

Gegharot is located near Mount Aragats, in the Tsaghkahovit Plain (Smith *et al.,* 2009), at an altitude of 2155 m asl. Typologically, the pottery is similar to 'Elar-Aragats' and 'Kura-Araxes I' traditions (Badalyan, 2014; Smith *et al.,* 2009: 43), corresponding to 3500-2900 BCE, as well as KA II, 2600-2400 BCE (Badalyan and Avetisyan, 2007: 98). Shrines and andirons are evident at Gegharot, but primarily in the Late Bronze Age and not associated with the KA cultural tradition (Smith and Leon, 2014). Smith and Leon (2014) interpret these rooms as divination centres. The Gegharot hill is composed of a lower Cretaceous granite intrusion (Badalyan and Avetisyan, 2007). Chipped stone tools of obsidian are most likely produced using raw materials from the Damlik volcano on the Tsaghkunyats ridge (Badalyan and

Avetisyan, 2007). Faunal resources include cattle (*Bos taurus*), sheep/goat (*Ovis/Capra*), pig (*Sus scrofa*), horse (*Equus*), deer (*Cervus*) and gazelle (*Gazella*). While pigs are recorded at low numbers, they were more common in KA II, rather than KA I (Badalyan *et al.*, 2010).

Potsherds selected from this site are from the West Citadel of the settlement (Badalyan *et al.*, 2014). Contexts are floor levels and well-contextualised; T30-101 (n=11, EBII), T36-3 (n=15, EBII), T30.82 (n=2, EBII), T30.65 (n=6, EBII), T39.31 (n=10, EBI), and T39.41 (n=15, EBI). These samples are dated to EB I (n=25) and II (n=34).

2.2.3 Margahovit

A recently excavated site, Margahovit has unearthed material culture corresponding to the KA horizon. Organic samples have been processed for radiocarbon dates at RLAHA, University of Oxford. The results provide a robust date for EB II: 2871-2620 cal BC (Unit D5b), marking the end of the EBA. (Figure 2.3; Gevorgyan *et al.*, 2021: 81).

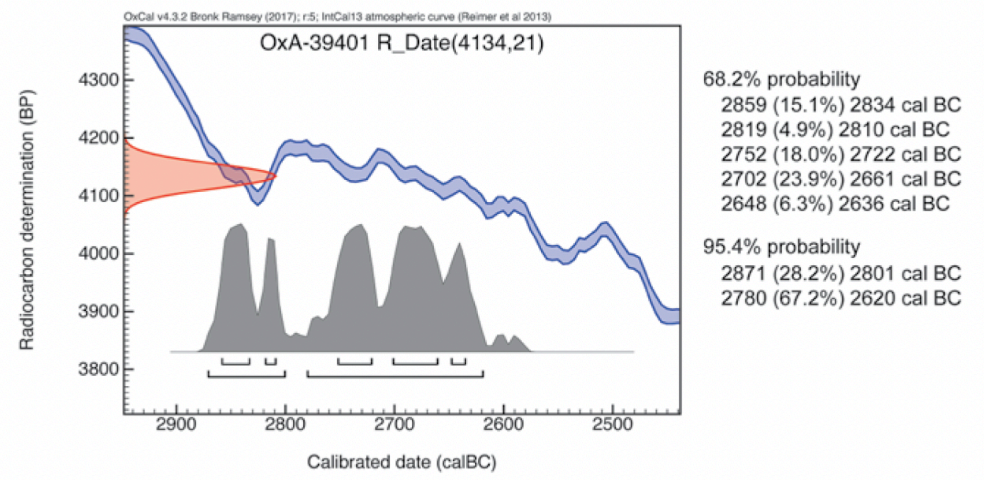


Figure 2. 3. Radiocarbon date of a sample from Margahovit (charred grain of naked wheat, *Triticum aestivum/durum*) from Trench D, Unit 5 (OxA-39,401). Dates were calibrated with OxCal version 4.4 (Bronk Ramsey, 2009) and IntCal20 atmospheric curve (Reimer *et al.*, 2021).

The site is located on Sari Sop hill, in the modern village of Margahovit, Lori region, at an altitude of 1850 m asl. Gevorgyan *et al.*, (2021) argue that Margahovit is a key site surrounded by smaller satellite sites. This is similar to Shengavit's structure in the Ararat plain.

More importantly, there is evidence of metal mines near the site of Margahovit, allowing access to a plethora of raw materials for craft production. Gevorgyan *et al*., (2021) suggest that Margahovit represents a specialised crafts production workshop centre.

The general economy of the site, similar to other KA sites, comprises C_3-based agriculture (analysed by Roman Hovsepyan, Gevorgyan *et al*., 2021), and domestic species of sheep/goat (*Ovis/Capra*), cattle (*Bos taurus*) and some pig (*Sus scrofa*) (analysed by Nina Manaseryan, Gevorgyan *et al*., 2021). Additional faunal remains include deer (*Cervus elaphus*), muflon (*Ovis orientalis*), roe deer (*Capreolus capreolus*) and brown bear (*Ursus arctos*) (Gevorgyan *et al*., 2021; Chahoud *et al*., 2016). Margahovit is located near the Aghtsev river, allowing access to freshwater resources. However, fish bones have not been excavated thus far. The extent of aquatic/fish processing at most of these selected sites is unknown. In terms of craft production, various clay moulds were found in the 2012 excavations (Gevorgyan *et al*., 2021).

2.2.4 Mokhra-Blur

Mokhra-Blur, similar to Shengavit, is located in a lowland zone, with an altitude of 844 masl. It is situated near the settlement of Shengavit (17 km apart). It was inhabited from roughly EB I, with extensive remains of black-burnished Kura-Araxes pottery. Although it is unlikely to have ever been a large settlement, Mokhra-Blur is 3.5 ha. Full analyses on Mokhra-Blur's excavations have not been thoroughly published (Simonyan and Rothman, 2015). Mokhra-Blur's levels (V-IX) contains pottery fragments that parallel with Shengavit's repertoire (Simonyan and Rothman, 2015: 11). However, some scholars see a major difference in typology/technology (Smith *et al*., 2009). Additional scientific analyses on Mokhra-Blur's KA sherds can be informative on similarities of construction techniques between KA settlements. Areshian (2006; 2007) suggests that the Ararat Plain area transformed from basic kinship to incipient polities during the KA horizon. Potsherd samples (n = 13) selected from Mokhra-Blur are poorly contextualised from the excavations of 1976 and 1977. However, they represent the EBA, associated with KA material culture and in close proximity to Shengavit.

2.2.5 Sotk-2

Sotk-2 is situated on the eastern edge of Lake Sevan, located near a popular archaeological and modern mine site, at an altitude of 2100 m asl (Kunze *et al*., 2011). The period corresponds to the end of KA II and the beginning of KA II (ca. 3000-2800 BCE). Domesticates and wild animals include cattle (*Bos taurus*), sheep/goat (*Ovis/Capra*), deer (*Cervus*), dog (*Canis familiaris*), horse (*Equus*), etc.

2.2.6 Talin Tombs

Talin is a multi-layer archaeological site and cemetery dated to the Bronze and Iron Ages (Badalyan and Avetisyan, 2007), at an altitude of 1600 m asl. It is located in the Aragatsotn Marz province. EBA layers include 'cult' enclosures of four tombs (numbered 7, 10, 11, 12) and dated to KA I (Badalyan and Avetisyan, 2007). Common material culture includes chipped obsidian stones, sherds, and walls made of stone (tuff). Faunal remains consist of cattle (*Bos taurus*), sheep/goat (*Ovis/Capra*) and horse (*Equus*). Pottery sherds comprise beakers, bowls, three-handled jars, etc., and are largely unburnished with decorative spirals and geometric motifs (Badalyan and Avetisyan, 2007). Potsherds are selected from Tombs 10-12 'cult structure'.

Sample	Context	Material	Uncalibrated BP	Calibrated BC (2 sigma)
R-2627	Tomb no. 10	Human bones	4230 ± 58	3019-2885
R-2628	Tomb no. 11	Human bones	4448 ± 53	3330-2936

2.2.7 Norabak-1

Norabak-1 (altitude of 2155 m asl) is located near Sotk-2 and dated to the KA II (ca. 3000-2800 BCE). This site is largely unpublished. Its coordinates are N 40° 09 10.1” E 45 52’ 24.9”. Norabak is composed of a fortress and a small necropolis (Guarducci, 2019). Potsherd samples (n=11) are from Trench C, units 3, 4 and 6 (EBA stratigraphic layers).

2.2.8 Karnut-1

Karnut-1 is an EBA hillfort, necropolis and settlement in the Karnut village in the Akhuryan region and Shirak Province of Armenia, at an altitude of 1600 m asl. The western and southern slopes consist of trachytic hills of Surb Minas and Karnut-1 is situated on the western flank of the Pambak range and eastern edge of the Shirak Plain (Badalyan and Avetisyan, 2007: 136). Excavations were carried out in the 1980s and more recently, in 2017-2019. The hillfort extends to about 7-8 ha. Burials are a common feature of this settlement (Aghikyan, 2020), including various vessels with KA ornamentations and bronze artefacts. Radiocarbon dates confirm the last phase of the KA culture, “Karnut-Shengavit” – ca. 2600-2500/2400 BCE (Badalyan, 2014).

Excavations at the site are ongoing. Potsherds from this site were obtained and collected in 2017, July-August field season. Typical potsherds include buff to black-burnished pottery, characteristic of Kura-Araxes features of the “Karnut-Shengavit” group (Badalyan, 2014). The pottery repertoire includes coarse cooking ware, jars with pointed bases, decorated and undecorated jugs, beakers, etc. Estimate of firing temperature is around 600-700 °C, and preliminary petrography reports of a few samples suggest some evidence of a slow-wheel (Badalyan and Avetisyan, 2007: 136). Significantly, organic (straw) temper and non-organic tempers are commonly used (i.e., plagioclase, pumice, dacite, volcanic glass, and amphiboles), between 0.4-2.5 mm (10-20%), including grog (1%). Large vessels (*karas*) and hearth features (andirons) are common at this site. Material culture consists of chipped stones (92% obsidian), including arrowheads (Badalyan and Avetisyan, 2007). Sickle blades are composed of flint, dacite, andesite or andesite-dacite. Ground stone tools include grinding slabs, handstones, pounders, anvils, pestles and mortars, composed of various igneous rocks, such as basalt, dacite, andesite, andesite-basalt, diorite, and slag (Badalyan and Avetisyan, 2007). The faunal economy is meat-based, similar to other KA settlements, cattle (*Bos taurus*), sheep/goat (*Ovis/Capra*), and deer (*Cervus*); however, additional analyses in the archaeobotanical and archaeozoological data are required.

Sample	Context	Material	Uncalibrated BP	Cal BC. (1 sigma)	Cal BC (2 sigmas)
LE-4488	Habitation no. 3	Bone	4490 ± 230	3550-2850	3800-2500
AA-7555	Habitation no. 4	Bone	4220 ± 60	2910-2680	2920-2620
AA-7787	Habitation no. 4	Charred bone	3915 ± 65	2490-2290	2580-2200

2.3 Microscopy

2.3.1 Stereomicroscopy

Stereomicroscopy is used to characterise a full spectrum of potsherds and assess them for further analyses. Macroscopic fabric analyses cover colour (Munsell), hardness, particular texture: type, size, shape and density; non-particular texture: voids, firing (underfired, oxidized, reduced or vitrified), manufacture/forming technique(s), surface treatment, decoration, etc., where applicable. Typological and stylistic descriptions are based on Prudence Rice's pottery analysis handbook (1987; 2015). All potsherds (n = 420) were examined and screened using LEICA EZ4 at RLAHA, School of Archaeology, University of Oxford. Various attributes were recorded (Appendix C). This is a non-destructive method, which allows archaeologists to become aware of a larger assemblage of pottery, where such materials are found in vast numbers at archaeological sites. The process of forming preliminary groups for further analyses can be done this way. Optical light microscopy is used as a common research tool for imaging, screening samples, and understanding the pottery assemblage. Rim diameter, inclusions, length/width and source (local/non-local) could not be recorded sufficiently, due to sampling done at archaeological sites. Rim diameter is only possible to record when the sample is in fact a large piece of rim. Length and width were not recorded, as most potsherds were initially cut from original samples in the field/lab in Armenia. Due to availability of samples, most potsherds selected were fragmented pieces. Visible residues were also recorded, where applicable.

2.3.2 Thin section petrography

Thin-section petrography is employed as the primary method of analysis in reconstructing pottery technology and investigating aspects of raw materials acquisition; it is essential to characterise and classify sherds based on paste, temper and fabric, as well as provide a detailed technological reconstruction. Whitbread (1986; 1989; 1995; 1996), Reedy (2008) and Quinn (2013) are used to classify thin-sections of selected potsherds (n=140). Thin-section petrography is a method used by many archaeomaterials specialists, which can be applied to various materials, including rocks, minerals, slag, concrete, mudbrick, plaster, and fired clays (Peterson, 2009; Reedy, 2008; Quinn, 2013). The most effective analytical methods to address the fabrics of ancient ceramics and pottery are macroscopic fabric analysis (Arnold, 2005; Rice, 1987), microscopic fabric analysis and elemental/chemical identification (Hilditch, 2008; Quinn, 2013). Thin section petrography is a standard method acquired by archaeologists in order to study the microstructure of pottery and ceramic materials (Quinn, 2013). This enables archaeologists to determine and distinguish the differences between samples and groups and/or populations of samples. Consequently, this allows archaeologists to interpret such differences as either the raw material choice or the choices by potters. As part of the *chaîne opératoire* sequence, this method enables a partial reconstruction of the sequence. From clay choice and processing to vessel forming, finishing and firing, these choices may be revealed through the macroscopic examination of fabric, followed by selective sampling for microscopic analyses (Rice, 1987; 2015; Velde and Druc, 1999). Thin-sections were examined using the polarising microscope in the School of Geography and the Environment (GeoLab), University of Oxford (Olympus BX43 model).

The main features of a ceramic fabric can be observed in thin section:

- Nature and characteristics of non-plastic inclusions (mineralogical composition and relative percentage, size, shape, distribution, and orientation of different particles).
- Textural and optical characteristics of the clay matrix (such as birefringence and colour).
- Shape, quantity, and orientation of voids.
- Relationship between the body of the ceramic material and the surface/decoration.

2.3.2.1 Thin-section preparation protocol

Thin-section preparation was conducted at the Earth Sciences department, at University of Oxford. Vertical thin-sections are preferred: rim to body profile. This enables an entire view of the sample in the orientation that potters formed their craft (Quinn, 2013). SEM-EDS samples were either fresh breaks or thin-sectioned samples. In general, samples were cut and sampled using Buehler IsoMet low speed precision cutting machine, diamond-tipped. Sherds were cut on both sides to obtain a flat surface. This provided an equal distribution and pressure when mounting samples on slides, to allow equal distribution of resin during the curing process.

Followed by this, the samples were ground down if they were uneven, using the fine-grinder. Porous samples required additional resin applied on the surface of mounting, in order to avoid fracture and/or breakage. Potsherd samples were then placed on a hot plate to completely dry, 50°C for 2 h. Resin was applied (PETROPOXY 154), 10 parts resin to 1-parts curing agent (PETROPOXY 154) and mixed thoroughly. Sherds were then placed on a hot plate for 5-20 min. Additional resin was applied on samples and further placed on tracing paper to cure on the hot plate. This process allows the resin to reach the potsherd sample's pores. If samples are porous, they were cured for an additional 1 h.

Samples were then ground down using the fine-grinder to obtain a matte surface. Furthermore, they were hand ground on glass plate with Al_2O_3 30s per sample, to reduce cracks and scratches on samples. Samples were further washed and placed on a hot plate to dry completely, 50°C for 2 h. Thin-section glass slides were frosted using LP50 Lapping Machine. Samples were further mounted on thin-section glass slides with a few (2-3) drops of UV-set resin (Loctite AA 358) and placed under UV light for 3min.

Sherds mounted on slides were ground down to ca. 40 μm using Buehler PetroThin machine. Following this step, samples were hand ground to 30 μm using a glass plate and Al_2O_3 + water (and occasionally LP50 Lapping Machine, depending on the thickness). This thickness is estimated by comparing the birefringence colours of known minerals within the section to the Michel-Lévy chart (MacKenzie and Adams, 1994). Quartz grains are often used as a control to obtain the proper thickness. Samples prepared in such a way are commonly analysed under polarised light microscopy and have traditionally been used in petrographic studies to identify inorganic materials and locate their source, to group items with a common source, or, less frequently, to provide information on manufacturing technology. Prior to applying a glass cover, slides were cleaned with Kemet cleaning fluid type CO42 with trigger spray. UV-set resin (Loctite AA 358) was used to apply glass covers on slides and placed under UV light to fully harden, ready for petrographic analyses.

The preparation of thin-section slides for SEM-EDS followed similar protocols above; however, glass slides were not applied, and sherds were polished using Logitech WG2 polishing machine. Consumables used through this process include 0.3 μm aluminium oxide polishing powder, a low nap textile polishing cloth, and distilled water. Thin-sections can be ground down to 600 grade prior to polishing. Samples were rotated for five to six cycles, 15-minute intervals. The thickness required for SEM-EDS is roughly 40-50 μm per section.

2.3.3 Scanning electron microscopy energy dispersive spectroscopy (SEM-EDS)

Potsherd samples were polished and carbon coated to prevent charging. The process of sample prep consists of (1) cutting, (2) mounting, (3) grinding, (4) polishing, and (5) carbon coating. SEM is used to analyse the topographic and morphological features, clay chemistry, as well as the identification of certain grains and/or inclusions. Primarily, SEM-EDS is used to analyse the surface feature technique of black-burnished or black 'polished' pottery associated with the KA culture, including fine-ware potsherds that cannot be analysed macroscopically and through thin-section petrography. Topography means the surface features and texture of the sample's surface and/or clay porosity and content. These features consist of the size and shape of particles, such as morphology. The composition of samples is classified as the elements and compounds that the sample is composed of, including the relative amount and properties. For sample preparation, the protocol was similar to thin-section sample preparation, as most samples were prepared on slides at the Department of Earth Sciences, University of Oxford.

The chemical analysis provides information on the vitreous inclusions, including tuff, volcanic ash, and/or obsidian inclusions evident in the region of Armenia and pottery (Palumbi *et al.,* 2014). SEM-EDS was used at RLAHA, University of Oxford. In general, this method was employed to analyse fine-wares in detail. Furthermore, fresh-break samples were analysed for its microstructure and any notable inclusions. Surface features were recorded, if potsherds were slipped, or if any other technology was visible (i.e., slips, residues, etc.).

2.4 Organic residue analysis

The analysis of amorphous residues preserved in archaeological potsherds has been widely investigated to determine diet, subsistence practices and commodities processed in the past. This is possible through the direct analysis and interpretation of commodities processed and cooked in archaeological vessels. Unglazed potsherds are commonly found at prehistoric archaeological sites. The porosity of pottery provides a medium for preservation of biomolecules and their degradation products, especially due to the inorganic matrix (Hammann and Cramp, 2018). In terms of archaeological artefacts and contexts, lipids are resistant to degradation by chemical and microbial processes and can survive over archaeological timescales (Heron *et al*., 1991; Dudd *et al*., 1999; Evershed, 2008a). As ceramic vessels are widely recovered at archaeological sites and relatively well-preserved, they represent an important class of artefacts in studying past prehistoric cultures. Once produced, they are indestructible; as such, they are important material remains in archaeological research (Tite, 2008).

Lipids are a diverse group of biomolecules, including fatty acids and their derivatives (fats and oils), waxes, steroids and terpenes (Brown and Brown, 2011: 4). Due to the hydrophobic nature of lipids, they can be preserved over time and remain entrapped within a ceramic matrix for thousands of years. Furthermore, their chemical stability and immobility within the burial environment make them essential components as biomarkers (Evershed, 2008).

Table 2. 2. Commodities of interest in organic residue analysis investigations.

Source	**Molecules/biomarkers**	**References**
Ruminant fat	Saturated ($C_{X:0}$) and monounsaturated fatty acids ($C_{X:Y}$).	Copley *et al*., 2003; Dudd and Evershed, 1998; Evershed *et al*., 2002
Dairy fat/adipose fat	Same as above with the addition of short-chain fatty acids. Most identified through isotope values of *n*-$C_{18:0}$ and *n*-$C_{16:0}$.	Copley *et al*., 2003; Dudd and Evershed 1998; Heron *et al*., 2015
Plants	*n*-$C_{18:0}$, *n*-$C_{16:0}$ and unsaturated fatty acids, e.g., $C_{18:1}$; hydroxy fatty acids, dicarboxylic acids, diacids, and *n*-alkanes.	Reber and Evershed, 2004; Copley *et al*., 2005; Stern *et al*., 2003; Colonese *et al*., 2017; Dunne *et al*., 2016; Dunne, 2021; Heron *et al*., 2016
Resins and tars	Terpenoids and diterpenoids.	Charters *et al*., 1993; Urem-Kotsou *et al*., 2002; Rageot *et al*., 2015; Rageot *et al*., 2019; Regert, 2004; Pollard *et al*., 2017
Leafy waxes	Wax esters, long-chain alkanes and alkanols, and even number $C_{X:0}$ above carbon chain lengths of $C_{14:X}$.	Charters *et al*., 1993 Evershed *et al*., 1991
Aquatic and marine	Dihydroxy acids, isoprenoid fatty acids, and APAAs (w-(o-alkylphenyl)alkanoic acids.	Copley *et al*., 2004; Hansel and Evershed, 2009; Cramp and Evershed, 2014; Cramp *et al*., 2014a; Cramp *et al*., 2014b; Cramp *et al*., 2019; Hansel *et al*., 2004; 2011; Lucquin *et al*., 2016; Shoda *et al*., 2017; Admiraal *et al*., 2020; Bondetti *et al*., 2020
Cooking temperature	Ketones	Evershed *et al*., 1995

Analysis of lipids preserved in pottery can identify plant, dairy, and meat sources being prepared and processed (Evershed, 1993; 2008). One of the most common lipids detected include fats and oils, which are preserved as triacylglycerols or their hydrolysis products, diacylglycerols, monoacylglycerols and free fatty acids (Stern *et al.*, 2003; Reber and Evershed, 2004). Significantly, waxes, resins, tar and pitch, can reveal plant and/or animal resources that were processed in vessels.

Miller *et al.*, (2020) claim that charred residues are one cooking event but absorbed residues generally represent a combination of cooking events, which is why absorbed residues are explored in this thesis. Significantly, charred surface residues may also originate from exogenous sources (Heron *et al.*, 1999), such as soil lipids and the burial environment (Eglinton and Logan, 1991). Therefore, sampling and cleaning sherds are important tasks prior to extraction of lipids and analyses. In general, there are sooting or cloudy patterns on ceramics if cooked. Despite the plethora of organic residue analysis studies in the past decades, no organic residue analysis has yet been performed on Kura-Araxes pottery and data from the South Caucasus is lacking.

2.4.1 Archaeological biomarkers

A number of archaeological biomarkers can be investigated through lipid residue analysis (Appendix D). For this thesis, terrestrial animal fats, aquatic commodities and plant lipids were targeted, in order to define pottery use and reconstruct the Kura-Araxes economy.

2.4.1.1 Terrestrial animal fats

The most commonly identified residues found in pottery vessels originate from degraded animal fats, characterised by distributions of free fatty acids, monoacylglycerols (MAG), diacylglycerols (DAG) and triacylglycerols (TAG; Dudd *et al.*, 1999) (see Table 2.3). Terrestrial lipids are commonly identified by the dominance of the *n*-hexadecanoic ($C_{16:0}$) and *n*-octadecanoic ($C_{18:0}$) fatty acids, either free or as mono-, di-, and triacylglycerols (Copley *et al.*, 2003). Saturated fatty acids ($C_{16:0}$ and $C_{18:0}$) have been used to characterise the origin of animal fats and classify them as domesticated ruminant, non-ruminant animals, and between ruminant dairy and adipose fats (Evershed *et al*., 1997; Dudd *et al*., 1999; Mottram *et al*., 1999; Copley *et al*., 2003; Roffet-Salque *et al*., 2017). Degradation experiments confirm the predominance of free fatty acids (Charters *et al*., 1997; Dudd, 1998; Evershed, 2008). Fatty acids are divided into two classes, depending on the structure of the hydrocarbon chain: saturated or unsaturated (Brown and Brown, 2011: 55) (Table 2.2). A challenging task is to identify milk-derived compounds from short chain fatty acids ($C_{4:0}$ to $C_{12:0}$), as they are present naturally in sediments (Copley *et al*., 2003: 1527). Branched chain fatty acids, such as C_{15} and C_{17}, are biomarkers of the bacterial action involved in ruminant lipid biosynthesis; however, due to alterations in the burial environment, they are not reliable indicators (Dudd *et al*., 1998; Mottram *et al*., 1999). Thus, additional characterisation methods are required in identifying terrestrial animal fats; this is accomplished through compound-specific stable isotopic analysis of the fatty acids (n-$C_{16:0}$ and n-$C_{18:0}$) (Cappellini *et al*., 2018).

Additionally, long mid-chain ketones are characteristic of heating vessels at high temperatures (~400 °C). The presence of these compounds within potsherds is indicative of heating vessels, thereby assigning vessels used for cooking rather than storage or other functions (Evershed *et al*., 1995; Raven *et al*., 1997).

Table 2. 3. Fatty acids (obtained from Brown and Brown, 2011: 55, Table 4.1).

Structural designation	Common Name, Systematic Name
Saturated	
12:0	Lauric acid, dodecanoic acid
14:0	Myristic acid, tetradecanoic acid
16:0	Palmitic acid, hexadecenoic acid
18:0	Stearic acid, octadecanoic acid
20:0	Arachidic acid, eicosanoic acid
22:0	Behenic acid, docosanoic acid
24:0	Lignoceric acid, tetracosanoic acid
Monounsaturated	
16:1	Palmitoleic acid
18:1	Oleic acid
Polyunsaturated	
18:2	Linoleic acid
18:3	Linolenic acid
20:4	Arachidonic acid

2.4.1.2 Aquatic biomarkers

New research in organic residue analysis and experimental archaeology of marine and freshwater lipids have identified various aquatic biomarkers (Hansel *et al*., 2004; Hansel *et al*., 2011; Cramp and Evershed, 2014; Cramp *et al*., 2019; Bondetti *et al*., 2021). Polyunsaturated fatty acids (PUFAs) are found in aquatic commodities (Passi *et al*., 2002). Due to oxidative degradation during vessel use and the burial environment (Evershed *et al*., 2008a), polyunsaturated fatty acids do not survive. Biomarkers associated with the processing of aquatic and/or marine sources include isoprenoid fatty acids and *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs). Isoprenoid fatty acids (IFAs) include 4,8,12-trimethyltridecanoic acid, (3,7,11,15)-tetramethylhexadecanoic acid (phytanic acid), and 2,6,10,14-tetramethyl pentadecanoic acids (pristanic acid). These fatty acids are derived from the metabolism of phytol in marine algae and occur naturally in herbivore animal tissues and aquatic organisms (Cramp and Evershed, 2014). As they occur in non-aquatic organisms as well, additional aquatic biomarkers alongside the detection of isoprenoid fatty acids can aid in the interpretation of the exploitation of aquatic commodities. However, IFAs are found at high concentrations in marine animals, and they are resistant to degradation, as they can survive in the food chain (Cramp and Evershed, 2014).

APAAs are stable biomarkers and do not occur in nature but are produced when unsaturated fatty acids ($C_{16:3}$, $C_{18:3}$, $C_{20:3}$, and $C_{22:3}$) are subjected to heating >200 °C within the potsherd matrix (Matikainen *et al*., 2003; Hansel *et al*., 2004; Evershed *et al*., 2008a; Bondetti *et al*., 2021). Additionally, the metal oxides and salts (Ca, Fe, Mg, K and Na) associated with a potsherd's matrix act as a catalysing agent, isomerising the unsaturated double bonds of APAAs (Rice, 1987; Evershed *et al*., 1995; Evershed *et al*., 2008a; Hansel *et al*., 2004). APAAs are present in very small quantities, but mass spectrometry in selected ion monitoring (SIM) mode can detect these compounds with high sensitivity. The use of SIM increases sensitivity and targets APAA carbon chain lengths C_{16} to C_{22} and the fragment ion of the base peak *m/z* 105. For this thesis, potsherds were screened in order to assess the quantity of aquatic biomarkers and whether freshwater resources were exploited, as most of the KA settlements examined are located within the vicinity of freshwater lakes and river systems. To date, there is no evidence for the processing of aquatic commodities in pottery vessels from any KA South Caucasus settlements (Wilkinson, 2014b).

2.4.1.3 Plant lipids, waxes and resins

Plant exploitation is relatively unexplored in organic residue analysis, specifically from the Ancient Near East and South Caucasus region. Resistant to degradation, the distribution of long-chain constituents of epicuticular waxes are indicative of lipids of plant origin. The combination of *n*-alkanes, *n*-alkanols, α,ω-dicarboxylic acids (diacids), α,ω-hydroxyacids, even numbered long-chain fatty acids (LCFAs) and ketones are indicative of plant processing (Eglinton and Hamilton, 1967; Diefendorf *et al*., 2011; Dunne *et al*., 2016; Dunne, 2021). Plant waxes typically occur in the *n*-C_{25} to *n*-C_{35} range with a dominance of odd over even carbon number (Eglinton and Hamilton, 1967). *N*-alkanols display an even/odd carbon number predominance (*n*-C_{20} to *n*-C_{34}) (Eglinton and Hamilton, 1967). Long-chain ketones are also constituents of plant epicuticular waxes (Kolattukudy, 1976) and can range between C_{24} to C_{33} (Evershed *et al*., 1995; Raven *et al*., 1997). As mentioned, the processing and heating of animal fats in archaeological pottery can also yield long mid-chain ketones. However, plant sources can be individually identified as *Brassica oleracea* (cabbage) (*n*-nonacosan-15-one); for example, from a Late Saxon/Medieval cooking vessel (Evershed *et al*., 1991; Charters *et al*., 1997). Furthermore, direct evidence of millet can be detected through the identification of the biomarker, miliacin (Heron *et al*., 2016).

Based on the preservation of *n*-alkanes in lipid extracts, it is possible to explore the nature of lipid distributions in pottery, to define whether plant lipids are derived from the burial environment or processed by humans. Calculations include, but are not limited to, palmitic/stearic acid ratios (P/S ratio), carbon preference index (CPI), P_{aq} proxy ratio and compound-specific $\delta^{13}C$ values. These calculations are further discussed in Chapter 4, applied to Kura-Araxes potsherds with plant lipid profiles. In particular, CPI is calculated to indicate whether the *n*-alkanes derive from terrestrial plants or oil-derived *n*-alkanes. A CPI > 1.6 is typically characteristic of terrestrial plants, whereas a CPI close to 1 is oil-derived (for calculations: Rommerskirchen *et al.,* 2006; Freeman and Pancost, 2014; Herrera-Herrera *et al*., 2020). Additionally, the $\delta^{13}C$ values of plant wax can aid archaeologists in determining the source of plants (i.e., C_3 or C_4 plants). These values can also serve as proxies for environmental reconstruction (Dunne *et al*., 2016).

Terpenes are one of the largest lipid classes of natural products, which include thousands of compounds, synthesised by plants and with a variety of functions, including disease resistance, signalling, and protection against predator attack, as well as involvement in important physiological processes such as photosynthesis (Brown and Brown, 2011: 54). Terpenes are made by plants, and many are specific for a single or small group of species that can be classified as biomarkers. These compounds are components of derivatives of resins such as adhesives, varnishes, incense, perfume, etc. (Brown and Brown, 2011: 59; Pollard *et al*., 2017). Modified terpenes are called terpenoids and vary in structure. The resinous terpenoids of pine, spruce and birch were exploited in the past as pitches, tars, and adhesives (Brown and Brown, 2011: 60). Coniferous resins of pine and spruce are composed of diterpenoids, abietic acid and pimaric acid (Mills and White, 1994).

The use of birch bark tar is widely documented in prehistory and utilised as hafting, waterproofing and/or repairing pottery vessels (Dudd and Evershed, 1999; Urem-Kotsou *et al.*, 2002; Lucquin *et al.*, 2007; Rageot *et al.*, 2019). Aside from the use of prehistoric technology, birch bark tar compounds have clinical applications as anti-inflammatory agents and may have been used for this purpose by some prehistoric groups (Brown and Brown, 2011: 60). Terpenoid compounds associated with birch bark tar include betulin, lupenone, lupeol and further degradation products (Aveling and Heron, 1998; Brown and Brown, 2011; Regert, 2004; Rageot *et al.*, 2019).

Biomarkers for the exploitation of higher plants include di- and triterpenoids (Hayek *et al.*, 1990; Charters *et al.*, 1993; Mills and White, 1994). These compounds are formed through the pyrolysis of resinous wood and processed into tars and pitches (Evershed, 1993; Mills and White, 1994). Additionally, pine resin is one of the most widespread commodities in antiquity (Colombini and Modugno, 2009). These compounds derive from Pines (*Pinus*), part of the Pinaceae family, largely available in the South Caucasus, as mentioned in Chapter 1. Resins from *Pinus* sp. are identified with the presence of the following biomarkers: abietic acid, dehydroabietic acid, primaric and isoprimaric acid (Pollard and Heron, 2008). Similar to birch bark tar's prehistoric uses, resins can be used as adhesives and waterproofing as well (Pollard and Heron, 2008; Rageot *et al.*, 2019).

2.4.2 Lipid extraction protocol

The preparation of samples was conducted at RLAHA, University of Oxford. Extraction and instrument analyses were completed at the Department of Chemistry, Organic Geochemistry Unit, University of Bristol. Tweezers and foil were used to handle samples. All potsherds selected for analysis were wrapped in aluminium foil to prevent contamination. Blanks were also prepared and analysed with the samples to prevent contamination during the extraction procedure. Lipid analysis and interpretations were performed using established protocols, discussed in detail in various publications (Dunne *et al.*, 2016; Whelton *et al.*, 2018;

Correa-Ascencio and Evershed, 2014). This extraction protocol heightens the yield of fatty acid methyl esters. Regert *et al.*, (2003: 1621) claim that one of the most important critical assessments in an ORA (organic residue analysis) study is to conduct the extraction protocol that will reveal compounds of interest. Solution and solvents should be clear and not contain any solid materials. Some solutions can exhibit yellow/orange transparency, indicating the high content of fatty acids or other lipid classes (i.e., terpenes).

All solvents used were HPLC grade (Rathburn) and the reagents were analytical grade (typically >98% of purity). All glassware was washed with Decon 90 (Decon Laboratories), acetone and dichloromethane (DCM), and further sterilized in the oven at 450 °C for 4 h. The syringes used during the extraction were solvent-rinsed (hexane, x10 and ethyl acetate, x10) before and after their use, and all the other tools were solvent-sonicated (15 min in dichloromethane [DCM]). For each lipid extraction batch (11 samples), analytical blanks were prepared in order to detect potential contamination from solvents or reagents. Rim and upper body sherds were selected for analysis, where possible, due to higher concentration of lipids preserved (Charter *et al*., 1993).

Briefly, ca. 2 g of potsherd were cleaned with a modelling drill to remove exogenous lipids, and further ground to homogenous powder, and transferred into culture tubes. An internal standard (IS) was added to enable quantification of the lipid extract (*n*-tetratriacontane, typically 20-40 μg), prior to methanolic acid extraction. The lipids were then esterified and/or transesterified using 5 mL of 2% sulfuric acid/methanol solution ($\delta^{13}C$ measured to correct for GC-C-IRMS measurements, see section 2.4.5.2) and heated for 1 h at 70 ℃ mixing every 10 min. The supernatant was removed to a clean test-tube and 2 mL of (DCM) extracted double-distilled water added. The remaining potsherd was washed with 5 mL of hexane and transferred to test-tubes before centrifuging (2500 rpm, 10 min). The hexane supernatant was then transferred to the sulfuric acid-methanol solution and whirlimixed to extract the lipids before being transferred to a vial, and a further 3 × 3 mL of hexane was added to the H_2SO_4-methanol solution. The hexane extracts were combined, and the solvent was removed under a gentle stream of nitrogen in a heating block at 40 °C. An aliquot of the extract was treated with *N,O*-bis(trimethylsilyl)trifluoroacetamide (BSTFA) for derivatisation, containing 1% *v/v* trimethylchlorosilane (Sigma Aldrich) prior to analysis via GC-FID, GC-MS and GC-C-IRMS.

2.4.3 Gas Chromatography-Mass Spectrometry (GC-MS)

GC-MS is an instrumental technique, comprising a gas chromatograph (GC) coupled to a mass spectrometer (MS), by which complex mixtures of chemicals may be separated, identified, and quantified (Pollard *et al*., 2017). Instruments and instrument conditions for GC-MS followed protocols outlined in various publications (Whelton *et al*., 2018). Analyses of acid extracted fatty acid methyl esters (FAMEs) total lipid extracts (TLEs) were performed using an Agilent 7890A gas chromatograph. The FID (Flame Ionisation Detector) used to monitor column effluent was set to 300 °C. Trimethylsilylated FAMEs were introduced to the system via on-column injection (1.0 µL). Data was acquired using HP Chemstation software (Rev. C.01.07[27] Agilent Technologies) and eluted peaks were identified by comparison of retention times with those of an external standard (FAME), quantification was calculated using a known amount of internal standard introduced during sample preparation.

GC-MS analyses of trimethylsilylated FAME aliquots were performed using ThermoScientific Trace 1300 gas chromatograph couple to an ISQ single quadrupole mass spectrometer. Samples were introduced to an injector set to splitless mode. The GC temperature programme was set to hold at 50 °C for 1 min, followed by a gradient increase to 300 °C at 10 °C min, once at 300 °C the oven was run isothermally for 10 min. The MS was operated in electron ionisation (EI) mode operating at 70 eV, with a GC transfer line temperature of 300

°C and a source temperature of 300 °C. The emission current was set to 150 µA and the MS was set to acquire in the range of *m/z* 50-650 at 2 scans s^{-1} in full scan mode.

For the detection of *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs) and isoprenoid fatty acids, TLEs were injected onto a 60 m × 0.32 mm fused silica capillary column coasted with a VF-23ms stationary phase (50% cyanopropyl-methylpolysiloxane, Varian, Factor Four 0.15 µm). The GC temperature programme was set to hold at 50 °C for 2 min, followed by a gradient to 100 °C at 10 °C min^{-1} and then to 240 °C at 4 °C min^{-1} before a final isothermal at 240 °C for 15 min. Helium was used as the carrier gas and maintained at a constant flow of 2 mL min^{-1}. The MS was operated in electron ionisation (EI) mode operating at 70 eV, with a GC transfer line temperature of 250 °C and a source temperature of 200 °C, the emission current was set to 150 µA. The MS was set to operate in selected ion monitoring (SIM) mode, scanning for the molecular ions ($M^{+\bullet}$) for APAAs of carbon chain lengths C_{16} to C_{22} at *m/z* 262, 290, 318 and 346 and the fragment ion of the base peak *m/z* 105 (Cramp and Evershed, 2014), and IFAs (the fragmentation of 4,8,12-trimethyltridecanoic acid was identifiable with ions *m/z* 87, 213, 270; pristanic with ions *m/z* 88, 101, 312; and phytanic with ions *m/z* 101, 171, 326). Data acquisition and processing were carried out using XCalibur software, version 3.0. Compounds were identified by comparison with the NIST mass spectra library (version 2.0) or with reference to external sources such as The Lipid Library (www.lipidlibrary.aocs.org), for the identification of APAAs mass chromatograms were compared to an archaeological standard known to contain C_{16}, C_{18}, C_{20} and C_{22} APAAs.

2.4.4 Compound-Specific Isotopic Analysis

Compound-specific isotope analysis is regularly used to assess lipids residues absorbed in archaeological pottery vessels, which provide information on the source organism. Due to the differential routing of dietary carbon and fatty acids during biosynthesis of adipose and ruminant fats, it is possible to identify the animal commodity based on isotopic differentiation (Copley *et al.,* 2003; Capellini *et al*., 2018). The metabolic differences result in specific $\delta^{13}C$ values for non-ruminant, ruminant adipose fat, and ruminant dairy (Dudd, 1998; Copley *et al*., 2003; Mukherjee *et al*., 2007). The difference in $\delta^{13}C$ values for the saturated *n*-$C_{18:0}$ fatty acid can distinguish between ruminant adipose and dairy fats (Copley *et al*., 2003). Significantly, the $\Delta^{13}C$ ($\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) value, plotted against the $\delta^{13}C$ value of the *n*-$C_{16:0}$ fatty acid can characterise the animal fat to its taxonomic origin, i.e., non-ruminant adipose fats, ruminant adipose fats, ruminant dairy fats, as well as fats of aquatic origin (Evershed *et al*., 1997; Dudd, 1998; Evershed *et al*., 1999; Copley *et al*., 2004; Evershed *et al.,* 2008a; Cramp and Evershed, 2014). Moreover, the $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values of adipose fat from animals raised on a diet with a C_4 or aquatic input will cause an enrichment and offset from those animals with a diet comprising terrestrial C_3 plants.

2.4.4.1 Gas Chromatography-Combustion-Isotope Ratio Mass Spectrometry (GC-C-IRMS)

Compound specific carbon stable isotope analyses (*n*-$C_{16:0}$ and *n*-$C_{18:0}$) were performed using an Agilent Industries 7890A gas chromatograph coupled to an IsoPrime 100 mass spectrometer. Samples were introduced via a split/splitless injector in splitless mode onto a 50 m × 0.32 mm fused silica capillary column coated with a HP-1 stationary phase (100% dimethylpolysiloxane, Agilent, 0.17µm). The GC oven temperature programme was set to hold at 40 °C for 2 min, followed by a gradient increase to 300°C at 10°C min^{-1}, the oven was then run isothermally for 10 min. Helium was used as a carrier gas and maintained at a constant flow of 2 mL min^{-1}. The combustion reactor consisted of a quartz tube filled with copper oxide pellets which was maintained at a temperature of 850 °C. Instrument accuracy was determined using an external FAME standard mixture (C_{11}, C_{13}, C_{16}, C_{18}, C_{21}, and C_{23}) of known isotopic composition (determined using a two-point calibration using IAEA-CH-7 (δ^{13}C value = -32.2 ± 0.05 ‰) and FIRMS phenacetin (δ^{13}C value = -26.7 ± 0.2 ‰). Samples were run in duplicate and an average recorded (difference between duplicates < 0.5 ‰). The δ^{13}C values are the ratios $^{13}C/^{12}C$ and expressed relative to the Vienna Pee Dee Belemnite, calibrated against a CO_2 reference gas of known isotopic composition. Instrument error was ±0.3‰. Data processing was carried out using Ion Vantage software (version 1.5.6.0, IsoPrime Elementar).

2.4.5 Data Processing

2.4.5.1 Quantification of lipids from archaeological pottery

To determine the concentration of absorbed lipid residues within each potsherd, calculation was based on the known amount of the internal standard, *n*-tetratriacontane (C_{34} *n*-alkane). For each analysis, 20 µg of IS was added to the crushed potsherd. The concentration of lipids in the total lipid extracted was calculated using the following formula, where C_{LIPID} = concentration of lipids in the total lipid extract (in µg g^{-1}), A_{IS} = peak area of internal standard (in %), A_{CONT} = sum of the peak areas of contamination (in %), V_{IS} = volume of the internal standard added (in µL), C_{IS} = concentration of internal standard (in mg mL^{-1}), and M_{SHERD} = mass of powdered sherd extract:

$$C_{LIPID} = \frac{((100 - (A_{IS} - A_{CONT}) \times (V_{IS} \times C_{IS})}{A_{IS} \times M_{SHERD}}$$

2.4.5.2 δ¹³C values

The δ^{13}C values are calculated relative to the VPDB standard, where $\delta^{13}C_{SAMPLE}$ = δ^{13}C values of the sample (in ‰), R_{SAMPLE} = $^{13}C/^{12}C$ in the sample, and $R_{STANDARD}$ = $^{13}C/^{12}C$ in the standard:

$$\delta^{13}C_{SAMPLE} = \left(\frac{R_{SAMPLE}}{R_{SHERD}} - 1\right) \times 1000$$

An average of $\delta^{13}C$ values obtained from duplicate analyses was used to calculate $\delta^{13}C_{FA}$ for each archaeological sample. To ensure instrument stability, an external standard consisting of a mixture of five FAMEs (n-$C_{11:0}$, n-$C_{13:0}$, n-$C_{16:0}$, n-$C_{21:0}$, n-$C_{23:0}$) of known isotopic composition was run immediately before and after archaeological samples. Results were calibrated against a CO_2 reference gas injected directly into the ion source as two pulses at the beginning of each sample run.

The $\delta^{13}C$ measured for each sample was corrected to consider the exogenous carbon added after methylation. The determination of the corrected $\delta^{13}C_{FA}$ values was performed according to the following mass balance equation (Rieley, 1994) where, $\delta^{13}C_{FA}$ = $\delta^{13}C$ of the original fatty acid (in ‰), $\delta^{13}C_{FAME}$ = measured $\delta^{13}C$ of the FAME (in ‰), $\delta^{13}C_{CH_3OH}$ = measured $\delta^{13}C$ value of the CH_3OH used for methylation, no.C_{FAME} = total number of carbon atoms in the FAME, and no.C_{FA} = total number of carbon atoms in the fatty acid:

$$\delta^{13}C_{FA} = \frac{(\text{no.}\,C_{FAME} \times \delta^{13}C_{FAME}) - \delta^{13}C_{CH_3OH}}{\text{no.}\,C_{FA}}$$

2.5.5.3 Statistical application of the data

Statistical analysis of the data was carried out using Microsoft Excel and RStudio, Inc. (Version 1.2.5033). Through the latter software, visuals and data presentation were created through box and whisker plots and scatter graphs, primarily for lipid residue data.

CHAPTER 3

Pottery technology at Kura-Araxes Settlements in Armenia: Microscopy Analysis

3.1 Introduction

This chapter presents and discusses results from stereomicroscopy, scanning electron microscopy energy dispersive spectroscopy (SEM-EDS), and thin-section petrographic analyses, through the examination of pottery samples from various Kura-Araxes sites in Armenia, as introduced in Chapter 2.2. All potsherd samples were analysed macroscopically (and with a stereomicroscope), in order to select appropriate samples for SEM-EDS, thin-section petrography, and lipid residue analysis. This chapter culminates an analysis of 420 KA pottery samples from Armenia, macroscopically, an analysis of 17 thin-walled fine-ware potsherds *via* SEM-EDS, and 140 thin-sections of potsherds for petrographic analyses from selected Kura-Araxes settlements (see Appendix A for typology). Fine-wares are thin-walled and difficult to assess macroscopically and through thin-section petrography. This term is not to be confused with fine-grained, where sherds exhibit very fine inclusions (i.e., 0.01-0.25 mm). Thus, representative potsherd samples were selected for SEM-EDS analyses (fine-wares and mostly black-burnished).

The most effective analytical approaches to analyse pottery fabrics are macroscopic and microscopic methods, including elemental and chemical identification of inclusions (Rye, 1981; Hilditch, 2008; Quinn, 2013). This level of analysis will provide information on the manufacturing technique, including a closer analysis of how the inclusions are aligned to determine pottery production, clay processing, burnishing and/or addition of slips, temper, possible firing temperature, and variability of clay. Furthermore, aspects on provenance and/or use of specific clays can be explored with the aid of geological maps and published geological data.

Section 3.2 addresses the visual characteristics of pottery, primarily its surface and components of the pottery fabric. These results will open the main groundwork for Sections 3.4 and 3.5, which will focus on a detailed petrographic analysis of Kura-Araxes potsherds. Results from these chapters will feed into the overall discussion in Section 3.5. Furthermore, Chapter 5 will combine and synthesise the results and discussion from this chapter concerning the research framework's theme of *transformation* and *transmission* of pottery technology across Kura-Araxes settlements in Armenia.

3.1.1 Aims of ceramic analysis and petrography

The aims of petrographic analyses are highlighted in Chapter 2; however, it is important to highlight the theoretical premise of ceramic analyses and the research questions introduced in Chapter 1. In brief, the main aim of this chapter is to investigate how KA vessels were made and reconstruct the *chaîne opératoires*; through the following:

- Is there technological change or continuity across Kura-Araxes settlements in Armenia?
- Are potters producing pottery in a similar fashion (i.e., homogenous fabrics); are KA vessels products of mass production due to the homogeneous style?
- What are the main raw material(s) that formed the KA pottery repertoire?

It is useful to reiterate the contribution of petrographic analyses in pottery studies. The three main tasks associated with petrographic analyses include (1) classification and grouping through fabric description, (2) evaluation of technology production (i.e., aspects on forming methods, firing and surface treatment), and (3) determining provenance and/or selectivity of the clay use. The combination of these tasks forms the basis for interpreting pottery technology.

Task one is the first step and provides the basis and raw data for tasks two and three. The correct identification of the constituent minerals and other phases draws on a knowledge of the local geology. Moreover, the evaluation of technology production (2) forms the basis for interpreting the *chaîne opératoire*. This methodological framework requires an understanding of the selectivity of clay use, in order to model the range of clays that potters could have selected (i.e., provenance). The *chaîne opératoire* order of pottery production is the following: raw materials and paste preparation, forming of the vessel and shape, firing, surface treatment, use, and discard (Figure 3.1; Hommel *et al.*, 2017: 141; Roux and Courty, 2019: 15; Doherty, 2013a; 2013b). The *chaîne opératoire* step concerning 'use' of pottery will be presented and discussed in Chapter 4 (organic residue analyses).

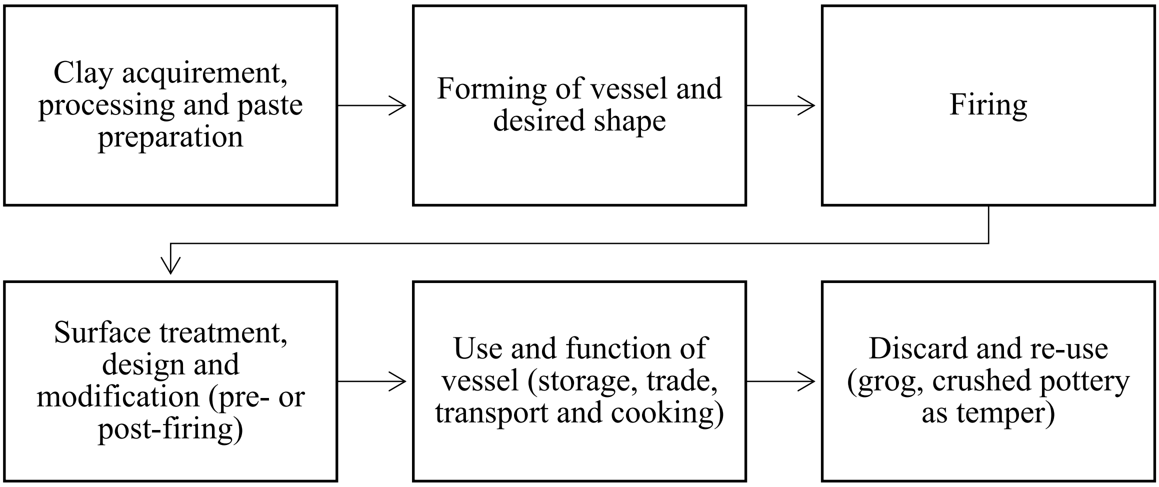


Figure 3. 1. *Chaîne opératoire* sequence and the pottery technology scheme (i.e., life history of a ceramic vessel); modified from Hommel *et al.*, (2017: 141).

In order to complete the *chaine operatoire* sequence, knowledge of the geological framework of the studied site and region of interest is required. The tasks mentioned above (1-3) are socially-embedded and related to the potter's choices. The correct identification of minerals and other phases draws on knowledge of the local geology and other modified features (i.e., mineral phase alterations due to weathering or firing temperature). The determination of the production sequence (2) requires an understanding of textural features, clay availability and use, and other factors such as porosity (voids) and the alignment of inclusions. Based on these observations, inferences on the source of clays and provenance (3) are suggested.

Petrographic analysis can be complicated due to the natural weathering and alteration of many minerals, obscuring some of the diagnostic optical properties. Other complications can be transformation of many minerals caused by the firing process, as well as the fine grain size of the clay matrix. If light microscopy limits the identification of certain inclusions and fine-grained areas, it was supplemented by SEM-EDS (Section 3.4).

3.1.2 Methodology

As mentioned in Chapter 2, all samples were initially observed using low-magnification stereomicroscopy in the state in which potsherds were provided (i.e., fragmentary) to record macro-characteristics (i.e., overall colour, colour distribution, presence of mica and/or noticeable inclusions, surface treatment, etc.) (see Figure 3.2). Next, the sherds were prepared as standard petrographic thin-sections following impregnation with epoxy resin (see Chapter 2.3 for detailed methodology; Quinn, 2013). Thin sections were examined using a polarising microscope to record the nature of the inclusions and clay matrix, i.e., the fabric of the sherd. The comparison of crossed and plane polarised transmitted light of potsherd thin-sections allows the identification of various mineral and rock constituents.

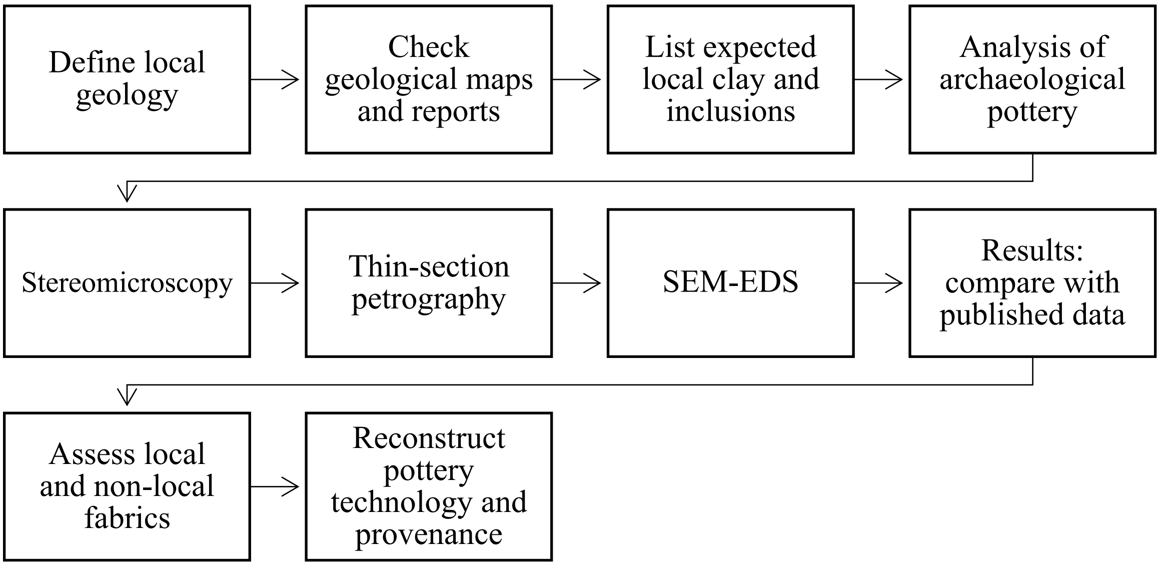


Figure 3. 2. Outline of microscopic analyses and sequence of methods used for determining pottery technology.

Compositionally, these fabrics are complex, containing a relatively large suite of minerals and other inclusions. This is consistent with the highly varied geology of Armenia (see geological map, Figure 3.3, Table 3.1; refer to geology legend in Appendix C). The petrography is further complicated due to natural weathering of many of the minerals, obscuring some of their diagnostic optical properties; transformation of many minerals due to firing; and the very fine grain size.

3.1.3 The importance of the geological context

It is important to highlight the geological context of Armenia, as it is compositionally complex, containing a relatively large suite of minerals and other inclusions (Figure 3.3, Table 3.1). Discriminating between locally produced pottery and that which may have been traded, demands a comprehensive understanding of the compositional characterisation of the local clay. Pottery provenance studies involve the sampling of clay sources near and at the site. Unfortunately, obtaining clay samples for thesis was not possible; however, the clay paste, and availability of raw materials were modelled indirectly, using geological maps (Kharzyan, 2005). Modelling from published maps provides a prediction of the type of inclusions and rocks likely present in local clays (Table 3.1).

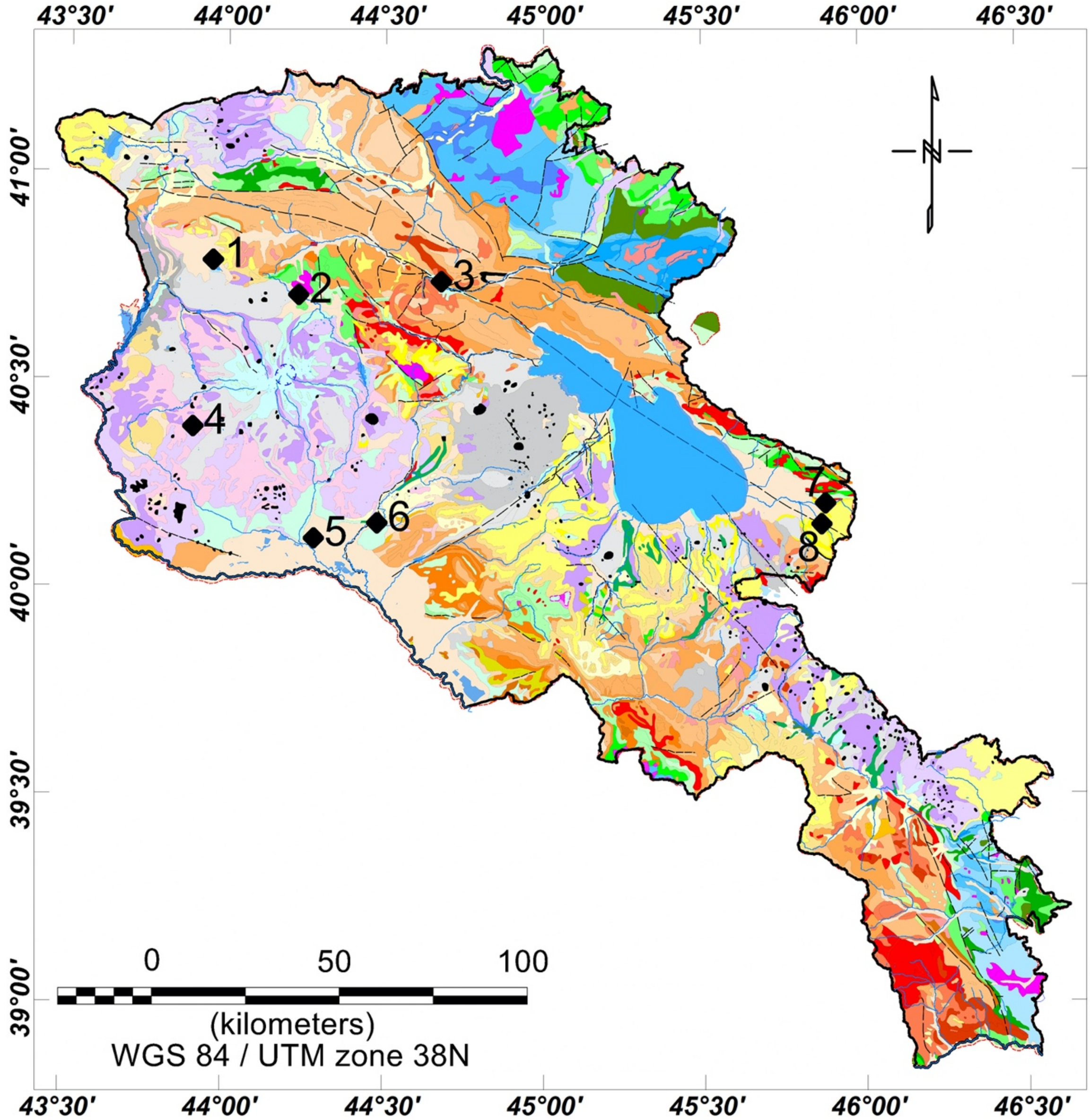


Figure 3. 3. Geological map of Armenia with archaeological settlements examined in this chapter, (1) Karnut-1, (2) Gegharot, (3) Margahovit, (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1; modified from (Kharzyan, 2005).

Table 3. 1. The geology of Armenia; predicted characteristics of Armenia clay; summary of the main rock types within the region of interest. This is based on a survey of the following geological maps and published reports: (Kharzyan, 2005).

Site	Geology
Gegharot	Mesozoic – marine-sedimentary rocks. Limestones, marls, dolomites and limestone (550 m). Intrusive rocks; albites, gneiss, granites, serpentines, gabbros, gabbrodiorite. Cretaceous – marine volcano-sedimentary rocks; sandstones, limestimes, marls, alevrolites, tuff-alevrolites, layers of tuff-alevrolites (500 m).
Karnut-1	Jurassic – marine volcanic-sedimentary rocks. Andesites, andesite-basalts, diabases, conglomerates (600 m). Cenozoic – terrigenous molassic sediments. Hrazdan, Dilijan, Bandivan, suites; part-coloured reddish clays, sandstones, alevrites, conglomerates, with layers of schists and dark coals (550 m). Quaternary – lacustrine, alluvial sediments of Shirak, Aparan, Araratian sands, clays, pebbles, diatomites; loess clay-soils (130 m). Quaternary – volcanic lava flows and lava floods; andesite-basalts, dacites (1500 m).
Margahovit	Quaternary – volcanic lava flows, basalts, andesite-basalts, andesites, andesite-dacites (35 m). Cenozoic – marine volcanogenic formations; andesites, andesite-basalts, their pyroclastic rocks, lava-breccias, tuff-breccias (500 m).
Mokhra-Blur	Quaternary – lacustrine-alluvial, flood alluvial, alluvial slope sediment, pebbles, sands, sandsoils and sand loams (30 m); volcanic lava flows, basalts andesite-basalts, andesites, andesite-dacites (35 m).
Norabak-1 Sotk-2	Quaternary (Holocene) – lacustrine-alluvial, flood alluvial, alluvial slope sediment, pebbles, sands, sandsoils and sand loams (30 m). Intrusive rocks – porphyraceous granites and granodiorites; extrusive subvolcanic intrusions; trachy-andesites and trachy-rhyolites. Olivines, olivine-magnetite; gabbros, gabbrodiorite, granodiorite, quartz diorite, monzonites (intermediate igneous intrusive rock), alkali and nepheline syenites; plagiogranites, leucogranites, quartz syenites. Extrusive subvolcanic intrusions. Trachy-rhyolites and quartz dacites.
Shengavit	Quaternary – lacustrine-alluvial, flood alluvial, alluvial slope sediment, pebbles, sands, sandsoils and sand loams (30 m); volcanic lava flows, basalts andesite-basalts, andesites, andesite-dacites (35 m); volcanic lava flows and lava floods; basalts, andesite-basalts, andesites (100 m). Cenozoic – lacustrine-alluvial, lacustrine-alluvial formations; tuff-sandstones, diatomites, clays, sands, lapilli sands, breccias (400 m).
Talin Tombs	Quaternary – lacustrine, lacustrine-alluvial sediments of Shirak, Aparan, Araratian, sands, clays, pebbles, diatomites, loess clay-soils (130 m); volcanic lava flows and lava floods; andesite-basalts and dacites (1500 m).

3.2 Results: Stereomicroscopy and macroscopic study of Kura-Araxes pottery

Macroscopic characteristics recorded are often less evident in thin-section and other geochemical analyses, such as, overall colour of the sherd, colour distribution, notable inclusions present on the surface, etc. Observations were made using a Leica EZ5 Stereomicroscope at University of Oxford, School of Archaeology. A total of 420 rim, rim to body, or body sherds were examined (Table 3.2). These potsherd samples were provided by archaeologists and selection was based on fragments from excavated contexts, instead of whole vessels. Eight sites were examined, and results are reported through categories: (1) surface treatment, (2) firing conditions (Munsell), and (3) fabric, temper and inclusions. For descriptive terminology and guides/charts used for macroscopic and microscopic analyses, refer to Appendix C. Detailed information on each site and potsherd contextual information are provided in Chapter 2, Section 2.2 (Appendix D, Table 1). In general, all potsherds examined vary in fabric type, texture, colour, firing, and surface finish. Differences between assemblages and sites are recorded.

Table 3. 2. Potsherd samples for stereomicroscopy analyses.

Site	Number of potsherds
Gegharot	59
Karnut-1	66
Margahovit	46
Mokhra-Blur	13
Norabak-1	11
Shengavit	135
Sotk-2	80
Talin Tombs	10
TOTAL	**420**

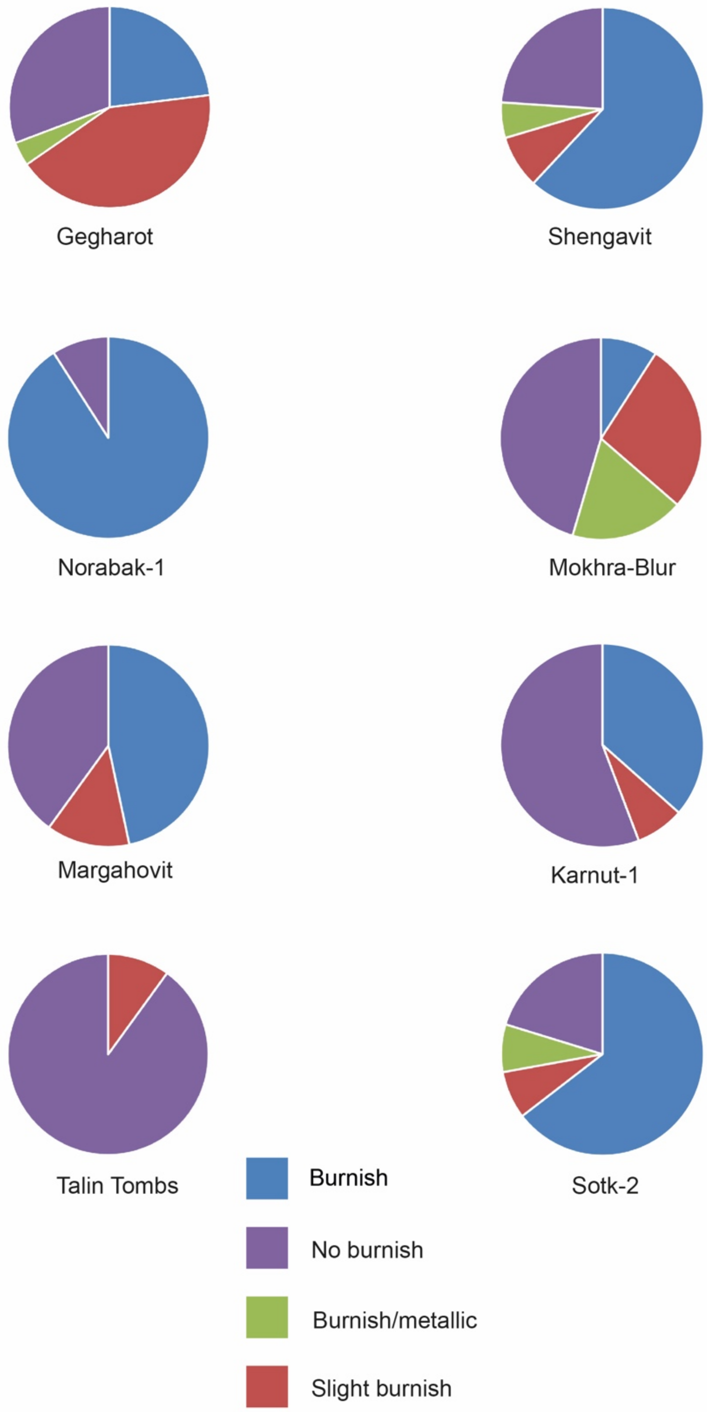


Figure 3. 4. Pie charts displaying the surface treatment of pottery across various Kura-Araxes archaeological sites. As noted, un-burnished samples comprise more than half the assemblage at various sites, i.e., Talin Tombs, Mokhra-Blur, and Karnut-1. Burnish/metallic category resembles potsherds that exhibit striations and lustre; slight burnish category resembles a smooth burnish/shiny effect (fragmentary) on the potsherd. No burnish category resembles a surface feature with no visible finishing techniques.

3.2.1 Surface treatment

All Kura-Araxes sites examined showed some variation in their surface treatment, fabrics, and firing practices (control of oxidising-reducing conditions). Burnishing appears to predominate assemblages at Gegharot, Norabak-1, Sot-2, Margahovit, and Shengavit (Figure 3.4). This is imperative to note, as scholars have categorised KA vessels based on surface design and typology (Sagona, 2018). Surface treatment assumes particular importance, as scholars have categorised KA vessels based on surface design and typology (Sagona, 2018). Surface treatment and burnishing results are quantified in Figure 3.4. Striations are often visible, appearing slightly metallic. These surfaces were most likely burnished using a tool (Roux *et al*., 2018; 2020). Most Gegharot sherds display Munsell colour GLEY 1 3/N (dark grey), indicating their firing in a reducing environment. Through light microscopy, it is possible to characterise the surface finish and variation in firing and/or treatment. For Shengavit, about 72% (n = 97) of potsherds are burnished, but surface colours vary (red, brown, grey, and black). Some potsherds are highly burnished, displaying a metallic 'silver sheen' finish in which tool marks/striations are visible. The main observation from Gegharot is that black-burnish dominates the assemblage, as at Shengavit, though only 5% of potsherds are finished with a 'silver sheen' at Shengavit.

Furthermore, at Norabak-1, ten out of eleven potsherds are black-burnished (91%), while 62% of Mokhra-Blur and 56% of Margahovit sherds exhibit this surface finish. In contrast, potsherds (n=10) examined at Talin Tombs do not show this characteristic Kura-Araxes trait, as 90% (n=9) are not burnished: only one potsherd (T2) is slightly burnished. Karnut-1 is in-between (over 50% not burnished) (Figure 3.4). Sotk-2 is similar to Shengavit and Gegharot in terms of its surface finish technology (77% burnished) but differs in that potsherd SK6 is painted red on the exterior of the sherd (Figure 3.5). This is the only sherd in the assemblage exhibiting such distinctive features. Polychromy is recorded at Shengavit but only the rims are coloured differently than the body, and this is a firing condition as opposed to paint. Furthermore, Mokhra-Blur potsherd MB2 contains some burnt and sooting patches, including some red and yellow colouration. Based on these observations, while burnishing is evident across the assemblage, it is not the main surface design. Regarding the surface features at these KA sites, more detailed methods (thin-section petrography and SEM-EDS) are required to reveal whether potters were applying slips and/or other organic materials or using tools to smooth/burnish the exterior vessels prior to firing or post-firing.

Figure 3. 5. Sotk sherd (SK6), black burnished and painted red below the rim.

3.2.2 Firing conditions

For the KA potsherds examined as a whole, the prevailing reducing-oxidising (redox) conditions of the firing atmosphere, as recorded by the clay matrices, varies from unoxidised (UNOX), irregularly fired (IRF) to oxidised (OX). At Gegharot, 90% of sherds display Munsell colour GLEY 1 3/N (dark grey) for their external surfaces, indicating the predominant use of reduction firing to achieve the desired grey/black-burnished exterior surface finish (Figure 3.4).

Shengavit's pottery assemblage is more diverse as typified by varied Munsell descriptions (10 YR 7/1, 7.5 YR 4/0, 5YR 5/4, 2.5 YR 6/6, etc.). Interior and exterior surface colours include grey, orange, buff/beige, black, red, and brown. As such, firing conditions, based on the clay matrices vary between UNOX, OX and IRF. Contrary to this, at Talin Tombs, firing varies slightly (UNOX and OX), but 70% (n=7) of potsherds are oxidised completely (Munsell 5YR 6/4 for both interior and exterior).

At Norabak-1, potsherds (n=11) do not display variation in surface or firing, with 91% of potsherds being wholly unoxidised. Only one (NB11, N13-337) shows oxidation colouration. At the site of Sotk-2, firing conditions varied between OX and UNOX; however, most sherds are UNOX, with variable OX/UNOX/IRF conditions for the core/matrix. Mokhra-Blur is similar, where 62% (n=8) of potsherds are unoxidised. Munsell and colour of sherds at Mokhra-Blur range from black, red/orange and beige/buff. At Karnut-1, firing conditions varied between UNOX and OX, with dark grey/black surface exterior and orange interior (5 YR 5/1 exterior and 5YR 6/6 interior). Lastly, at Margahovit, the firing regimen also varied, there being no clear pattern (i.e, OX, UNOX and IRF). Munsell colours vary from grey, black, brown, buff/beige, orange, and red (7.5YR 5/6, 7.5YR 3/0, 5YR 4/2, 2.5YR 3/0).

3.2.3 Fabric: temper and inclusions

A degree of fabric variation is evident at all sites. Observations on those inclusions that can be identified by low-power stereomicroscopy are as follows. Gegharot is slightly micaceous (confirmed through thin-section analysis; Fabric 6, Section 3.3.1.6; similar observations from geochemical studies previously published on clay samples (see Smith *et al.*, 2009). This is evident through the identification of shiny orange minerals visible on the surface and interior of the sherd, with inclusions of sub-rounded ferro-magnesian minerals and basaltic fragments, volcanic ash, or pale igneous groundmass (rhyolite-dacite-andesite), and chalky feldspars that vary in size (slightly weathered). Orange sub-rounded inclusions are clay pellets produced during clay deposit or working by the potters. Macroscopically, the grain size ranges from medium to coarse (1.00 mm), poorly to moderately sorted. Potters most likely did not refine (and/or levigate) the clay, and perhaps used a wide range of raw material sources as temper (i.e., basaltic, andesitic, and rhyolitic fragments). However, these observations are further investigated through thin-section petrography and SEM-EDS.

At Shengavit, fabrics range from fine-grained to coarse-grained, typically well-sorted with an inclusion abundance 30-50%. Aplastic inclusions include volcanic ash, sand, rock fragments, and coarse-grained inclusions, i.e., basalt. There is presence of soot on some vessels, indicative of culinary practices such as high temperature burning and/or cooking (Rice, 1987).

In general, the inclusions at Talin Tombs correspond to ferro-magnesian and volcaniclastic minerals (identified through the black glassy inclusions). More specifically, potsherd T2 contains black sub-rounded pellets and minerals. Volcanic glasses/aggregates are dominant across the KA assemblage, which is entirely consistent with the igneous nature of much of the regional geology, and therefore of the resultant clays produced by weathering.

At Norabak-1, one potsherd (NB11, N13-337) is organic-tempered (either straw/chaff). This is 15.56 mm in width, whereas sherds from this site are typically finer, smooth in terms of texture, and thin-walled (4.2 to 10.8 mm). Due to the fine micro-structure, they were selected for SEM-EDS. At Sotk-2, the assemblage is also dominated by thin-walled fine-wares (n=80, 100%). Such fabrics are too fine for the inclusions to be characterised by stereomicroscopy. As such, four of these sherds were selected for thin-section petrography, as well as organic residue analyses to test the use of these vessels.

Furthermore, at the settlement of Mokhra-Blur, conspicuous inclusions are of siltstones and sand-grained (possibly identified as weathered feldspar), mica, some ferro-magnesian minerals, and generally well-sorted. It is difficult to characterise these inclusions at low magnification stereomicroscopy, but volcanic ash seems to be well represented. These tentative identifications will therefore be checked using a thin-section petrographic analyses and SEM-EDS (for sherds MB2, MB3, and MB11). Potsherd MB3 has a heavily-burnt interior; this potsherd is identified as a good candidate for lipid residue analysis to determine its function and use.

At the site of Karnut-1 potsherd samples are thick-walled and coarse-grained. In general, potters were using coarse-grained rock fragments/tempers and did not refine the clay prior to forming. These body sherds most likely correspond to large vessels, i.e., storage vessels such as *karas*, large beakers and/or cooking pots. Perhaps coarse-grained vessels are indicative of raw material selectivity for larger vessels, requiring some additive advantages in plasticity and workability of clay.

Margahovit sherds are similar to those of Shengavit. There is no strict technological pattern evident at this site and fabric recipes vary. The most common observed fabrics at the site are coarse-tempered, comprising volcanic ash, igneous rock fragments and typically grit-tempered. Textures also vary from smooth, sandy and coarse (0.75 to 1.8 mm). Potsherd MG2 contains a lot of igneous inclusions and clasts: scoria/basalt, biotite, and clay pellets. Potsherd MG9 is distinctive in the sense that there are visible rounded sandy inclusions derived from sedimentary rocks, calcite/quartz, possibly pyroxenes and rock fragments. However, subsequently through thin-section petrography, this potsherd is classified as Fabric 1 and inclusions most likely resemble andesitic grains (Section 3.3.6.1). Hornblende, amphiboles, iron pellets, and feldspars are among the other common inclusions and, tentatively, possible minor olivine or tourmaline. Overall, the inclusion assemblages in these sherds are very common to abundant and poor- to well-sorted. These observations are confirmed by thin-section analysis (Section 3.3). Overall, observations through stereomicroscopy suggest the use of igneous-based rock fragments varying in abundance and grain-size.

3.3 Results: Thin-section petrography

Referring to Chapter 1 – Section 1.5.3, Kura-Araxes pottery technology has been explored across various coeval settlements. However, we have yet to conclusively examine technological traditions across Kura-Araxes settlements in the South Caucasus region, depicted as the core/homeland area of the cultural phenomenon. This section presents new data on Kura-Araxes pottery analysis, examining pottery from various archaeological sites in Armenia, using a detailed thin-section petrographic approach. This section provides descriptions of the petrography of the various fabrics identified within several archaeological sites. Geological reports and maps were consulted to establish the expected characteristics of local fabrics, against which the observed fabrics could then be compared. The presented data is central to the interpretation and analysis of pottery technological traditions across Kura-Araxes settlements in the South Caucasus. Relevant published data on thin-section petrography is mentioned in Chapter 1 (Babetto *et al*., 2020; Batiuk, 2013; Hayrapetyan, 2008; Hovsepyan, 2014; Hovsepyan and Mnatsakanyan, 2011; Heydarian *et al.*, 2020; Iserlis *et al.*, 2010; 2015; Mason and Cooper, 1999), which will combine with results in this chapter and form the main discussion in Chapter 5, synthesising the current viewpoint on Kura-Araxes potting communities within this region. While raw material selection, manipulation and clay sourcing are important aspects of petrographic analyses, evidence of technological practices (forming, modification of clay, firing, etc.) are equally examined and discussed in this section.

Petrography is the descriptive part of the overall study of rocks and their origins (petrology), where the minerals and overall micro-texture of clay and rocks are analysed to define key features and observations (Hommel *et al*., 2017; Peterson, 2009; Quinn, 2013; Rice, 1987; Roux *et al*., 2018). The way pottery vessels are produced and shaped is strongly correlated to the function it will serve (Sillar and Tite, 2000: 5-6). This way, archaeologists can reconstruct and reverse-engineer the way pottery vessels were made in order to reconstruct the choices made by people in the past. Whitbread (1989), Lombard (1987) and Quinn (2013) provide meaningful ways in collecting data from thin-sections. The areas of interest, defined by Quinn (2013), include (1) classification or grouping, (2) characterisation and description, (3) provenance interpretation (where the pots were made and the provenance of raw materials), and (4) technological reconstruction. This section provides information on how Kura-Araxes vessels were made and focuses on three main fabric components: (1) clay matrix, (2) inclusions, and (3) voids.

Through petrographic analysis, it is possible to reconstruct forming techniques to a certain degree, given the sherd size (i.e., pinching, coiling and wheel throwing). These processes can be often seen through the orientation and alignment of inclusions along the vessel wall of the sherd, microscopically through thin-section analyses (Thér *et al.*, 2017: 1268). Archaeologists can identify the raw material source that the potters used, based on the mineralogical and petrographic composition, and georeferenced clay/inclusions nearest to the archaeological sites (Thér *et al.*, 2017: 1270; Velde and Druc, 1999; Reedy, 2008; Quinn, 2013). Petrographic analysis may also allow the estimation of firing conditions, based on the mineralogical changes according to the clay matrix (i.e., the degree of vitrification of the matrix) and non-plastic inclusions (Thér *et al.*, 2017: 1270; Maggetti, 1982; Rice, 1987; Velde and Druc, 1999; Ionescu and Ghergari, 2002; Grapes, 2006; Reedy, 2008; Quinn, 2013).

As mentioned in Chapter 2 – Section 2.3.2, "a thin section is created by sawing off a small fragment of the material to be studied, attaching the resulting flat surface to a glass microscope slide, and grinding the exposed surface of the fragment down to a standard thickness (ca. 25-30 micrometers)" (Peterson, 2009: 1; Nesse, 2004). At this standardised thickness, minerals can be identified based on their characteristic optical properties (Deer *et al.*, 1996; Gribble *et al.*, 2012). The fabric is further classified based on its plastic and aplastic components, microstructure and texture (Peterson, 2009). Non-plastic materials are (1) mineral inclusions or rock fragments, (2) organic inclusions (plant, shells, bones, etc.) and (3) grog (crushed pottery) and can be differentiated due to the characteristic optical properties (transparency, colour, pleochroism, morphology, birefringence, isotropism or anisotropism) (Peterson, 2009: 10). Grog inclusions, according to Peterson (2009: 12) exhibit angular properties, due to crushing sherds and reusing them as temper. Organic tempers can be identified based on carbonized spots or by voids, vesicles and vughs[1] (see morphologies of voids, vesicles and vughs in Appendix C) within the clay matrix (Whitbread, 1986; Orton *et al.*, 1993; Velde and Druc, 1999; Stoops, 2003; Reedy, 2008). Voids can also be formed due to bloating pores (Quinn, 2013: 98).

The clay matrix is formed with clay minerals and other materials whose grain size is less than 2 micrometers in diameter (Velde and Druc, 1999: 5, 35). Non-clay minerals in the clay matrix may be added intentionally or occur naturally within raw materials (therefore already present at the time of clay procurement). It is often difficult to determine whether inclusions are naturally occurring or intentionally added; scholars have suggested modality and bimodality estimation (Quinn, 2013). However, it is important to examine the geological framework within and around the settlement/site, to determine what rock fragments are naturally occurring. For instance, bimodality as an indicator of temper is unreliable in volcanic terrains (i.e., Armenia) as eruptions produce phenocrysts and volcanic ash (crypto-tephra) (Trifonov *et al.*, 2017). Thus, clay deposits can contain natural inclusions of volcanic ash, which are often naturally bimodal.

This section presents new data on Kura-Araxes pottery analysis, examining pottery from various archaeological sites in Armenia. Furthermore, this section will feed into the wider discussion of technological transformation and/or transmission across these sites and introduce

[1] Voids – "Planar voids and channels are thin and elongate, vughs have an amorphous shape, and vesicles are spherical" (Quinn, 2013: 65).

new ideas and debates concerning the Kura-Araxes cultural phenomenon (Chapter 5). Moreover, published data from neighbouring sites and regions (Chapter 1, Figure 1.1), including sites in Georgia and Azerbaijan, will add to the current debates concerning the producing and making of this product (Greenberg and Goren, 2009; Iserlis *et al.*, 2010).

Thin-section petrographic analysis has been undertaken on 140 samples from seven Early Bronze Age archaeological sites in Armenia, in order to characterise the pottery samples and investigate their technological characteristics, raw material sources and manufacturing techniques, such as aspects of paste preparation technology, refining, tempering and clay mixing. *The atlas of igneous rocks and their textures* and other reference collections (Adams and MacKenzie, 1998; Adams *et al.*, 1984; Bathurst, 1975; MacKenzie and Adams, 1994; 2017; Deer *et al.*, 1996; 2013; Quinn, 2013; Reedy, 2008; Yardley *et al.*, 1990), were consulted to identify the igneous inclusions which dominated most of the fabrics. Fabric descriptions were produced using reference charts (abundance, size, shape, etc., available in the Appendix C). A detailed analysis of the *chaîne opératoires* is discussed in Section 3.5 and Chapter 5.

3.3.1 Gegharot (n=36)

The typological assemblage of Gegharot consists of jars, kraters, lids, bowls, *karas* (pithoi), etc. Voids are rare (1 to 3 %) and clay is not porous, exhibiting an impermeable matrix. Open vessels were most likely burnished interior as well, similar to vessels from other KA settlements in Armenia (i.e., Aparan III; Iserlis *et al.*, 2010). Regarding the pottery fabric recipes at Gegharot, there are six groups classified, spanning 36 sherds (Table 3.3). There is not much variability in paste preparation among these groups, as clay is derived from igneous-rich sources available in the region and the fabric mainly ranges between medium- and coarse-grained igneous rock fragments.

Table 3. 3. List of fabrics identified in the potsherd samples from Gegharot.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Medium-grained igneous rock fragments and slag/ore minerals	5	G11, G12, G21, G27, G36
Sub-fabric 1 and 2	Combined fabric 1 and 2		G11, G12, G27
Fabric 2	Medium-grained hematite/iron and grog	6	G1, G2, G7, G16, G24, G25
Fabric 3	Medium-grained basalt-tempered and igneous rock fragments	5	G3, G4, G6, G17, G26
Fabric 4	Fine-grained igneous rock fragments (andesitic)	3	G8, G18, G31
Fabric 5	Medium- and coarse-grained igneous rock fragments and weathered feldspars	13	G5, G9, G10, G19, G20, G22, G23, G28, G29, G30, G32, G33, G34
Fabric 6	Medium-grained igneous rock fragments and biotite mica	4	G13, G14, G15, G35

At Gegharot, the clay paste consists mainly medium- to coarse-grained matrices, where various igneous and metamorphic lithologies are likely naturally present in the clay. The largest differences are observed in fabric 2, where 'grog' (crushed pottery) inclusions were observed. Furthermore, in fabric 5, coarse inclusions of weathered feldspars and igneous rock fragments were observed. Each group is categorised based on notable inclusions and their grain sizes (fine, medium and coarse).

3.3.1.1 Fabric 1 – Medium-grained igneous rock fragments and slag/ore minerals (n=5)

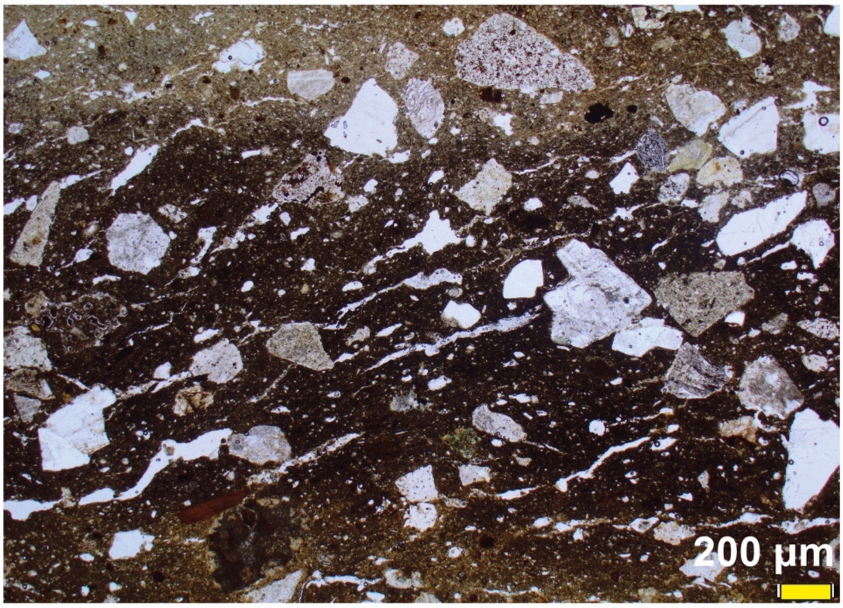


Figure 3. 6. G21 in PPL, x2 magnification. Scale on the lower right of photomicrograph.

Table 3. 4. Summary of fabric 1 and sub-fabric at Gegharot.

Categories	Fabric 1: G11, G12, G21, G27, G36
Sorting	Moderately to poorly
Inclusion frequency (average %)	25-30%
Dominant inclusions (average %)	• Igneous and metamorphic lithologies (20-30%); • Nepheline, Nepheline syenite • Andesite, • Hornblende (15%) • Alkali amphibole • Pyroxenes (15%) • Biotite (20%) • Quartz sub-angular to sub-rounded (20-40%); mono- and poly-crystalline • Feldspars (alkali and potassic); plagioclase; sub-angular to sub-rounded • Iron opaques (10%) • Metamorphosed rock fragments (15%) • Olivine (10%)
Rare inclusions (average %)	• Possible slag inclusions or ore minerals (2-5%, angular and sub-rounded) in potsherds, G11, G12, and G27. • Porphyritic andesites (2%) • Chert (1%)

	• Calcite growth within some rock fragments (1%) • Muscovite mica (3-5%)
Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Planar and elongate, distributed vertically and evenly (5%).
Textural features/comments	Medium-coarse; possible granitic source

This fabric is medium-coarse (Figure 3.6, Table 3.4) and most likely resembles a type of clay source that has not been processed or heavily levigated. Rock fragments and minerals in the clay can be sourced around Mt. Tsilkar or Aragats, indicating a local source (referring to Leah Minc's geochemical study of clay from this region; Smith *et al.*, 2009). Notable inclusions within this fabric include nepheline syenite, which is a coarse-grained, felsic rock consisting of alkali feldspar and nepheline with a small proportion of mafic minerals, usually alkali amphibole or pyroxene or both (MacKenzie *et al.*, 1982). Furthermore, olivines (10%) within the fabric are present with some chrome-spinel banding (MacKenzie *et al.*, 1982; Sahu *et al.*, 2020: 182). Granitoid igneous rocks are composed of interlocking crystals of quartz, feldspars, muscovite mica, and occasional pyroxenes are evident within this group. The morphologies of the igneous rock fragments (aplastic inclusions) vary in between angular to sub-angular. The feldspar coarse inclusions are weathered and in combination with iron-rich minerals. Inclusions that are characteristic of ore minerals (slag morphologies) are evident in potsherds G11, G12 and G27 (compared with published data, Martin *et al.*, 2013; Quinn, 2013). Given the archaeological importance of slag used as temper, these particular samples should be examined with further techniques to confirm whether they are by-products of metal production or within the clay supply as ore minerals (i.e., SEM-EDS[2]).

[2] Due to COVID-19 and lab closures, these samples were not subjected to SEM-EDS for this particular thesis.

Possible slag-type inclusions are noted, particularly in potsherds G11, G12 and G27, though these will need to be confirmed in future studies and unless present in large amount should not be considered as intentional temper addition. While slag/ore minerals inclusions look very similar morphologically to various iron opaques, olivine, serpentine, in combination to feldspars, the observations reported in this thesis require additional analyses.

Overall, the vessels are burnished and fired in a reduction environment. However, potsherds G11 and G21 consist of an exterior oxidised layer. Based on the direction and abundance of voids, it appears that most vessels are built with slabs, and the clay is drawn upwards, as the inclusions appear to be directional. This observation is based on the alignment of inclusions, and comparison with published data (Quinn, 2013; Thér, 2016). There is no evidence of other forming methods within this fabric group (i.e., coiling).

3.3.1.1.2 Sub-Fabric – Combined Fabric

Potsherd G27 contains some characteristics as Fabric 1 in combination with Fabric 2. The inclusions include slag (2-5%), medium-coarse grained igneous rock fragments (25-30%) and grog (5%). Slag inclusions are identified using comparative photomicrographs from published data (Quinn, 2013; Martin *et al.*, 2013). The clay used for this fabric displays heterogeneity in clay type (Figure 3.7). Clay mixing is a common manufacturing process by potters (Quinn, 2013: 132). However, it is difficult to suggest whether clay heterogeneity is a process done by potters or a natural geological process.

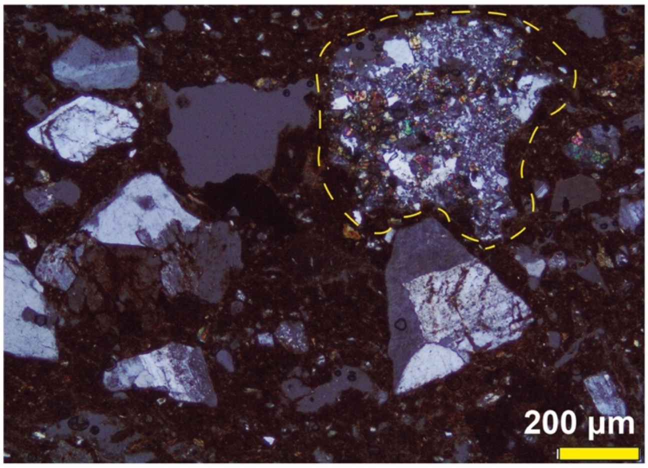


Figure 3. 7. G27 in XP, x4 magnification, exhibiting angular feldspars and slag/ore minerals (circled; 400-500 μm in size). Scale on the lower right of photomicrograph.

3.3.1.2 Fabric 2 – Fine- and Medium-grained hematite/iron and grog (n=6)

This group is similar to Fabric 1, which comprises igneous inclusions (Figure 3.8; Table 3.5). The majority of potsherds in this group contain iron opaques of various angularity (rounded to sub-angular), suggesting a possible iron-rich source. Inclusions include clay nodules and unhydrated lumps of clay (1%) aligned with voids. Potsherd sample G2 includes some plant material, identification based on the profile of voids; however, due to the low frequency, it is not possible to suggest organic temper. In general, voids are distributed unevenly. Forming technology is not standardised for this fabric, as both fine and medium-inclusions are evident. Perhaps the clay was not properly refined, or it was mixed with other sources. The clay matrix is optically active around the interior and exterior of the vessel (oxidised).

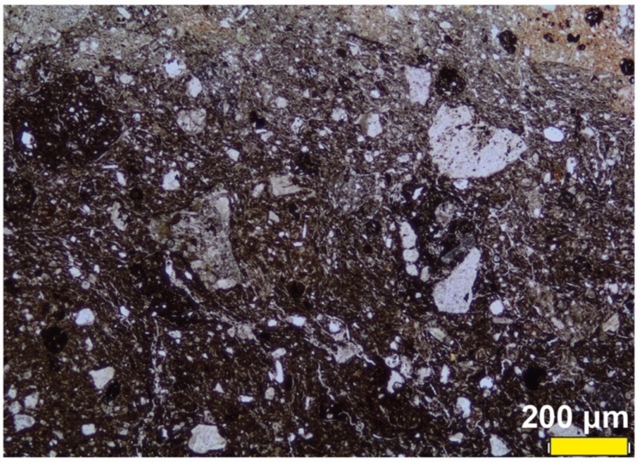


Figure 3. 8. G2 in PPL, x4 magnification. Scale on the lower right of photomicrograph.

Table 3. 5. Summary of fabric 2 at Gegharot.

Categories	**Fabric 2**: G1, G2, G7, G16, G24, G25
Sorting	Mostly poorly to moderately sorted
Inclusion frequency (average %)	35-50%
Dominant inclusions (average %)	• Basalt (20%) • Welded tuff (20%) • Plagioclase feldspar (50%), poorly to moderately sorted • Quartz (equant), fine-grained, well-sorted (30%) • Biotite (5%) • Grog (5%)
Rare inclusions (average %)	• Clay nodules/unhydrated lumps of clay (1%) • Plant material (in potsherd G2, 1%) • Augite (2%) • Amphibole (2%) • Olivine (2%)
Matrix	• Non-calcareous • Optically active
Voids (shape and abundance, average %)	Micro- to meso-planar and elongate, distributed unevenly (3%).
Textural features/comments	Fine- and Medium-grained

Potsherd sample G1 contains fine- and medium-grained glassy inclusions that can be identified as pumice or tuff (2%) and medium-grained angular to sub-angular inclusions that are possibly characterised as grog (10%). The largest inclusions within this fabric vary, between 200-300 μm. These inclusions are slightly opaque in PPL indicating thick and coarse inclusions in the groundmass. Potsherd sample G2 includes glassy welded tuff inclusions (20%). Thus, the inclusions vary within this group, albeit displaying similarities with Fabric 1; however, there are some differences, which might indicate different raw materials, and/or mixing of raw materials.

3.3.1.3 Fabric 3 – Medium-grained basalt-tempered and igneous rock fragments (n=5)

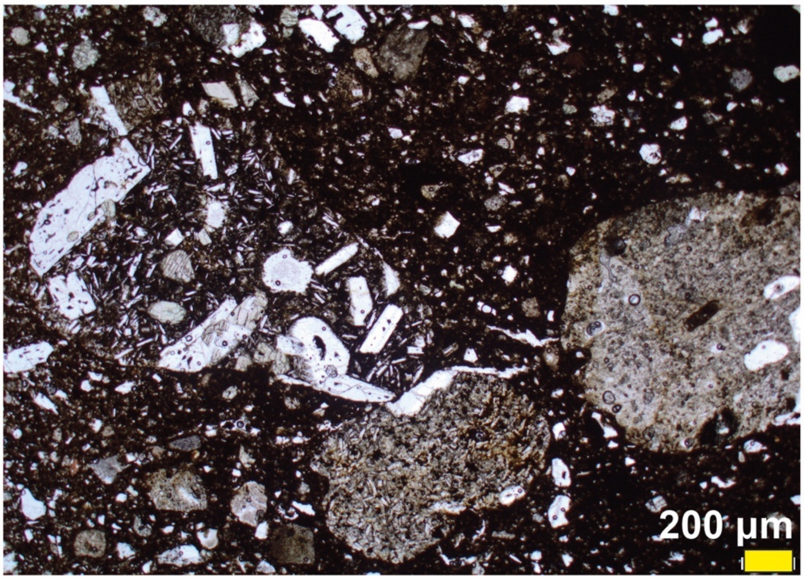


Figure 3. 9. G17 in PPL, x2 magnification. Scale on the lower right of photomicrograph.

Table 3. 6. Summary of fabric 3 at Gegharot.

Categories	**Fabric 3**: G3, G4, G6, G17, G26
Sorting	Poorly to moderately sorted
Inclusion frequency (average %)	25-30%
Dominant inclusions (average %)	• Basalt (30%), well to poorly sorted (sub-angular to sub-rounded) • Igneous rock fragments (andesite; 10-20%)
Rare inclusions (average %)	Fine-fraction of clay: • Quartz (10%), angular to sub-rounded • Iron opaques (15%) • Andesitic grains (5%) • Clay pellets (2%) • Pyroxenes (1%) • Alkali feldspars (5%) • Hornblende (2%) • Rhyolite (2%)

Matrix	• Non-calcareous • Optically active (G3, G4, G6, G26) • Optically inactive (G17)
Voids (shape and abundance, average %)	Planar and elongate (3%)
Textural features/comments	Medium-grained

This fabric is characterised by medium-grained 30% basaltic rock fragments, well to poorly sorted and sub-angular to sub-rounded, in a fine silty clay matrix (Figure 3.9; Table 3.6). Coarse-grained basalt and other igneous inclusions dominate the clay matrix, as the main aplastic components, specifically andesites (20-30%). Basalt sources are widely available in this area, suggesting an additional source of possible temper, due to the size and angularity of these inclusions. The silty component of this fabric comprises quartz inclusions (10% of the fabric), angular to sub-rounded. Other inclusions include porphyritic textured inclusions, iron opaques (15%), formed as magnetite or spinels. Voids are planar and elongate, indicating the drawing of clay, upwards and minimal shrinkage during firing, as the abundance of voids is quite low.

3.3.1.4 Fabric 4 – Fine-grained igneous rock fragments (andesitic) (n=3)

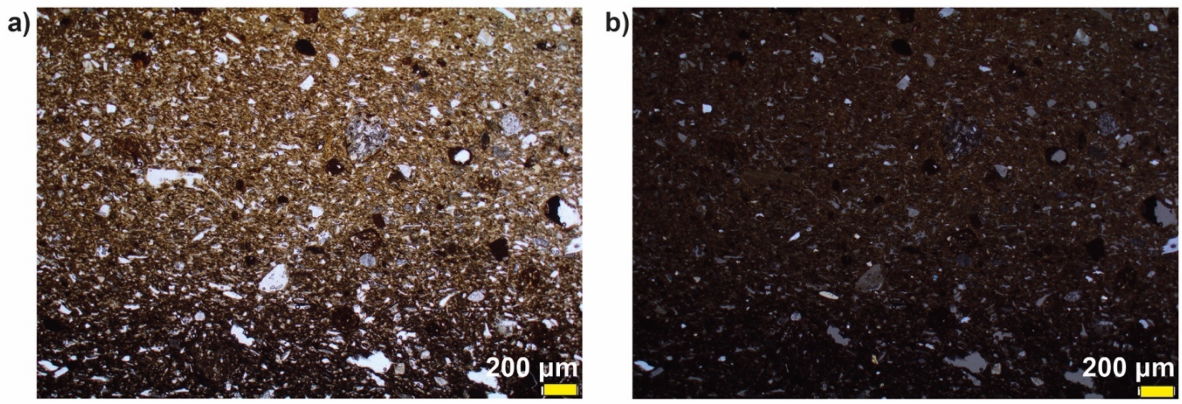


Figure 3. 10. G8 in (a) PPL and (b) XP, x2 magnification. Scale on the lower right of each photomicrograph.

This fabric, similar to the coarse- to medium-grained igneous (fabric 5), is characterised by andesites and gabbro and other igneous rocks locally available in the region (Figure 3.10;

Table 3.7). However, the inclusions are fine-grained with some glassy inclusions (tuff and/or pumice) well- to moderately-sorted, especially for potsherd sample G18. About 5% of the inclusions are coarse rock fragments, distributed in a finer groundmass. Large crystals in a matrix or groundmass of much smaller crystals are described as phenocrysts (MacKenzie and Adams, 1994; MacKenzie *et al*., 2017). The clay for this fabric was most likely refined by potters, due to its fine-grained inclusions, compared to other fabrics from Gegharot. Potters most likely refined clay by removing impurities and coarse inclusions (Rice, 1987; Roux and Courty, 2019).

Table 3. 7. Summary of fabric 4 at Gegharot.

Categories	**Fabric 4**: G8, G18, G31
Sorting	Well to moderately sorted
Inclusion frequency (average %)	(20%)
Dominant inclusions (average %)	Aplastic inclusions: • Andesite aggregates (5-15%) • Volcanic ash (15-20%)
Rare inclusions (average %)	Silty component: • Quartz (5%) • Volcanic ash/glass (5%) • Feldspars (2-3%) • Pyroxenes (2%) • Clay pellets (2%)
Matrix	• Non-calcareous • Optically active (G8) • Optically inactive (G18)
Voids (shape and abundance, average %)	Micro-planar and elongate (G8) Micro-planar, elongate, and micro-vughs (G18) (1%)
Textural features/comments	Fine-grained and silty

3.3.1.5 Fabric 5 – Medium- and coarse-grained igneous rock fragments and weathered feldspars (n=13)

As the largest fabric group evident at Gegharot, the findings reported within this fabric group suggest potters were either tempering or not levigating the clay, given the coarse- to medium-grained aplastic inclusions (Figure 3.11; Table 3.8). In potsherd G10, there are various zoned feldspars as natural phenocrysts. It is possible that there is an olivine-gabbro in potsherd G22, as the groundmass rock. Within some of the rock fragments, haematite and/or magnetite is evident, formed by the oxidation of olivines (MacKenzie *et al.*, 1982). As MacKenzie *et al.*, (1982) claim that some orthopyroxene crystals can contain narrow lamellae of augite, which is evident in this fabric group. As such, it is common that porphyritic andesites consist of plagioclase, hornblende, augite, and magnetite, surrounded by fine-grained groundmass of plagioclase, magnetite and glass. Based on these observations, olivine-gabbro is the base rock and main raw material source.

Potsherds G10, and G19 display optical activity, but the rest of the samples are fired in a reduction environment. This fabric is characterised by the presence of quartzite sand-grained inclusions, varying in size, shape and abundance (i.e., mono-crystalline and poly-crystalline quartz) and medium and coarse-grained weathered feldspars (Figure 3.11). It is possible to suggest the provenance of clay, where the alluvial soil/sand is characteristic of Kasakh River sediments (Iserlis *et al.*, 2010). The general fabric is characterised by igneous rock inclusions with trachytic textures and an arrangement of prismatic crystals, locally available near various Kura-Araxes settlements of this region.

Despite the fact that sample G19 is thin-walled and fine, it is dominated by medium-grained inclusions, indicating that potters were not levigating the clay. This particular potsherd (G19) includes polycrystalline quartz (40%), feldspars (15%), all sub-angular to sub-rounded. Iron opaques (10%) and metamorphosed rock fragments (5%) are also evident.

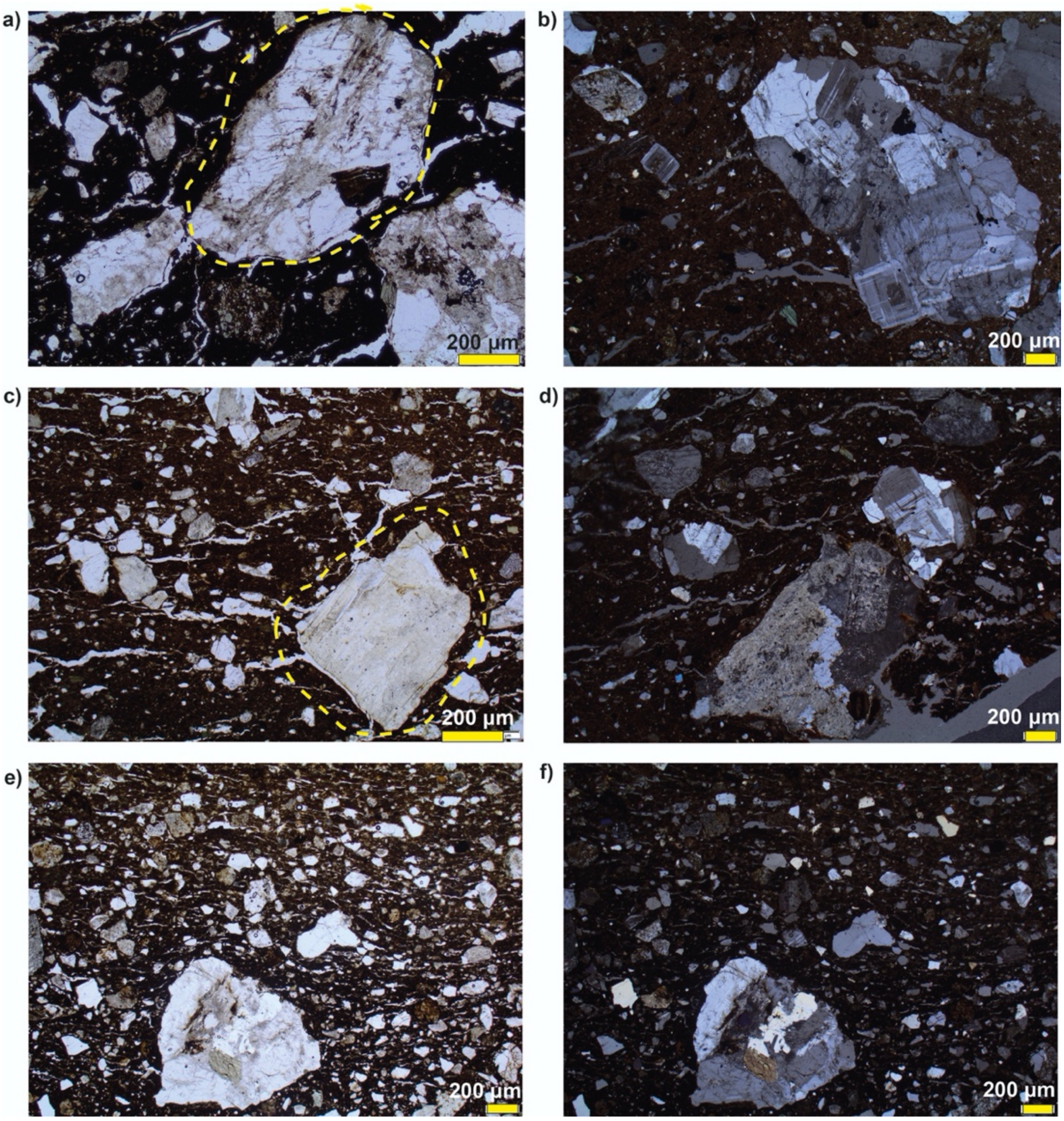


Figure 3. 11. (a) Potsherd G5 in PPL, x4 magnification. (b) Potsherd G5 in XP, x2 magnification. (c) Potsherd G10 in PPL, x2 magnification. (d) Potsherd G10 in XP, x2 magnification. (e) and (f) potsherd G20 in PPL and XP, x2 magnification. Inclusions characteristic of weathered feldspars, circled with dashed lines. Scale bars on lower right.

Table 3. 8. Summary of fabric 5 at Gegharot.

Categories	**Fabric 5**: G5, G9, G10, G29, G20, G22, G23, G28, G29, G30, G32, G33, G34
Sorting	Poorly sorted
Inclusion frequency (average %)	25-30%
Dominant inclusions (average %)	Aplastic inclusions: • Weathered feldspars (10-15%); plagioclase (2%) • Quartz (mono- and poly-crystalline, 5-10%) • Biotite mica (10%) • Porphyritic andesites (5-10%) • Rhyolite (10%)

	• Olivine (15%) • Anorthosite (5%)
Rare inclusions (average %)	• Quartz (2-3%) • Gabbro (equant, 3%) • Anorthoclase (2%) • Iron opaques (5-10%) • Augite (lamellae, 5%) • Orthopyroxene (1%) (green in XP and PPL) • Hornblende (1%) • Volcanic glass? (1%)
Matrix	• Non-calcareous • Optically inactive (G5, G9, G20, G22, G23, G28, G29, G30, G32, G33, G34) • Optically active (G10, G19)
Voids (shape and abundance, average %)	Micro-planar, micro- to meso-vughs, and micro-channels, distributed randomly (5%).
Textural features/comments	Coarse- and medium-grained

3.3.1.6 Fabric 6 – Medium-grained igneous rock fragments and biotite mica (n=4)

The inclusions within this fabric group are characterised by elongate biotite mica (micaceous clay). Firing regimen for this fabric group is mostly reduced and some oxidised layers (i.e., for G13, G14 and G35). Potsherds from this group were reported in macroscopic observations using stereomicroscopy, described as shiny-orange particles pertaining to mica (Section 3.2; Figure 3.12). The thin-section analyses confirmed these interpretations, especially in understanding the frequency of such inclusions.

Table 3. 9. Summary of fabric 6 at Gegharot.

Categories	**Fabric 6**: G13, G14, G15, G35
Sorting	Moderately to well sorted
Inclusion frequency (average %)	35%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Biotite mica (elongate fine- and medium-grained, 20-25%) • Igneous rock fragments; granitic source (20%) • Weathered feldspars (plagioclase and microcline, 10%)

Rare inclusions (average %)	Silty component (>1-5%): • Quartz (equant to elongate sub-angular to angular, 4%) • Olivine (2%) • Augite (2%) • Clinopyroxene (2-3%) • Orthopyroxene (2%) • Iron opaques (2%) • Hornblende amphibole (2%) • Serpentine (1%) • Chert (sub-rounded, 1%)
Matrix	• Non-calcareous • Optically inactive (moderate)
Voids (shape and abundance, average %)	Micro-planar and elongate (5-10%); Micro- to meso-vughs and channels (3%)
Textural features/comments	Micaceous clay and granodioritic source(?)

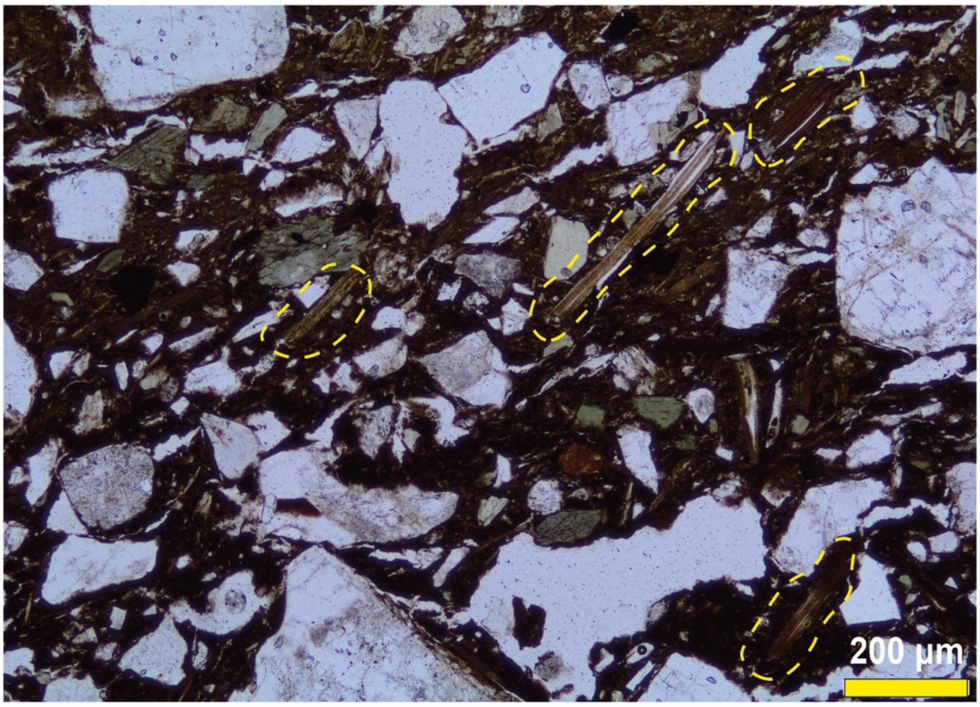


Figure 3. 12. Potsherd G13, PPL and XP, x4 magnification; biotite mica outlined in fabric paste (yellow dashed lines). Scale on the lower right of each photomicrograph.

Aplastic inclusions (<20%) are igneous rock fragments and biotite mica, characteristic of a granodioritic source. Weathered feldspars (plagioclase and microcline) similar to fabric 5 are also evident. Elongate biotite mica range in size from fine to medium-grained (20%). Few sub-rounded to rounded chert fragments are visible (i.e., in potsherd G13). Regarding potsherd G13, euhedral olivines, euhedral augites, as well as one inclusion of serpentine are present. In potsherd sample G15, the iron opaque/magnetite are either completely black in XP and PPL, or contain micro-inclusions of quartz, pyroxenes and biotite, angular to sub-rounded inclusions. Augite dominates most samples (G14, for instance), which is pale green in PPL, as well as hornblende amphiboles (light green colour in PPL).

Vessel G13 might be formed in a slab-built technology, where clay is drawn upwards and flattened, as voids and inclusions are oriented vertically. For the rest of the sherds, there is some evidence of inclusions circulated in a similar fashion, which is indicative of coiling (Quinn, 2013).

3.3.2 Shengavit (n=35)

The typological assemblage of Shengavit consists of jars, kraters, lids, bowls, *karas* (pithoi), etc., typical of the KA pottery repertoire (Appendix A). Vessels exhibit a well-burnished slip on the exterior and interior, as well as some cooking vessels and/or utility vessels that are not treated with a surface burnish. There are four fabric groups evident at this site, and one sub-group. Volcanic ash is the dominant inclusion within this assemblage. Within the largest fabric group (Fabric 1), sub-groups are evident, where potters mixed clay sources.

Table 3. 10. List of fabrics identified in the potsherd samples from Shengavit.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Fine- and medium-grained volcanic ash and rock fragments	12	SH30, SH32, SH35, SH37, SH58, SH64, SH105, SH110, SH118, SH121, SH130, SH132
Fabric 2	Medium to coarse-grained volcanic ash and basalt	8	SH10, SH23, SH27, SH79, SH115, SH116, SH123, SH124
Fabric 3	Fine-grained silt and grog	6	SH12, SH38, SH67, SH114, SH122, SH128
Sub-Fabric 3.1	Ironstones and grog	1	SH48
Fabric 4	Medium to coarse-grained sandstones	8	SH11, SH13, SH14, SH15, SH43, SH117, SH129, SH134

3.3.2.1 Fabric 1 – Medium-grained volcanic ash and rock fragments (n=12)

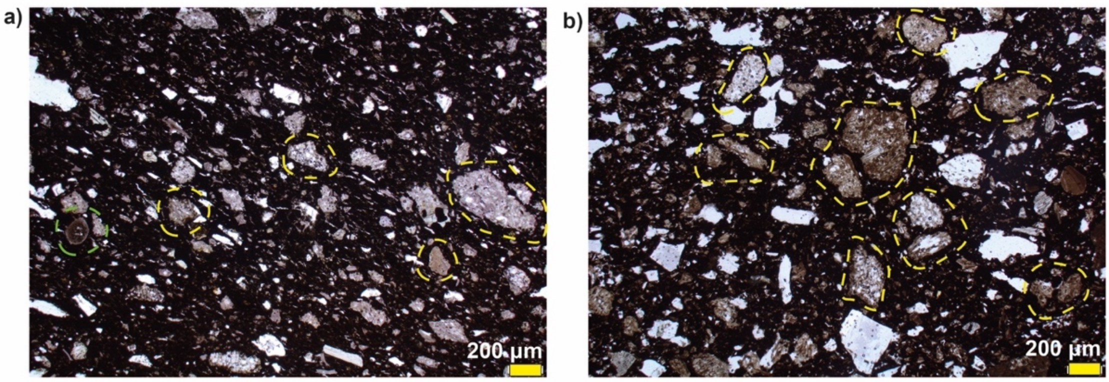


Figure 3. 13. (a) Potsherd SH110 and (b) SH30 in PPL, x2 magnification. Scale on the lower right of each photomicrograph. Volcanic ash fragments circled in yellow dashed lines; rounded particles known as peds, encircled in green dotted lines (Stoops *et al*., 2018).

Based on the typology of these potsherds, they most likely resemble fine- and utility-wares. Despite the fact that SH132 is fully oxidised, it is not optically active. Due to the glassy matrix of the fabric, it is rather difficult to reconstruct the forming technology; the clay matrix is dominated by volcanic ash which is why the matrix appears 'glassy'. The presence of bloating pores is mainly in volcanic ash fragments, characteristic of typical pumice morphologies. However, based on the alignment of inclusions across the fabrics (Quinn, 2013), there is evidence of coiling and drawing the clay upwards, indicating various forming technologies associated with this fabric. Coiling is evident for potsherds SH30, SH35, SH58, SH105, SH121, SH130, and SH132. Furthermore, it is possible that the vessels produced through coiling were also pinched and smoothed. The alignment of inclusions within potsherds SH37 and SH118 suggests that clay was drawn upwards and/or slab built. Most of the vessels were burnished to a high degree and most likely while the vessels were leather-hard (Lepère, 2014; Roux, 2016; Thér, 2016).

Feldspars are alkali-rich (plagioclase, orthoclase and sanidine) and some exhibit zoning. Potsherd SH130 contains one inclusion of angular obsidian (1%); however, this is not enough to quantify as temper due to its low frequency compared to other datasets comprising a large number of obsidian particles within sherds and clay sources (see Palumbi *et al.*, 2014). The feldspars and quartz inclusions are fine- to medium-grained, and moderately to poorly sorted.

Table 3. 11. Summary of fabric 1 at Shengavit.

Categories	**Fabric 1**: SH30, SH32, SH35, SH37, SH58, SH64, SH105, SH110, SH118, SH121, SH130, SH132
Sorting	Well to moderately sorted
Inclusion frequency (average %)	25-35%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Volcanic ash (fine- and medium-grained, well to poorly sorted, 30-35%)

	• Trachyandesite (medium-grained, 3%) • Rhyolite (medium-grained, 2%)
Rare inclusions (average %)	Silty component (>1-5%): • Quartz (equant to elongate sub-angular to angular, 5%) • Weathered plagioclase feldspars (4%, poorly sorted) • Sanidine (1%) • Iron opaques (sub-rounded to sub-angular, 5-10%) • Hornblende amphibole (1%) • Olivine (euhedral, 1%) • Pyroxenes (2%) • Angular obsidian (1%) • Peds (3%)
Matrix	• Non-calcareous • Optically inactive core; oxidised regions are optically active (SH118) • Optically active (SH37) • Optically inactive (SH30, SH32, SH35, SH58, SH64, SH105, SH110, SH121, SH130, SH132)
Voids (shape and abundance, average %)	Planar and micro-vughs; distributed randomly (1%)
Textural features/comments	Volcanic ash matrix exhibiting no evidence of organic and/or plant matter within this fabric group; fine- and medium-grained.

The aplastic inclusions are mainly medium-grained volcanic ash particles, varying in texture and morphology (Figure 3.13). The morphological characterisation of volcanic ash/rocks can be helpful in determining the geological context of clay sources. Based on comparative thin-section images, it is possible to suggest that Shengavit's potters acquired clay naturally rich in inclusions of tuff, scoria, pumice, and weathered rock fragments (Sedov *et al.*, 2010; Stoops *et al.*, 2018: 724). Scoria and pumice are dominant in this fabric group. Potsherd SH110 (Figure 3.13) contains some inclusions of peds (3%), which are aggregates of soil particles formed as a result of pedogenic processes, sometimes with well-developed concentric internal fabric (Stoops *et al*., 2018). Fragments of trachyandesite (3%) and trachytic rock with plagioclase laths and other coarse grains in an opaque matrix are also common (5%) (Stoops *et al.*, 2018: 731). Furthermore, pumice fragments are identified based on the gas bubbles associated with these inclusions. The glass is colourless to light-brown in PPL. Other glassy inclusions include microcline within rhyolite exhibiting a 'sieve' texture (1%). Lastly, rhyolitic tuffs are present (1%) The abundant volcanic glass and ash fragments within this fabric indicate the various sources evident within and near the site of Shengavit (see geological map, Figure 3.3).

3.3.2.2 Fabric 2 – Medium and Coarse-grained volcanic ash and basalt (n=8)

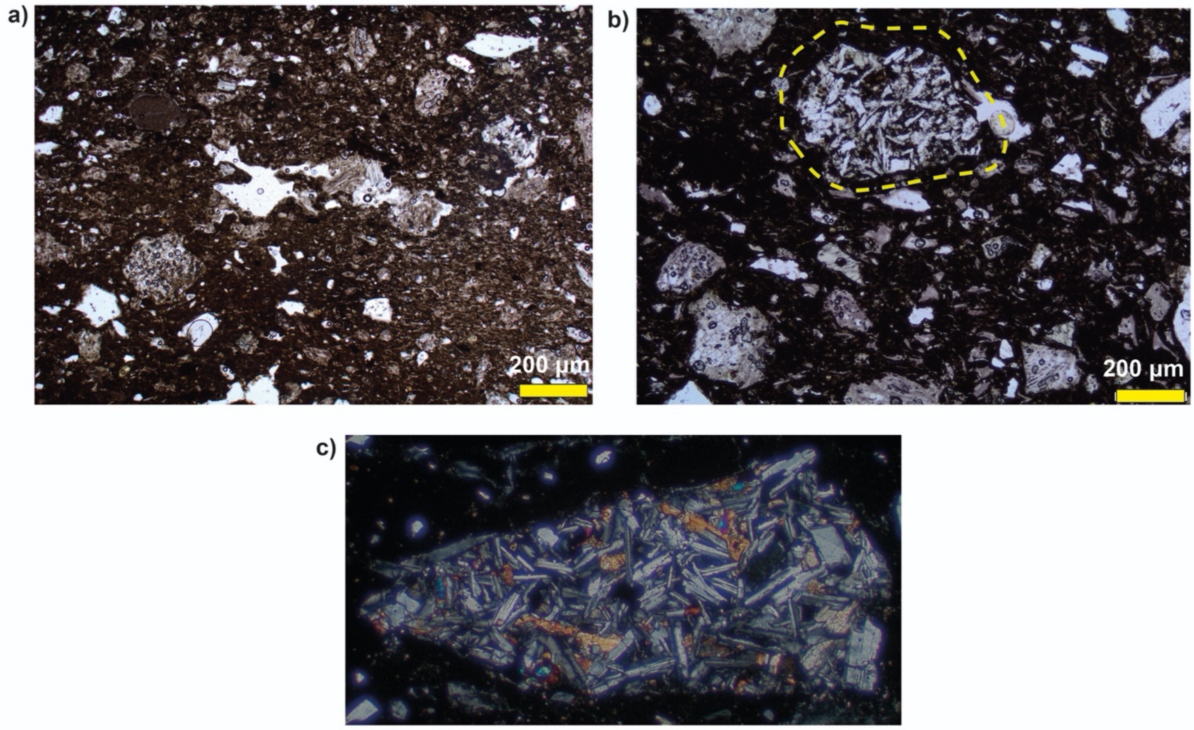


Figure 3. 14. (a) SH10 in PPL, x2 magnification. (b) SH27 in PPL, x4 magnification; sub-rounded basalt grain circled in yellow dashed lines. Scale on the lower right of each photomicrograph. (c) SH116 in XP, example of an angular basalt grain (photo not to scale).

Table 3. 12. Summary of fabric 2 at Shengavit.

Categories	**Fabric 2**: SH10, SH23, SH27, SH79, SH115, SH116, SH123, SH124
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	30-35%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Volcanic ash (medium-grained, well to poorly sorted, 30-35%) • Basalt (15-20%) • Andesite (2%) • Plagioclase feldspars (5%) • Sanidine (2%)

	• Pyroxenes (3%)
Rare inclusions (average %)	Silty component (>1-5%): • Quartz (equant, sub-angular, 3%) • Metamorphosed rock with calcite intergrowth (1%) (i.e., potsherd SH115) • Iron opaques (sub-angular to sub-rounded, 5%) • Pyroxenes (3%)
Matrix	• Non-calcareous • Optically inactive (SH10, SH23, SH27, SH79, SH116, SH123, SH124) • Optically active (SH115)
Voids (shape and abundance, average %)	Voids are planar and micro-vesicles, and some meso-vughs (1%).
Textural features/comments	Similar texture to fabric 1 comprising a volcanic ash matrix; medium-grained

Similar to fabric 1, this fabric is characterised by a volcanic ash matrix, comprising 35% of the inclusions, poorly to well sorted, varying in size, shape and abundance (Table 3.12). The shape of volcanic ash inclusions is angular to sub-rounded, varying in morphology (welded and unwelded tuff, pumice, scoria, etc). For instance, potsherd SH10 contains an inclusion of a spherulite, which is brown in PPL and XP. Tuff inclusions are of glassy unwelded rhyolite tuff. The glassy welded crystal tuff has a eutaxitic texture (MacKenzie *et al.*, 1982).

There are crystals of quartz and feldspar embedded in fine glassy particles (ash), as some feldspars are weathered. Basalt inclusions are medium-grained and sub-rounded to angular (see Figure 3.14). Basalt groundmass textures can be classified as 'interstitial' (MacKenzie *et al.*, 1982: 40). The difference is that most of the volcanic ash particles within this fabric are well-sorted fine-grained (20%), with occasional medium-grained ones poorly sorted (10%). Firing technology varies in this group. Most potsherds are fired in a reduction environment; however, SH115 is oxidised completely.

3.3.2.3 Fabric 3 – Fine-grained silt and medium-grained grog (n=6)

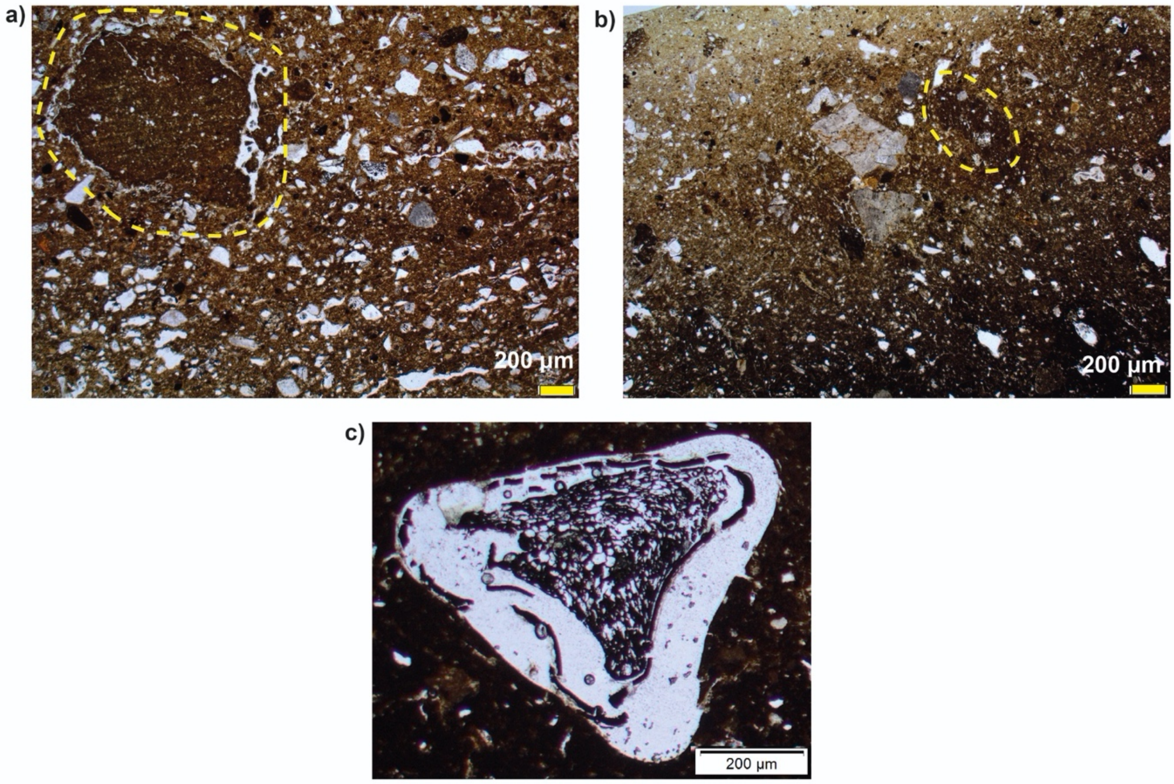


Figure 3. 15. (a) SH128 and (b) SH12 in PPL, x2 magnification; sub-angular to angular grog circled in yellow dashed lines. (c) SH67 in PPL; carbonized plant inclusion (reed). Scale on the lower right of each photomicrograph.

Table 3. 13. Summary of fabric 3 at Shengavit.

Categories	**Fabric 3**: SH12, SH38, SH67, SH114, SH122, SH128	**Sub-fabric 3.1:** SH48
Sorting	Well to moderately sorted	Well to moderately sorted
Inclusion frequency (average %)	20%	20%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Grog (angular to sub-angular, 20%) • Quartz (sub-rounded to angular, 20%)	Aplastic inclusions (<20%): • Grog (angular to sub-angular, 20%) • Ironstones/opaques (sub-rounded, 20%) containing laths of plagioclase feldspars
Rare inclusions (average %)	Silty component (>1-5%): • Quartz (mono- and poly-crystalline, equant to elongate, 10%) • Biotite mica (5%) • Pyroxenes (2%)	Silty component (>1-5%): • Quartz (mono-crystalline equant to elongate, 5%)

	• Iron opaques (sub-rounded to angular, 10%) • Plagioclase feldspars (10%) • Orthopyroxene feldspars (5%)	• Plagioclase feldspars (equant to elongate, 5%) • Pyroxenes (1%) • Clay pellets (1%)
Matrix	• Non-calcareous; Potsherd SH12 contains an inclusion of calcite enrichment and replacement • Optically inactive (SH114) • Optically active (SH12, SH38, SH67, SH122, SH128)	• Non-calcareous
Voids (shape and abundance, average %)	Elongate, micro- to meso-planar, micro-channels and micro-vughs, displaying no clear pattern of distribution. In potsherd SH128, there is a clear void that displays plant material burnt off (3-5%).	Elongate, micro- to meso-planar (3%).
Textural features/comments	Diverse textural characteristics for potsherd SH38 containing clay pellets (5-10% in abundance); fine- and medium-grained	Fine- to medium-grained ironstones and grog.

This fabric is characterised by quartz inclusions (50%), which vary in grain-size (Figure 3.15, Table 3.13). Aplastic inclusions include 'grog'. The rationale for the identification of grog is due to the textural differences between the 'grog' itself and the ceramic paste/fabric, including the angularity of these inclusions (Quinn, 2013: 240). The grog fragments are silty and contain various inclusions that are fine-grained (Figure 3.15). Potsherd SH67 contains plant matter, morphologically similar to a carbonized reed (see Figure 3.15c; Adams and MacKenzie, 1998).

In terms of firing technology, most of the sherds (SH38, SH67, SH114, and SH122) are fired in a reduced environment, occasionally exhibiting an oxidised layer. Potsherd SH128 is fully oxidised (Figure 3.15a and 3.15b). The random alignment of inclusions within this fine fabric suggests hand-building (i.e., producing a slab and joining to produce vessels) (Quinn, 2013). There is no evidence of bloating, particularly between voids; therefore, this fabric was fired at a relatively low temperature or fired only for a short time (Rice, 1987; 2015).

3.3.2.3.1 Sub-Fabric 3.1 – Ironstones and grog (n=1)

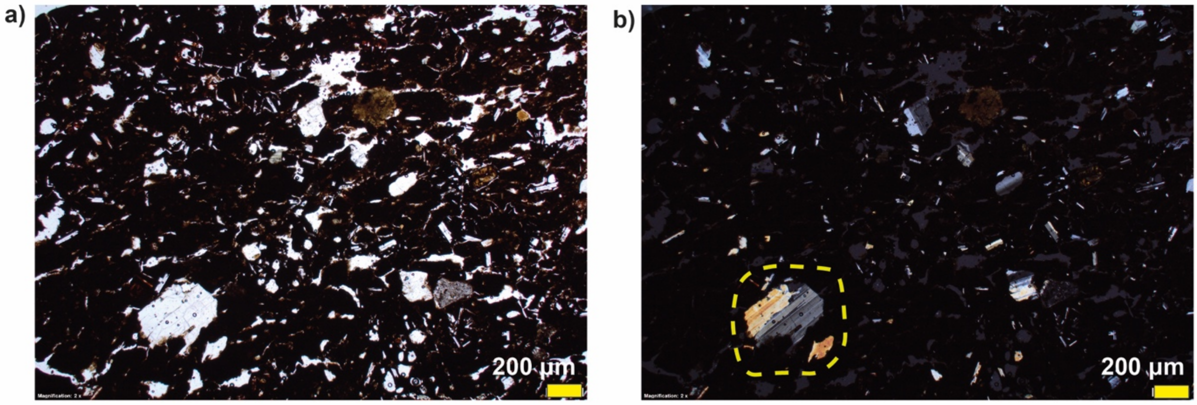


Figure 3. 16. SH48 in (a) PPL and (b) XP, x2 magnification. Scale on the lower right of each photomicrograph. Plagioclase feldspar circled in yellow dashed lines; laths of feldspars evident across the clay matrix.

A sub-fabric group for Fabric 3 can be classified with one potsherd, SH48 (Figure 3.16; Table 3.13). This potsherd does not correspond to any other fabric groups. Macroscopically, it is fired in a reduced environment, and the surface appears to be slightly dark red/burgundy colour. The style of this potsherd has been classified as "Bedeni ware" (Rothman, 2017, personal communication), due to the 'striation designs' applied on the surface of the vessel. Furthermore, the surface of this potsherd is not burnished. The fact that it does not match other fabrics, can be an indication of a non-local source. The alignment of inclusions within SH48 indicates some pinching and coiling (Quinn, 2013), but overall, this is difficult to ascertain, and no clear formation technology is visible.

3.3.2.4 Fabric 4 – Medium to coarse-grained sandstones (n=8)

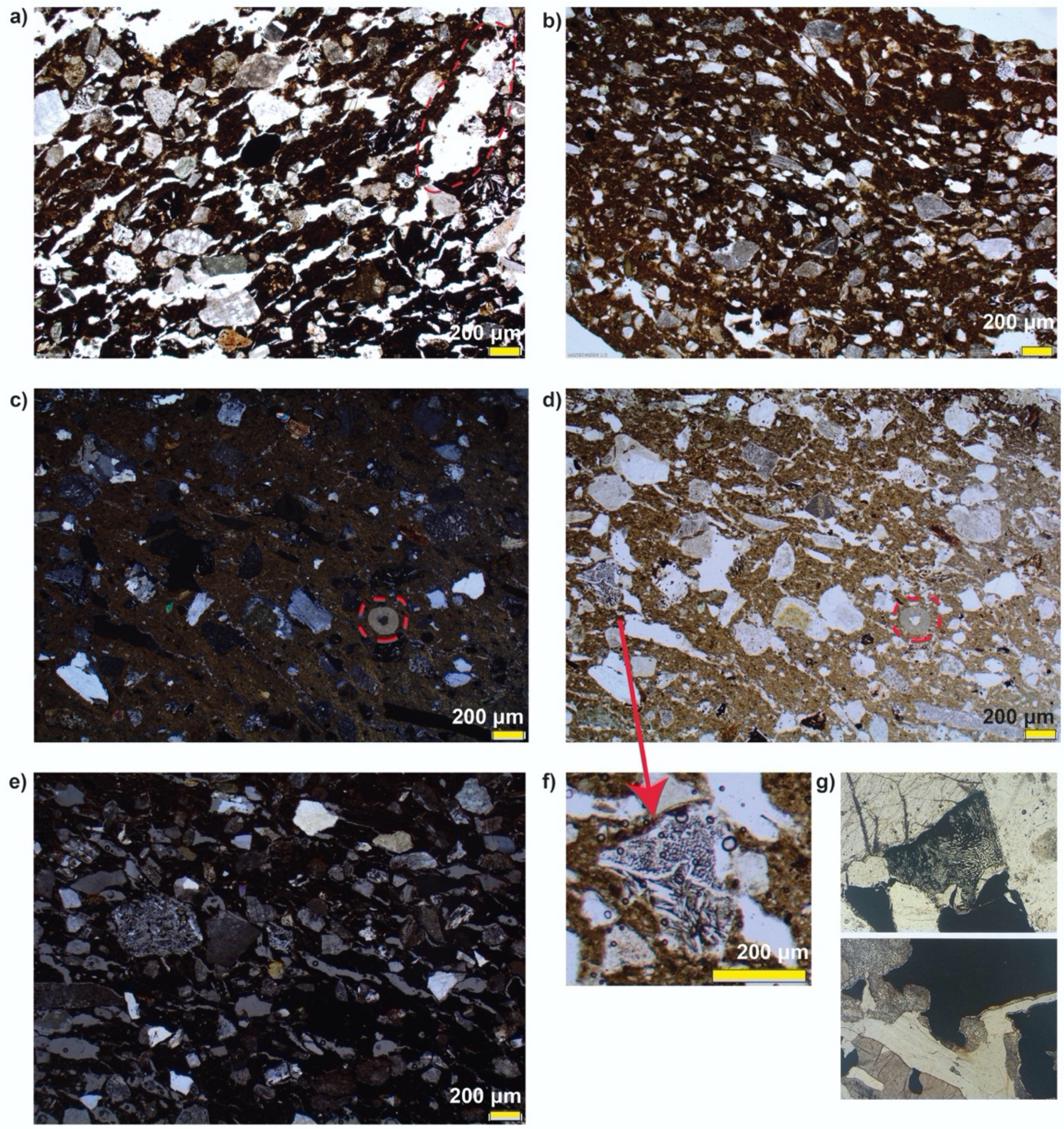


Figure 3. 17. (a) SH15 in PPL, x2 magnification; meso-vugh circled in red dotted lines. (b) SH11 in PPL, x2 magnification. (c) SH43 in XP and (d) PPL, x2 magnification. Echinoderm (echnoids and crinoids) inclusion circled in red. (e) SH114 in XP, x2 magnification. (f) SH43, arrow pointing to an iron ore (fayalite) inclusion, comparable to (g) photomicrograph image from MacKenzie *et al.*, (1982: 53) displaying symplectite of iron ore (fayalite and ilmenite). Scale on lower right of each photomicrograph.

Table 3. 14. Summary of fabric 4 at Shengavit.

Categories	**Fabric 2**: SH11, SH13, SH14, SH15, SH43, SH117, SH129, SH134
Sorting	Poorly sorted
Inclusion frequency (average %)	30-40%

Dominant inclusions (average %)	Aplastic inclusions (<10%): • Quartz (mono- and poly-crystalline, 20%) • Andesitic grains (sub-angular, 10%) • Basalt (rounded to sub-rounded, 10%) • Amphibolite (sub-rounded, 5-10%) Other aplastic inclusions (<5%) • Granitoid (sub-angular to sub-rounded, primarily in potsherd SH43) • Garnet schist (sub-angular, 5%) • Garnet biotite schist (1%)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Calcite (sub-rounded) • Quartz (mono- and poly-crystalline, 3-5%) • Weathered feldspars (plagioclase, sub-angular) • Hornblende amphibole (angular, 2%) • Olivine (angular, 2%) • Chert (sub-rounded, 2%) • Clay pellets (2%) • Biotite (5%) • Muscovite (2%) • Albite (2%) • Iron opaques (5%)
Matrix	• Calcareous (moderate) • Optically inactive (SH13, SH14, SH15, SH117, SH134) • Optically active (SH11, SH43, SH129)
Voids (shape and abundance, average %)	Meso-planar and meso-vughs and meso-channels (10-20%).
Textural features/comments	Medium/coarse-grained; Voids (pores) dominated by calcitic intergrowth.

Fabric 4 resembles a group defined by high porosity and medium- to coarse-grained inclusions in a calcareous (moderate) clay matrix, suggesting a different clay source compared to the other fabrics (see Figures 3.17; Table 3.14). Calcareous clay matrices are defined due to the ‘speckly’ appearance of fine particles of calcite naturally present in the clay (<0.05 mm). The characterisation of this fabric group is associated with medium to coarse-grained sand and various rock fragments of sedimentary and igneous origin. These inclusions are classified as medium- to coarse-sand (0.24-0.5 mm). Due to the nature of the medium-coarse-grained inclusions, this fabric contains many pores and voids (Figure 3.17). The porosity of this fabric group and inclusions resembles similarities with grit-temper (Palumbi *et al.*, 2014; Iserlis *et al.*, 2015). Inclusions are sub-rounded to rounded (low and high sphericity); this characterisation is based on grains classification for sedimentary-based inclusions (Pettijohn *et al.*, 1972).

The textures of metamorphic grains within this fabric are rotational and syntectonic porphyroblasts (Yardley *et al.*, 1990: 95). Other textures can be described as polymorphic (Yardley *et al.*, 1990). Zoned feldspars (plagioclase) in iron opaques (ironstones) are evident. This suggests highly weathered andesites and basalts as sources. The inclusions within this fabric resemble one of the most complex clay sources at this site, and the medium/coarse grains are not levigated (Figure 3.17). Thus, potters were primarily producing pottery with an alluvial clay source from a nearby river-bed.

The quartz inclusions within this fabric group vary between sub-rounded to sub-angular. This is partly due to redeposition of grains and diagenesis of carbonate minerals over time (Bathurst, 1975; Adams and MacKenzie, 1998: 101). Siltstones, shale and mudstone are present, but their inclusions are mainly too fine to identify. These are terrigenous clastic sediments (Adams *et al.*, 1984: 3), which are transported sediments derived from the weathering of pre-existing igneous, sedimentary or metamorphic rocks.

Regarding potsherd SH43, there is evidence of a bioclast inclusion, surrounding a quartz grain (Figure 3.17c-d). The classification for this bioclast is an echinoderm, particularly echinoids and crinoids, due to the variety of shapes composed of calcite and crystals with uniform extinction. Thus, the speckled and dusty appearance is due to the infilling of fine pores. These bioclasts are major contributors to the allochemical fraction of marine limestones (Adams *et al.*, 1984: 44). These inclusions complement the geological characterisation of the site corresponding to an alluvial clay source. Furthermore, another unusual inclusion is evident in SH43 (Figure 3.17f), depicting a 'symplectite' texture: "an intimate intergrowth of two minerals in which one mineral has a vernicular (wormlike) habit" (MacKenzie *et al.*, 1982: 53; Figure 3.17g). This inclusion is most likely characteristic of an iron ore deposit (i.e., ilmenite and fayalite), surrounded by feldspar. Other grains include holocrystalline granite, which is essentially crystals of biotite, quartz, perthitic potassium-rich feldspars and zoned sodium-rich feldspars (MacKenzie *et al.*, 1982). As mentioned, metamorphic rocks are also evident comprising mica-schist and possible forsterite (Yardley *et al.*, 1990). These aplastic inclusions contain a significant portion of iron opaques. Furthermore, small isotropic grains of dark brown spinels within grains are present.

Overall, this fabric group is extremely diverse and exhibits a high inclusions frequency compared to other fabrics. SH11 and SH14 are oxidised fully; SH13 and SH15 are fired in a reduced environment; lastly, SH43, SH117, SH129, and SH134 are irregularly fired.

3.3.3 Mokhra-Blur (n=11)

Mokhra-Blur is an archaeological settlement located near Shengavit in the Ararat Plain. Potsherds from this site might not be well-contextualised, but they are typologically categorised as Kura-Araxes (Chapter 2.2). Dr. Gregory Areshian and Dr. Pavel Avetisyan provided these sherds from the settlement, which were excavated in the 1970s. The general geological characterisation of this region is terrigenous molassic sediments (Hrazdan, Dilijan, Bandivan, suites); reddish clays, sandstones, alevrites, conglomerates, with layers of combustible schists and dark coals (550 m) (Kharzyan, 2005). Lacustrine-alluvial clay is also evident near the site. Neighbouring areas of the site correspond to Shengavit's geological characterisation (see geological map, Figure 3.3; Table 3.1). Samples associated with Mokhra-Blur are MB001 (potential cooking pot), MB1, MB2, MB3-2, MB4, MB5, MB6, MB7, MB8, MB9, MB10, and MB12. Samples MB3-1 and MB11 are reduced fine-wares analysed via SEM-EDS. There are three main groups associated with this archaeological site. In particular, fabric 3 is the most common fabric group. In general, the fabric paste is associated with a type of clay characteristic of sandy-origin (molassic sediments), as there are various inclusions of volcanic origin that may indicate some transported sediments allowing potters to use diverse clay sources nearby.

Table 3. 15. List of fabrics identified in the potsherd samples from Mokhra-Blur.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Medium- and coarse-grained volcanic ash and glass	2	MB001, MB10
Fabric 2	Medium- and coarse- grained rock fragments and sandstones	2	MB5, MB6
Fabric 3	Coarse-grained volcanic ash, andesites and sandstones	7	MB1, MB3-2, MB4, MB7, MB8, MB9, MB12

3.3.3.1 Fabric 1 – Medium- and coarse-grained volcanic ash and glass (n=2)

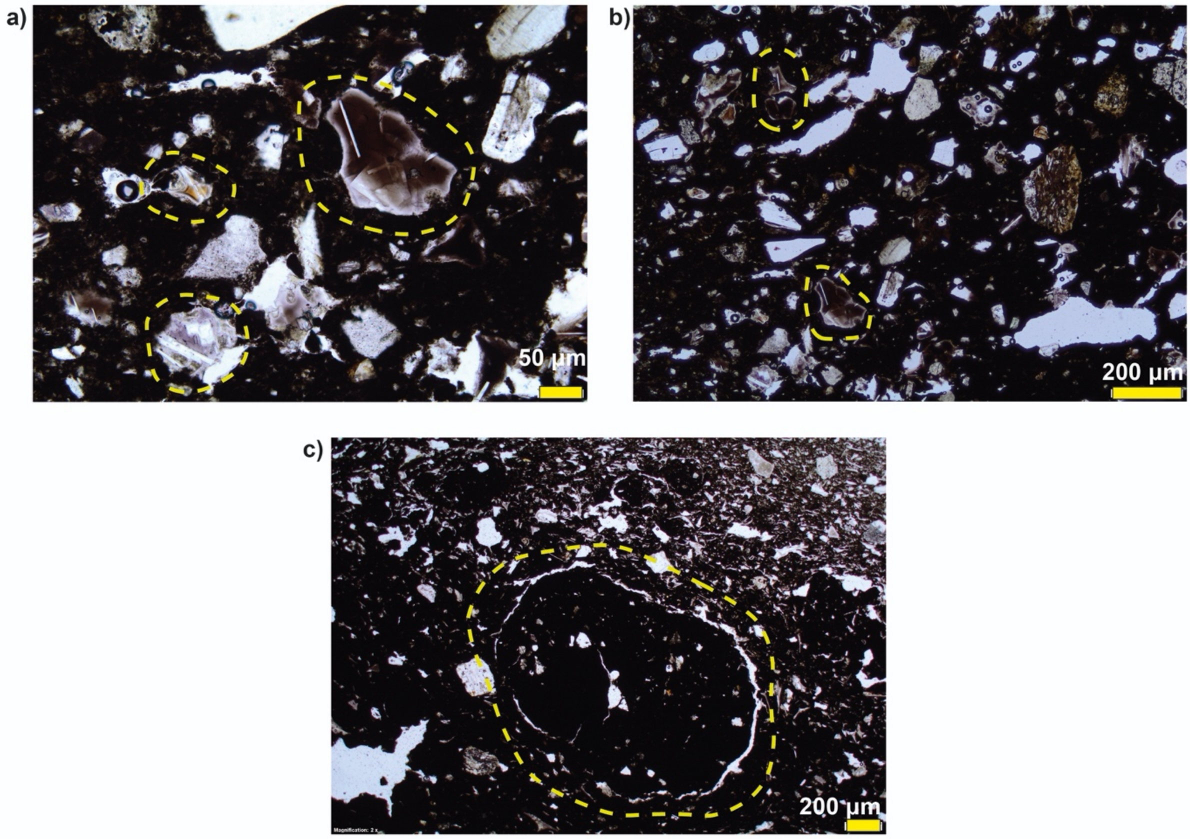


Figure 3. 18. (a) MB10 in PPL, x10 magnification and (b) x4 magnification; volcanic ash and glassy inclusions, circled in yellow dashed lines. (c) MB001 in PPL, x2 magnification; clay pellet circled in yellow dashed lines. Scale on the lower right of each photomicrograph.

Table 3. 16. Summary of fabric 1 at Mokhra-Blur.

Categories	**Fabric 1**: MB001 and MB10
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	20-30%
Dominant inclusions (average %)	Aplastic inclusions (<15%): • Clay pellets and unhydrated clay nodules • Pumice and tuff (well to poorly sorted, sub-angular to sub-rounded, fine to medium/coarse-grained)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant) • Plagioclase feldspars (and occasional weathered grains) • Sanidine (alkali feldspars) • Clinopyroxene • Shale (1%) • Volcanic ash/rock fragments • Iron opaques

Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Micro-planar and elongate to meso-vughs (3-5%).
Textural features/comments	Medium and coarse-grained

Potsherds associated with this group are MB001 and MB10 (Figure 3.18; Table 3.16). MB001 is a cooking pot, visually coarse, and MB10 is most likely a utility vessel, thin-walled. MB001 is fired in a reduction environment and MB10's core is reduced, with an oxidised layer. Regarding potsherd MB10, voids are micro-planar and difficult to assess due to the amount of ash and tuff in the fine silty matrix. Elongate meso-vughs are common in MB001, including various micro-planar voids.

The tuff inclusions can be classified as glassy unwelded rhyolite, as some are banded and slightly flattened in terms of texture (MacKenzie *et al.*, 1982). This fabric is essentially embedded in fine glassy particles (ash) naturally occurring in clay, characterising the well-sorted silty fabric (finer particles are difficult to examine through thin-section petrography). It is not possible to suggest that the volcanic ash was added as temper, as the size of inclusion vary from fine-grained to medium-grained. It is most likely quite common within the clay of the region (geological characterisation, Table 3.1). Other common textures in this fabric can be described as cryptocrystalline (i.e., consolidated ash), enclosed in fragments of shale and quartz crystals (MacKenzie *et al.*, 1982). Inclusions are not aligned parallel to the margins of the vessel. For potsherd MB10, inclusions are concentrated in various areas of the matrix, similar to a ring-shaped format which is characteristic of the coiling technique in forming pottery (Quinn, 2013). While both sherds are similar in clay matrix and composition of inclusions, potsherd MB001 is slightly different in terms of its interior lining with a possible slip layer. This is due to the fine silty concentration of inclusions evident in the fine interior layer (oxidised), compared to the rest of the clay matrix body (fired in a reduction environment). Significantly, potsherd MB001 contains more clay pellets than MB10 and there are coarser inclusions (i.e., 0.3-0.5 mm).

3.3.3.2 Fabric 2 – Medium- and coarse-grained rock fragments and sandstones (n=2)

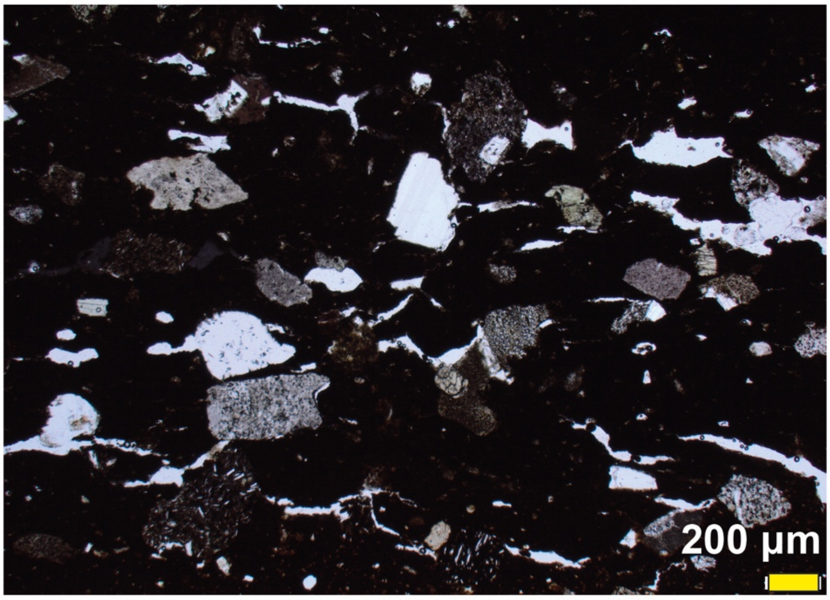


Figure 3. 19. MB5 in PPL, x2 magnification. Scale on the lower right of photomicrograph.

Both potsherds are fired in a reducing atmosphere, in order to achieve a black core and surface feature. There is a clear layer of a slip added by potters, where slips are slightly brown to dark brown (minimally oxidised) (Figure 3.19; Table 3.17). While both sherds contain similar inclusions and fabric, it appears that MB5 can be classified visually as a bimodal distribution of inclusions, where the aplastic inclusions predominate the clay matrix. The size of voids is most likely to due to the shrinkage and cracking during firing, given the medium-coarse inclusions, primarily evident in potsherd MB5. The general characterisation of this fabric is similar to fabric 3, but with some similarities to fabric 1 in terms of its silty volcanic ash. Due to the similarities within fabrics associated at Mokhra-Blur, it is possible to suggest that potters were using three sources of clay locally and occasionally mixing them and/or sieving for finer fractions (i.e., Fabric 1 is finer than Fabric 3); though local clay sources are required for comparative data.

Table 3. 17. Summary of fabric 2 at Mokhra-Blur.

Categories	**Fabric 2**: MB5, MB6
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	20-30%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Sandstones (sub-angular to sub-rounded) • Rock fragments (sub-angular) • Gabbro (fine-grained) • Andesite (sub-angular) • Rhyolite • Ignimbrite
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (mono-crystalline, equant angular to equant and elongate sub-rounded; poly-crystalline, sub-rounded to sub-angular) • Weathered feldspars (plagioclase) • Volcanic ash (tuff) • Iron opaque • Orthopyroxene and clinopyroxene • Chert (1%) • Trachyte (sub-rounded, 2-5%)
Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Micro-vesicles, micro- and meso-vughs, micro- and meso-planar (3%).
Textural features/comments	Medium and coarse-grained (up to 0.5mm) in size, sandstones evident as the main textural features.

Rock fragments are fine-grained gabbro (plagioclase, orthopyroxene and iron opaques), sub-angular andesite (containing micro-phenocrysts of plagioclase felspar and hornblende amphiboles). Other coarse rock fragments include rhyolite (phenocrysts of feldspar in a groundmass with laths of alkali feldspar), and ignimbrite (quartz, feldspars and welded tuff). Few inclusions within the aplastic inclusions include chert (1%) in MB5. Possible presence of sub-angular to sub-rounded trachyte (2-5%) due to the volcanic rock consisting fine-grained feldspars and iron opaques/ferro-magnesian minerals. Quartz is also present confined to the groundmass of the volcanic rock. In general, volcanic rock fragments have porphyritic textures. Other possible few inclusions include chlorite (>2%), which is black in XP but pale green in PPL. The inclusions and rock fragments within this fabric represent a mix of igneous and sedimentary base rocks; due to the angularly of aplastic inclusions and weathered fragments, it is possible to suggest an alluvial clay source from a nearby river-bed.

3.3.3.3 Fabric 3 – Coarse-grained volcanic ash, andesite and sandstones (n=7)

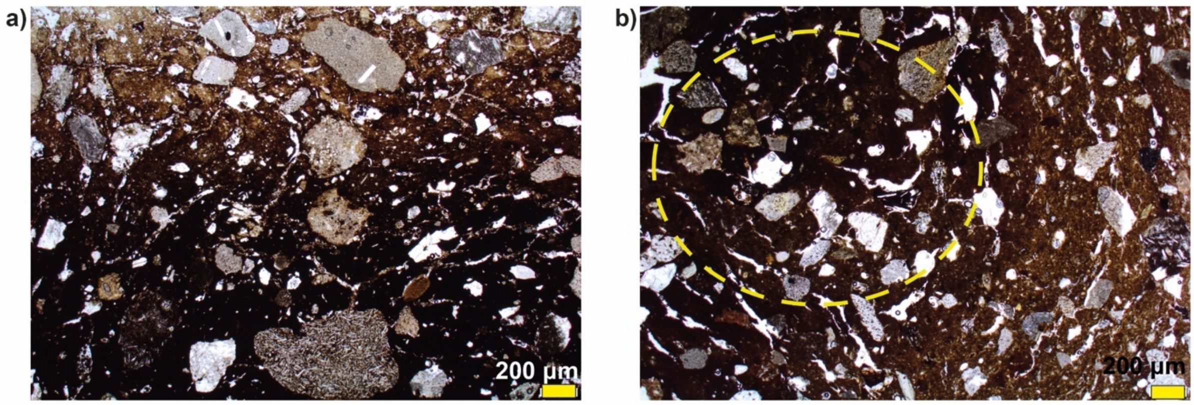


Figure 3. 20. (a) MB3-2 in PPL, x2 magnification. (b) MB12 in PPL, x2 magnification; planar and elongate voids as well as inclusions aligned in a concentric ring (circled in yellow dashed lines), implying the coiling technique. Scale on the lower right of each photomicrograph.

Table 3. 18. Summary of fabric 3 at Mokhra-Blur.

Categories	**Fabric 3**: MB1, MB3-2, MB4, MB7, MB8, MB9, MB12
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	20%
Dominant inclusions (average %)	Aplastic inclusions (<10%): • Andesite (sub-angular to rounded) • Sandstones (litharenites; sub-angular to rounded) • Volcanic ash and glass (10-15%)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant, angular to sub-rounded) • Clinopyroxene (equant) • Weathered feldspars (plagioclase) • Iron opaque (sub-rounded, 5%) • Siltstones (1%) • Carbonates (sub-rounded to rounded, i.e., lithoclasts, peloids, interclasts, 1%)
Matrix	• Calcareous (moderate)

	• Optically inactive
Voids (shape and abundance, average %)	Micro- to meso-planar and meso-vughs (5-10%).
Textural features/comments	Medium/coarse (0.5-1 mm); there is evidence of some calcite enrichment in voids (i.e., in MB7 and MB9); however, difficult to tell if it's related to the burial environment and unrelated to pottery technology.

Based on the inclusions present (Figure 3.20), this fabric is classified as coarse volcanic ash, andesite and sandstones (Table 3.18). Andesitic rock fragments (20%) are moderately sorted and range between equant and elongate sub-angular to sub-rounded. Other inclusions include litharenites, which are sandstones less than 95% quartz and mostly rock fragments than feldspar. The porphyritic texture suggests a volcanic origin and igneous parent rocks (Adams *et al.*, 1984). Greywackes are common sandstones as well, they contain a fine-grained matrix of quartz, feldspar, opaque minerals, and amphibole hornblende. Welded volcanic ash/tuff is also common across this fabric group (15%) and appear to be sub-angular. Ignimbrites (5%) are common, specifically in potsherds MB1, MB3-1, MB4, MB7, and MB9. Few inclusions include sub-rounded to rounded siltstones (1%) and rounded carbonate rocks (i.e., lithoclasts, peloids and interclasts), which are common in limestones. The presence of these aggregate grains is common in sedimentary environments. Ironstones are also evident (sedimentary rocks with >15% iron), and normally rounded. Inclusions are aligned parallel to the clay matrix, which might suggest slab building and drawing clay upwards. There is one potsherd with evidence of coiling (i.e., if inclusions are organised in a concentric ring) (Figure 3.21). The forming technology for MB9 is unique compared to the other potsherds, as there is a clear fine slip and two oxidised layers.

Based on the diverse inclusions present in the fabric paste, it is possible to suggest some clay mixing with Fabric 1 and Fabric 2. However, additional potsherds are required to re-sample and analyse the assemblage quantitatively. This is the largest fabric group, which is slightly similar to Fabric 2. The firing technology, in comparison to other fabrics, varies vessel by vessel. Potsherds MB1 and MB3-2 are fired in a reduction environment, achieving a complete black core and surface. Potsherds MB4, MB8 and MB9 consist of a black core and an oxidised exterior and/or internal layer. Potsherds MB7 and MB12 are irregularly fired, resulting in a black core and oxidised surface and interior. There is no standard firing technology, given the differences observed in firing conditions. The difference between Fabric 3 and Fabric 2 is that the inclusions are coarse and vary in size (0.5-1mm).

3.3.4 Karnut-1 (n=14)

As mentioned briefly in Section 3.3.3 (Table 3.1), Karnut-1 is characterised by volcanic and sedimentary rocks of the Pliocene-Miocene, granitoid intrusions and Late Cretaceous sedimentary formations (Aslanyan, 1958; Valesyan, 2007; Iserlis *et al.*, 2010: 250). In particular, “the Shirak Plain is covered by Upper Pliocene-Pleistocene alluvial-proluvial, fluvial, lacustrine sediments and recent tuff and pebble formations” (Aslanyan, 1958: 129-132; Valesyan, 2007; Iserlis *et al.*, 2010: 250). One of the petrographic groups reported by Iserlis *et al.*, (2010) confirmed organic temper; however, findings reported here illustrate an absence of organic temper.

There are three fabric groups associated with Karnut-1. As mentioned in Chapter 2, the site is located on the border between the Pambak Range and the Shirak Plain, western and southern slopes of Surb Minas, and the hill is characterised with trachytic deposits (Badalyan and Avetisyan, 2007: 136-149). Through excavations, ground stone tools were unearthed corresponding to raw materials such as basalt, dacite, andesite, and diorite (Badalyan and Avetisyan, 2007: 136-149). Previous analyses of Karnut-1 sherds (Iserlis *et al.*, 2010) will be compared here, as potsherds from this study are limited compared to published data (n = 51, Iserlis *et al.*, 2010). The repertoire includes burnished bowls, goblets, jars, kraters, and *karas* (pithoi), as well as unburnished cooking wares: pots and pans. The thick-walled vessels most likely represent *karas* (pithoi) sections from larger vessels. Other typologies include utility wares such as bowls, plates, jars, and goblets.

Table 3. 19. List of fabrics identified in the potsherd samples from Karnut-1.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Coarse-grained igneous rock fragments	2	KRT 58, KRT66
Fabric 2	Medium-grained igneous rock fragments and grog	2	KRT 63, KRT 64
Fabric 3	Medium-grained volcanic ash and tuff	10	KRT52, KRT53, KRT55, KRT56, KRT57, KRT59, KRT60, KRT61, KRT62, KRT65

3.3.4.1 Fabric 1 – Coarse-grained igneous rock fragments (n=2)

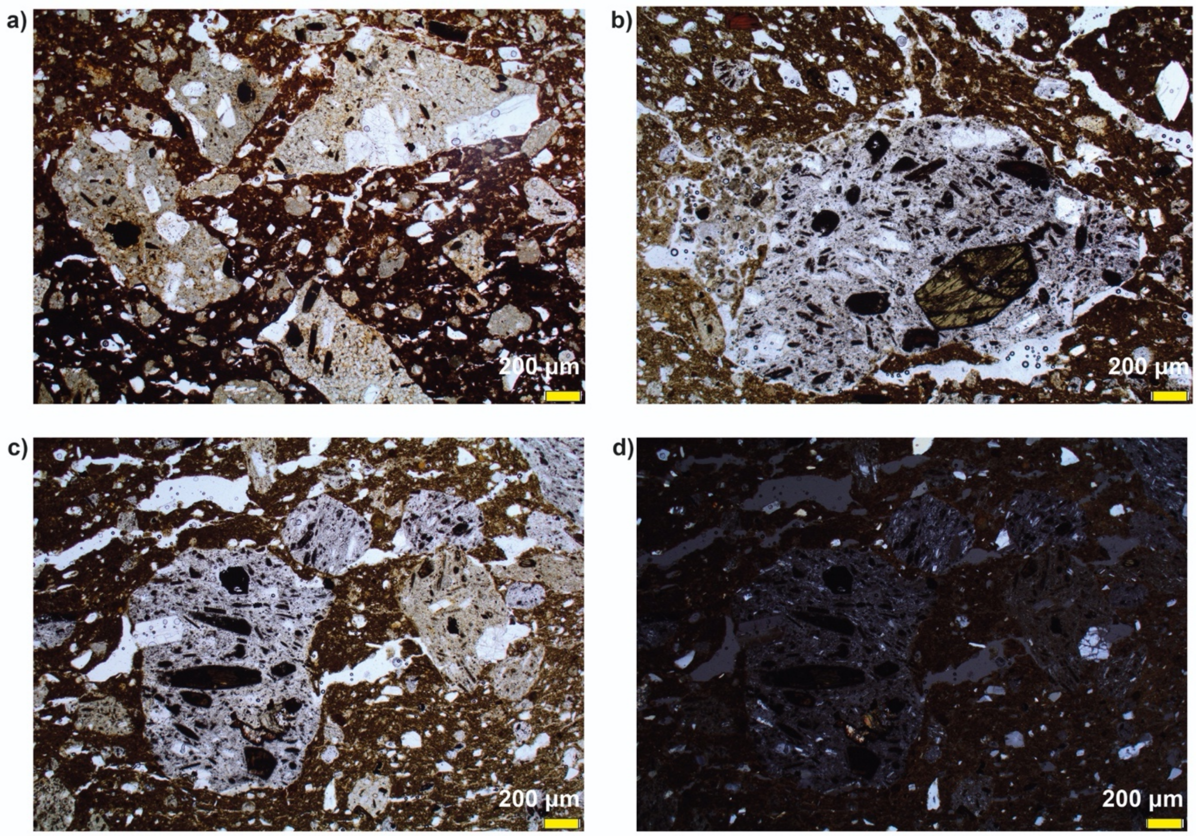


Figure 3. 21. (a) KRIT66 in PPL, x2 magnification. (b and c) KRT58 in PPL and (d) XP, x2 magnification. Scale on the lower right of each photomicrograph. The large inclusions are characterised as andesite, which show micro-phenocrysts of clear plagioclase feldspar and dark, lozenge-shaped hornblende.

Fabric 1 and 2 are similar, but this fabric (1) contains coarse inclusions of igneous rock fragments (Table 3.20). The rock fragments (i.e., xenoliths), contain elongate and equant sub-rounded iron oxide opaques (see Figure 3.21, KRT58) and amphibole hornblendes in a trachytic/porphyritic groundmass. Based on references, MacKenzie and Adams (1994: 40), "the black rims on amphiboles are due to the formation of iron oxide as a result of oxidation." Other rock fragments are characteristic of porphyritic andesites, with phenocrysts of plagioclase, hornblende (amphibole), possible augite, and iron oxides/opaques (magnetite) surrounded by a fine-grained groundmass of plagioclase, iron opaques and volcanic glass/ash. Figure (KRT58) contains coarse igneous rock fragments (>20%), identified as xenoliths[3], scoria and andesites/trachytic groundmasses.

While this fabric group is coarse-grained, it is predominated by finer and medium-grained minerals and rock fragments. Additional coarse inclusions include some visible sub-rounded scoria as well, bloated and red, brown to dark brown in PPL (5%). Aplastic inclusions are igneous rock fragments that have not been levigated and possibly added by potters to the silty groundmass. Inclusions are not aligned in any specific order in the vessel, implying a similar forming technology as fabric 2 (i.e., slab-building). Firing technology employed is oxidised and slightly reduced towards the edges of the surface, achieving a darker brown/black surface.

[3] Xenoliths are "rock fragments broken from the magma chamber or conduit walls"; MacKenzie and Adams (1994: 40)

Table 3. 20. Summary of fabric 1 at Karnut-1.

Categories	**Fabric 1**: KRT58, KRT66
Sorting	Poorly sorted
Inclusion frequency (average %)	30%
Dominant inclusions (average %)	Aplastic inclusions (<10%): • Igneous rock fragments (medium- to coarse-grained) • Scoria (sub-rounded, 5-10%) • Xenoliths • Amphibole hornblende in a porphyritic groundmass
Rare/fine inclusions (average %)	Silty component (>1-5%): • Quartz (equant angular to sub-rounded) • Arkosic sandstones (sub-rounded, 5%) • Clinopyroxene • Hornblende amphibole • Olivine • Weathered feldspars (plagioclase) • Volcanic ash/glass • Iron opaque (sub-rounded) • Radiolarian chert (1%)
Matrix	• Non-calcareous • Optically active (moderate)
Voids (shape and abundance, average %)	Meso-vughs and planar voids are evident throughout the fabric (3%).
Textural features/comments	Medium- to coarse-grained

3.3.4.2 Fabric 2 – Medium-grained igneous rock fragments and grog (n=2)

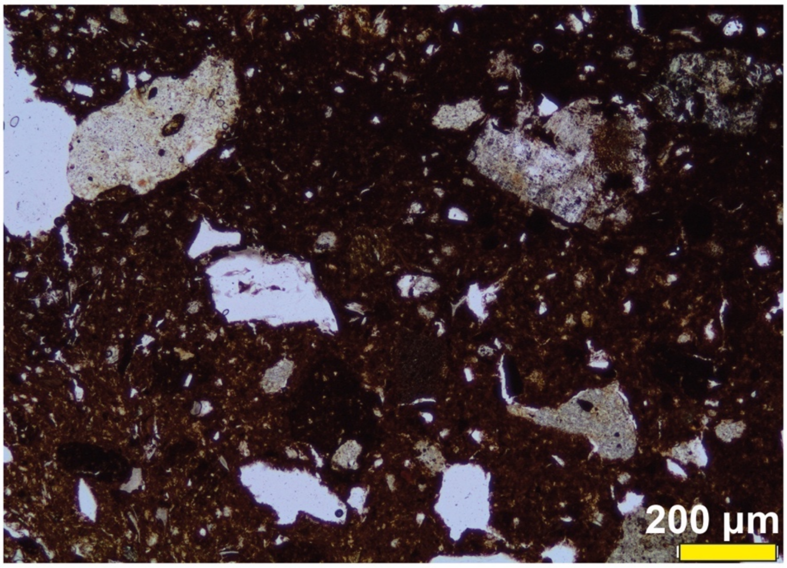


Figure 3. 22. KRT64 in PPL, x2 magnification. Scale on the lower right of photomicrograph.

Table 3. 21. Summary of fabric 2 at Karnut-1.

Categories	**Fabric 2**: KRT63, KRT64
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	25%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Grog (sub-angular to angular, 10%) • Igneous rock fragments (rhyolite, andesite and dacite) (15-20%)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant angular to sub-rounded) • Clinopyroxenes • Hornblende (amphibole) • Weathered feldspars (plagioclase) • Sanidine • Orthoclase • Volcanic ash/tuff • Iron opaque (sub-rounded)
Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Micro- to meso-channels and vughs; planar voids (1-3%).
Textural features/comments	Medium-grained

Fabric 2 is dominated by ‘grog’ and medium-grained rock fragments (Figure 3.22; Table 3.21). However, it is unlikely that grog is the main tempering material at Karnut-1, as it is not recorded at high abundance (10%). Grog fragments are identified due to various properties – angularity, colour/firing, inclusions within the grog (i.e., quartz and other fine-grained minerals such as feldspars and pyroxenes). This finding is similar to observations published by Iserlis *et al.*, (2010), in terms of confirming grog, but the fabric group is quite small (only 14% of the assemblage analysed contain possible grog).

Inclusions are not aligned in a specific order, and there is no evidence of forming techniques (including coiling), similar to fabric 1. Voids in this fabric are difficult to examine, due to the presence of volcanic glass and bloating of scoria and volcanic ash inclusions, however the porosity is quite low in this group (1-3%). Firing technology varies in this group; for potsherd KRT63, the core is black, and surfaces are oxidised. For KRT64, the exterior is black (reduced) and interior is orange (oxidised).

3.3.4.3 Fabric 3 – Medium-grained volcanic ash and tuff (n=10)

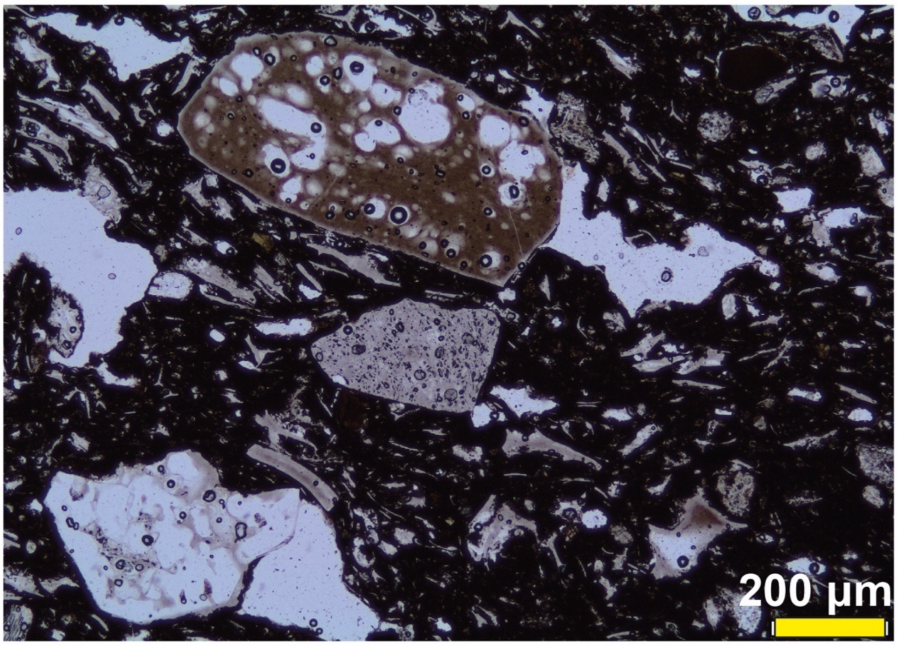


Figure 3. 23. KRT60 in PPL, x4 magnification. Scale on the lower right of photomicrograph.

Table 3. 22. Summary of fabric 3 at Karnut-1.

Categories	**Fabric 3**: KRT52, KRT53, KRT55, KRT56, KRT57, KRT59, KRT60, KRT61, KRT62, KRT65
Sorting	Moderately sorted (and occasionally poorly sorted, i.e., KRT56, KRT57, KRT62, KRT65)
Inclusion frequency (average %)	25-30%
Dominant inclusions (average %)	Aplastic inclusions (<15-20%): • Volcanic ash and tuff (angular, sub-angular and sub-rounded)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant angular to sub-angular and elongate sub-angular) • Microlites (5-10%), elongate and microcrystalline (<0.2 mm) • Feldspars (weathered) • Clinopyroxene • Biotite • Hornblende • Iron opaques (equant sub-angular) • Tuff (fine-grained and welded) • Ooids, ooliths and lithoclasts (2%) • Clay pellet (1%) • Metamorphic rock (mica-schist, 1%)

Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Micro-channels, micro- to meso-vughs, and planar (3-5%).
Textural features/comments	Fabric texture dominated by welded tuff and medium-grained volcanic ash.

The largest petrographic group here is also similar to the largest group observed in Iserlis *et al.*, (2010), dominated by fine- to medium-grained volcanic ash/glass (Figure 3.23; Table 3.22). However, inclusions differ in the fabric paste; contrary to published data, there is no organic temper added to this fabric group, compared to published findings (Iserlis *et al.*, 2010). The aplastic inclusions (>15-20%) within the clay are mostly volcanic ash/tuff, and they differ in terms of type and size, between fine, medium and coarse-grained (i.e., welded tuffs; Reedy, 2008; MacKenzie *et al.*, 1982). Given the various morphologies and size of inclusions, volcanic ash content is most likely present within the clay and not added as a temper by potters. As this region is highly volcanic, the presence of volcanic ash in the clay is expected. However, based on the medium-grained morphologies, potters most likely preferred clay with a high volcanic ash content.

Other notable inclusions within the clay fabric are worth highlighting. KRT55 contains some sedimentary inclusions, such as ooids, ooliths, and lithoclasts (2%). This is similar to the radiolarian chert visible in potsherd KRT66 (fabric 1). Chert fragments may persist in pottery and clay, as they are stable and resistant to weathering. Potentially, this might be different type of clay or a mixture, and it can be associated as a separate sub-group of this fabric. Also contains sub-angular polycrystalline quartz, one inclusion of a metamorphic rock (possible schist) and one clay pellet. In general, the silty matrix (5-10%) of KRT55 also contains volcanic ash.

Firing technology differs across this fabric group. Potsherds KRT52 and KRT61 are fully oxidised (orange). The rest of the potsherds are fired in a reduction environment, but some are irregularly fired and/or might contain a slip/oxidised layer added (potsherds KRT56, KRT57, KRT60 and KRT62). KRT57 contains a fine-grained slip, suggesting the application of levigated clay. Inclusions are generally aligned randomly, similar to fabric 1 and 2 and voids are not very common (3-5%).

Due to various morphologies of volcanic ash (>20%), there is evidence of bloating pores within rock fragments and the clay matrix. This is not to be confused with bloating pores evident in high-fired ceramics. Bloating pores evident in this fabric group are present due to the volcanic ash morphologies.

3.3.5 Sotk-2 (n=4)

Sotk-2 is a relatively underexplored site, as excavations were conducted recently. It is located on the eastern border of modern Armenia, and to this day, the site area coincides with a gold mine (Kunze *et al*., 2011). As such, the mineralogy and geological formation of this area have been extensively studied. In reference to the Geological framework (Section 3.3.3), in brief, the Sotk-2 area expected local sources and minerals in clay naturally occurring in the area include, but are not limited to the following: (1) marine volcano-sedimentary rocks, sandstones, marls, limestones, and alevrolites; (2) tuffbreccias, tuffconglomerates, lava floods of andesite-basalts, tuff-sandstones and limestones; (3) basalts; (4) radiolarites and other silicates; (4) volcanic lava flows and volcanic ash; (5) olivine, olivine-magnetite and other gabbros; (6) intrusive rocks—gabbros, gabbro-diorites, granodiorites, and quartz diorites; (7) extrusive subvolcanic intrusions—diorite-porphyrites, gabbro-porphyrites, and basalts.

Four potsherds were analysed for thin-section petrography, but an overall 79 samples were analysed via stereomicroscopy and results suggest a homogeneous surface technology (Section 3.2). The potsherds selected for thin-section analysis are SK6, SK23, SK46, and SK51 (see Figure 3.5 for a macroscopic image of SK6 sherd). The rationale for the small sample size from this site is thoroughly explained in the 'COVID-19 Disruption Statement'.

General characterisation

The majority of sherds from Sotk-2 are black-burnished, fired in a reduced/unoxidised atmosphere, resulting in a black/grey core and clay matrix (Figure 3.24). Igneous rocks and volcanic ash are the main inclusions, largely available as local sources at the site. All potsherds (four samples) are discussed separately, due to the limited sample size. In general, fabrics at Sotk-2 are coarse-grained (0.4-0.7 mm) and poorly sorted. Potters most likely did not levigate the clay. However, it is possible that these sherds were tempered (i.e., basalt, andesite, volcanic ash and limestone), and/or multiple use of various clay raw materials. The sedimentary rocks and source of clay at Sotk-2 most likely derive from river-bed areas, locally available. Typologically, these potsherds are thin-walled compared to other KA assemblages, very similar to Norabak-1, discussed in Section 3.4.

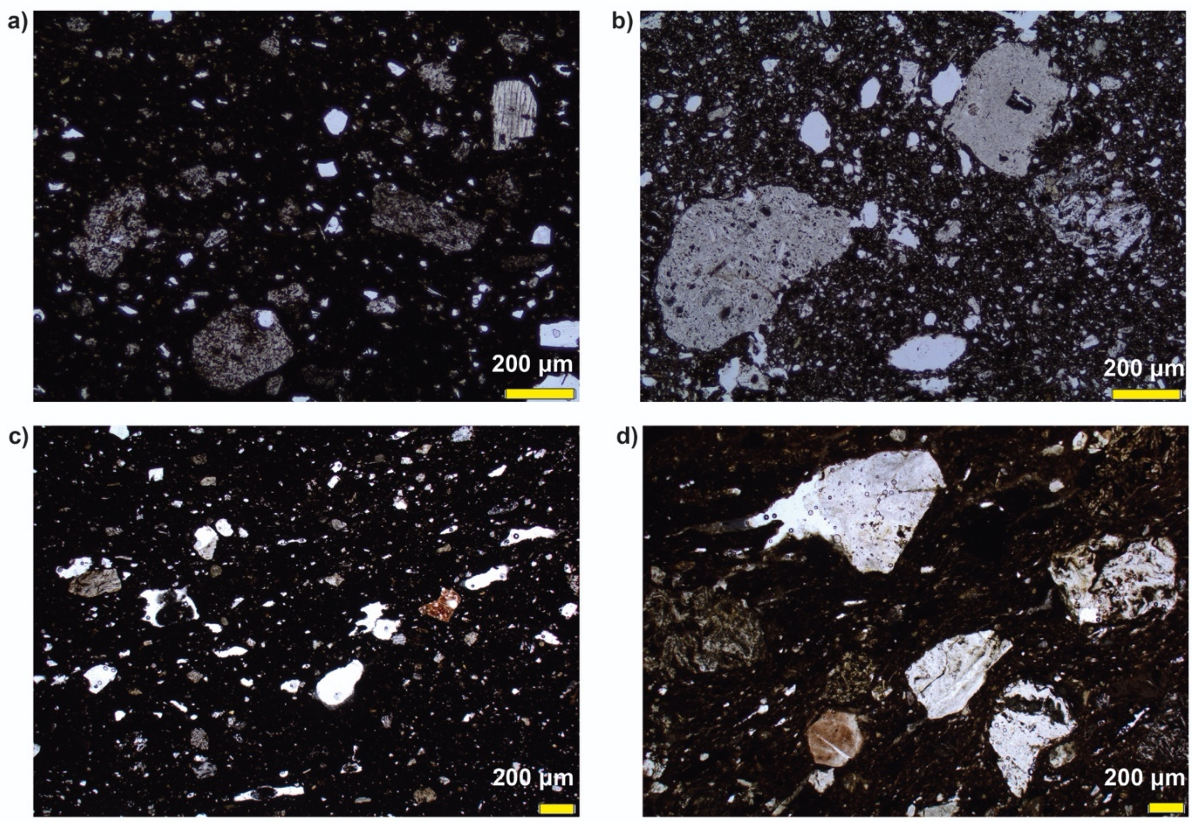


Figure 3. 24. (a) SK6, x4 magnification. (b) SK23, x4 magnification. (c) SK51, x2 magnification. (d) SK46, x2 magnification. All photomicrographs in PPL. Scale on the lower right of each photomicrograph.

Potsherd SK6

This potsherd is visually unique, due to its iron-rich pigment associated with the surface design (see Figure 3.24a). Potsherd SK6 is constructed with non-calcareous clay, and it is medium-coarse-grained. The dark core reflects firing in a is fired in a reducing environment. There is a slip on the inner layer of interior of the vessel; however, the composition does not appear different compared to the clay body. There is minimal presence of voids in this potsherds (roughly 2% in abundance), and the shape is defined as 'vesicular'. Inclusions are moderately to poorly sorted (10 -20 %, estimated visual percentage). Inclusions include equant and euhedral quartz (10%), plagioclase feldspars (10%), andesite/dacites (5-10%), trachyte (2%), iron opaques (5-10%), marine-volcano-sedimentary rocks (sub-rounded, 20%), and other ferro-magnesian minerals (few). Dacites are sub-rounded and contain feldspar/quartz inclusions, in a glassy groundmass. Trachytes are sub-rounded as well, in a groundmass of alkali feldspars, including minor constituents of iron oxides. Possible few inclusions include rhyolites and granitic groundmasses (5%). Sandstones (5%) are common as rounded inclusions, interlocking mainly metamorphic lithic fragments (i.e., schist) and over 90% of the framework contains quartz.

Potsherd SK23

The clay is non-calcareous and medium-coarse grained. The inclusions are abundant in 15-20% visual percentage estimation, and poorly sorted. The fine fraction of the clay body contains sub-rounded quartz and siltstone fragments, suggesting a possible river-bed clay source due to the rounded inclusions. Coarse inclusions are mainly volcanic rock fragments and glass (20%), with visible feldspar inclusions (20-30%) (Figure 3.24b). There are scattered phenocrysts of biotite (2%) and black magnetite (2%), characteristic of andesite, and sub-rounded andesites (5%) are also present in this potsherd. The andesites in this particular potsherd display a 'pilotaxitic' texture (Reedy, 2008: 20). This is due to the small microlites of feldspar in a glassy matrix, formed due to magma flow. Compared to potsherd SK6, few trachytes are visible (2%)—alkali feldspars as the main constituents and iron opaques. A different source of raw materials was most likely used for this potsherd, in comparison to the other sherds. and manufacturing techniques. Inclusions are distributed randomly and do not align vertically with the sherd.

Potsherd SK46

Compared to the other three sherds, potsherd SK46 is slightly calcareous, with slight optical activity (Figure 3.24d). Some inclusions are derived from sedimentary rock fragments (i.e., marine clay). Potsherd is fired in a reduction environment; however, there is a dark brown slip on the exterior of the vessel, suggesting a unique surface treatment for this particular KA vessel. The visual percentage estimation of inclusions is 15%, poorly sorted and coarse-grained. Secondary calcites are visible in the clay matrix (3%), primarily deposited within the voids, and shrinkage formed during the re-carbonation of the lime ($CaCO_3$) matrix within the sherd. Secondary calcites are formed in burial, due to post-depositional processes (Quinn, 2013). Voids are characteristic of planar shape. Inclusions are aligned vertically, implying that clay was drawn upwards (Quinn, 2013). Presence of equant angular fine-grained igneous rock fragments (10%); most likely volcanic basic rocks, consisting of micro-phenocrysts of plagioclase feldspar in a groundmass of feldspar, very small pyroxene crystals and iron opaques. Sub-rounded cherts are visible (2%), in very small quantity. In Figure 3.24d, one inclusion on the bottom left resembles a garnet mica schist (1%), due to the high relief compared to other inclusions and its properties. Iron opaques (10%) and various metamorphic and igneous rock fragments (10-20%) dominate the clay matrix within this potsherd. Angular quartz (5%) and sub-angular weathered feldspars (5%) are present in this potsherd as well. There is enrichment within voids and inclusions. Micaceous sandstones (5%) in sub-angular form (Figure 3.24d) are also common and form the medium/coarse-grained inclusions with other igneous and metamorphic rock fragments.

Potsherd SK51

This potsherd was fired in a reducing environment and is non-calcareous, though some areas show post-depositional secondary calcite enrichment (Figure 3.24c). The clay is optically inactive. Inclusions within this potsherd are abundant, with 30% visual percentage estimation and moderately sorted. There is calcite enrichment within the voids, similar to potsherd SK46. Within the fine fraction of the clay matrix, sub-angular quartz are common (40%). Voids are micro-planar and micro- to meso-vughs. Inclusions include biotite mica (2%), sub-angular polycrystalline quartz (2%), iron opaques (5%), clay pellet (1%), clinopyroxenes (2%), plagioclase feldspars (5%), and olivine (2%). Rhyolite (2%) is also present in this potsherd, showing phenocrysts of feldspar in a groundmass which is glassy but full of laths of alkali feldspar (MacKenzie and Adams, 1994).

Overall analysis

Igneous rocks are the main inclusions and parent rock composition, and this is similar to the geological make-up of the region. As the sample size is very low, these four potsherds indicate the use of various raw materials—volcanic-based clay and it is possible to suggest that potters did not levigate the clay and that pottery production was mainly hand-made. The inclusions within all potsherds were aligned randomly, with the exception of potsherd SK46, which might have been slab-built. However, based on these four potsherds, coiling is not evident.

Rock fragments that are poorly sorted (i.e., potsherd SK23) are most likely tempered (e.g., andesites). In general, these pots are very thin-walled compared to other Kura-Araxes assemblages examined in this thesis. The source for the clays analysed most likely come from river-bed areas, near the archaeological site of Sotk-2. All potsherds were fired in a reducing environment, with the intention to achieve grey/black core and exterior finish.

3.3.6 Margahovit (n=30)

As mentioned in Section 3.1—3.1.3, the general geography and geology of Margahovit differs from other settlements, as it is situated on a plateau in a unique micro-region (Gevorgyan *et al.*, 2021). The climate is humid, the landscape is forested, and the site is situated near water resources. Local geological sources include a variety of rock types. Eocene rocks are predominant: porphyritic granites, tuff breccia and limestone (Gevorgyan *et al.*, 2021). This region is also characteristic of rich ore deposits, such as copper ore (chalcopyrite) (Vardapetyan *et al*., 1967: 322; Gevorgyan *et al*., 2021). Other rocks in this region include intrusive rocks such as granites and granodiorites, olivine-magnetite, gabbros, gabbrodiorites, quartz diorites, plagiogranites, leucogranites, alkali- and nepheline-syenites. Extrusive volcanic intrusions are also present, including trachydiorites, diorite-pophyrites, gabbro-porphyrites, basalts, rhyolites, rhyodacites and andesite-dacites. Tuff sandstones and tuffbreccias, lava flows and andesit-basalts, andesites and pyroclasts are evident (1000 m). Sedimentary rocks include volcano-sandstones, alevrites, limestones, tuffsandstones, tuffbreccias, andesitebasalts, andesites and andesitedacites.

Table 3. 23. List of fabrics identified in the potsherd samples from Margahovit.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Fine-grained volcanic and medium-grained andesite	3	MG9, MG15, MG33
Fabric 2	Fine-grained volcanic	2	MG43, MG44
Fabric 3	Medium-grained volcanic	10	MG2, MG7, MG14, MG16, MG21, MG26, MG27, MG30, MG34, MG40
Fabric 4	Coarse-grained volcanic	7	MG5, MG17, MG24, MG28, MG29, MG39, MG45
Fabric 5	Medium-grained volcanic rock fragments and slag/ore minerals	8	MG3, MG10, MG19, MG20, MG22, MG23, MG31, MG46

3.3.6.1 Fabric 1 – Fine-grained volcanic and medium-grained andesite (n=3)

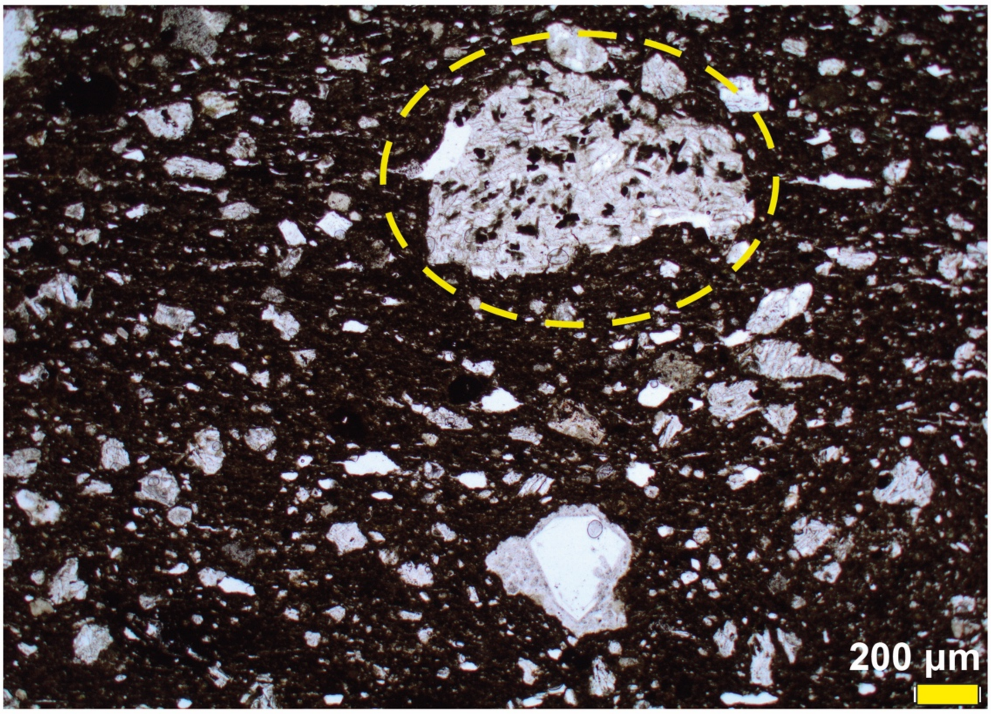


Figure 3. 25. MG33, PPL, x2 magnification; andesite inclusion circled. Scale on the lower right of photomicrograph.

Table 3. 24. Summary of fabric 1 at Margahovit.

Categories	**Fabric 1**: MG9, MG15, MG33
Sorting	Moderately sorted
Inclusion frequency (average %)	25-30%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Igneous rock/volcanic fragments; andesites (medium-grained, 25%)
Rare and finer inclusions (average %)	Silty and finer component (>1-10%): • Quartz (equant, mono- and poly-crystalline) • Weathered feldspars (plagioclase and orthoclase) • Biotite • Iron opaques • Pyroxenes • Clay pellets and unhydrated clay nodules (1%, in potsherd MG15)
Matrix	• Non-calcareous • Optically inactive
Voids (shape and abundance, average %)	Planar, meso-vughs, micro- to meso- channels (3%).
Textural features/comments	Fine and Medium-grained; plant matter in MG33 and MG15 (5% in abundance).

All potsherds were fired in a reducing environment (black burnished and core) (Figure 3.25). However, an oxidised external layer is evident on potsherds MG9 and MG15. There is no difference between the oxidised layer and the reduced matrix, in terms of inclusions and/or clay properties. Aplastic inclusions (igneous rock fragments) identified as andesites, are present in the local geology of the region (Table 3.24). Potsherd MG33 contains far more andesitic rock fragments (estimated to >20%), compared to potsherds MG9 and MG15. In general, the fine-fraction consists of a variety of inclusions, most notably weathered feldspars. The medium-grained inclusions are sub-angular to angular andesitic rock fragments. The size and frequency of these inclusions suggest a bimodal fraction (Quinn, 2013; Babetto *et al.*, 2021).

3.3.6.2 Fabric 2 – Fine-grained volcanic (n=2)

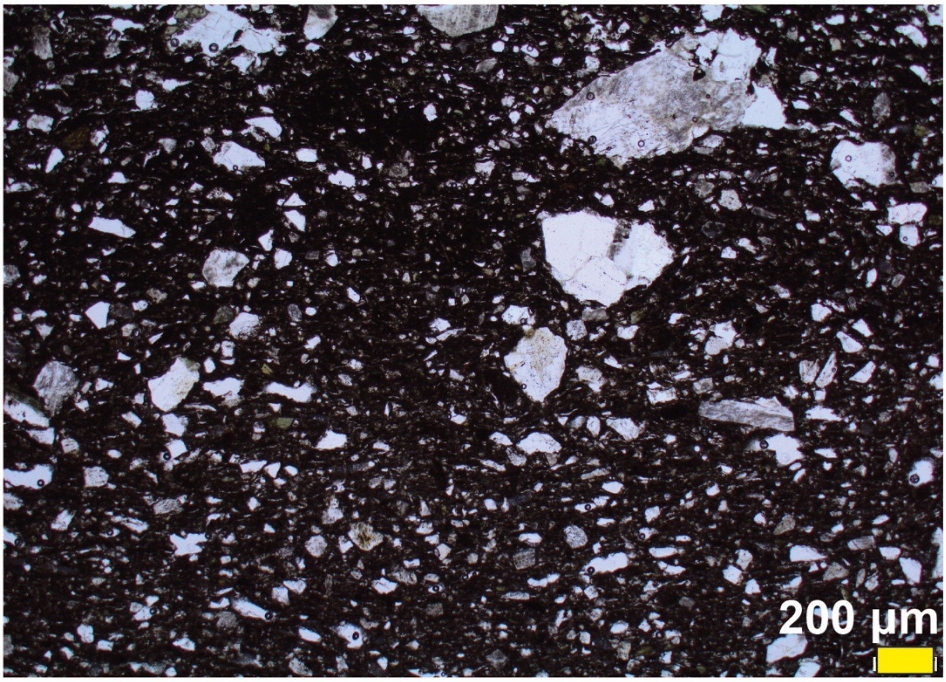


Figure 3. 26. MG44, PPL, x2 magnification. Scale on the lower right of photomicrograph.

Table 3. 25. Summary of fabric 2 at Margahovit.

Categories	**Fabric 2**: MG43, MG44
Sorting	Well to moderately sorted
Inclusion frequency (average %)	30%
Dominant inclusions (average %)	Aplastic inclusions (<20%): • Quartz (equant sub-angular to angular) • Feldspars (sub-angular)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz • Biotite mica (2-5%) • Plagioclase feldspars (5%) • Clinopyroxene (5%) • Iron opaques (2%) • Chert (2%)
Matrix	• Non-calcareous • Optically inactive (MG44) • Optically active (MG43)
Voids (shape and abundance, average %)	Micro-channels (5%)
Textural features/comments	Fine-grained, inclusions randomly oriented.

Potsherd MG44 has been fired in a reducing atmosphere, whereas potsherd MG43 was fired in an oxidising environment (Table 3.25). Both sherds are dominated by equant sub-angular to angular quartz fragments (>20%) and sub-angular feldspars (10%) (Figure 3.26). Medium-grained aplastic inclusions of feldspars (2%) and chert (2%) are evident, specifically in MG44, most likely due to poor refining of the clay. Occasionally, some of the medium-grained feldspars are weathered.

3.3.6.3 Fabric 3 – Medium-grained volcanic (n=10)

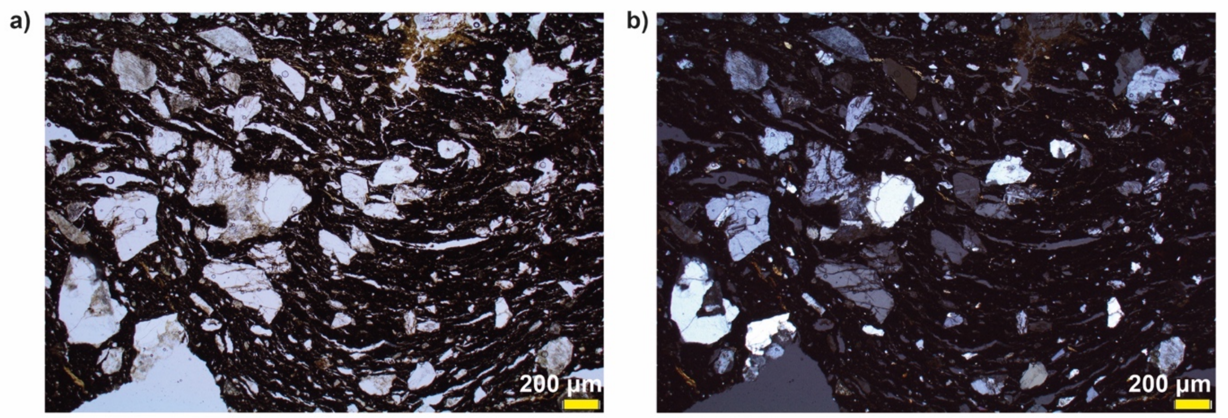


Figure 3. 27. MG7 in (a) PPL and (b) XP, x2 magnification. Scale on the lower right of each photomicrograph.

Table 3. 26. Summary of fabric 3 at Margahovit.

Categories	**Fabric 3**: MG2, MG7, MG14, MG16, MG21, MG26, MG27, MG30, MG34, MG40.
Sorting	Moderately to poorly sorted
Inclusion frequency (average %)	20%
Dominant inclusions (average %)	Aplastic inclusions (10-20%): • Quartz (weathered, mono-crystalline equant sub-angular; medium-grained, 15%) • Feldspar (weathered, sanidine and plagioclase, 15%) • Iron opaques (10%)
Rare and finer inclusions (average %)	Silty component (1-10%): • Quartz (mono-crystalline, equant sub-angular to angular; elongate angular, 5-10%; poly-crystalline, 5%) • Feldspars (weathered, equant and elongate sub-angular to angular, 5-10%) • Biotite mica • Olivine • Hornblende (amphibole) • Iron opaques • Clinopyroxene • Microcline
Matrix	• Non-calcareous • Optically inactive (MG2, MG7, MG14, MG16, MG21, MG26, MG30, MG34, MG40) • Optically active (MG27)
Voids (shape and abundance, average %)	Planar, micro- and meso-channels and micro-meso vughs (10%).

Textural features/comments	Medium-grained

This fabric is the largest group of potsherds (Figure 3.27; Table 3.26). It is similar in composition to fabric 2 and 4 but differs in terms of the size of inclusions. For instance, inclusions in this fabric group are medium-grained in a finer silty matrix (the clay is similar to fabric 2). The firing regimen differs across all vessels examined here. The following potsherds were fired in a reducing environment: MG7, MG21, MG16, MG21, MG26, MG30, and MG40. The rest were fired in an atmosphere than became oxidising as the fuel burnt away: MG14, MG27, and MG34. Potsherd MG2 is irregularly fired, resulting in a black core.

In general, the inclusions are sorted randomly and slightly aligned to the clay matrix. There is no evidence of specific forming techniques in this group; however, some potsherds display parallel orientation implying that the clay was drawn upwards (potsherds MG7, MG14, MG27 and MG40; Figure 3.27a). Slab-building, drawing the clay, and pinching are most likely used as the general forming technology.

3.3.6.4 Fabric 4 – Coarse-grained volcanic (n=7)

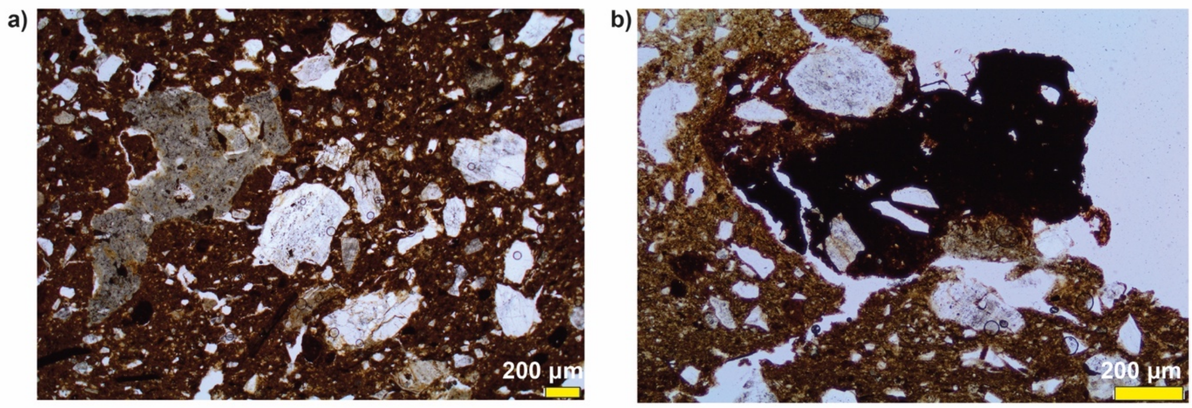


Figure 3. 28. (a) MG39 in PPL, x2 magnification and (b) x4 magnification; (b) iron opaque with micro-phenocrysts of feldspars and clinopyroxene. Scale on the lower right of each photomicrograph.

Table 3. 27. Summary of fabric 4 at Margahovit.

Categories	**Fabric 4**: **MG5, MG17, MG24, MG28, MG29, MG39, MG45**
Sorting	Poorly sorted
Inclusion frequency (average %)	25%
Dominant inclusions (average %)	Aplastic inclusions (10-25%): • Quartz (weathered, medium- and coarse-grained, equant sub-angular to angular; mono- and poly-crystalline) • Feldspar (weathered, medium- and coarse-grained)
Rare and finer inclusions (average %)	Silty component (1-10%): • Quartz • Feldspar (plagioclase and orthoclase) • Clinopyroxene • Biotite • Iron opaques (rounded to sub-rounded)
Matrix	• Non-calcareous • Optically inactive (MG5, MG17, MG24, MG28, MG29, MG45) • Optically active, moderate (MG39)
Voids (shape and abundance, average %)	Planar, meso-vughs, and micro-channels (5%).
Textural features/comments	Medium- and coarse-grained, random orientation.

Potsherds from this group contain coarse-grained inclusions (Figure 3.28; Table 3.27). The firing technology is consistent with a reduction environment, apart from potsherds MG39 (irregularly fired and mostly oxidised) and MG5 (oxidised with a black core, reduced). Overall, the medium- to coarse-grained inclusions are poorly sorted in a finer-grained matrix comprising similar composition to fabric 2 and 3. The vessels in this group correspond to fine-wares, as well as cooking/utility wares. The fine-wares also display coarse inclusions; this is important to note, as potters preferred raw materials that are not refined for thin-walled vessels (i.e., MG17). Occasional iron opaques with some inclusions (such as quartz) are also present as coarse-inclusions.

3.3.6.5 Fabric 5 – Medium-grained volcanic rock fragments and slag/ore minerals (n=8)

Table 3. 28. Summary of fabric 5 at Margahovit.

Categories	**Fabric 5**: MG3, MG10, MG19, MG20, MG22, MG23, MG31, MG46
Sorting	Moderately sorted
Inclusion frequency (average %)	25%
Dominant inclusions (average %)	Aplastic inclusions (10-20%): • Igneous rock fragments (andesites, dacites, and granodiorites)
Rare and finer inclusions (average %)	Silty component (1-10%): • Quartz (equant to elongate sub-angular; slightly weathered) • Feldspar (plagioclase and orthoclase; slightly weathered) • Iron opaque (sub-angular to rounded) • Pyroxenes • Biotite • Hornblende (2%) • Clay pellet (1%)
Matrix	• Non-calcareous (moderate) • Optically active (MG10, MG20, MG22, MG31) • Optically inactive (MG3, MG19, MG23, MG46)
Voids (shape and abundance, average %)	Planar, micro-channels and few meso-vughs (5%).
Textural features/comments	Medium-grained; inclusions aligned in a circular motion for MG3 and MG46 (evident of coiling forming technology).

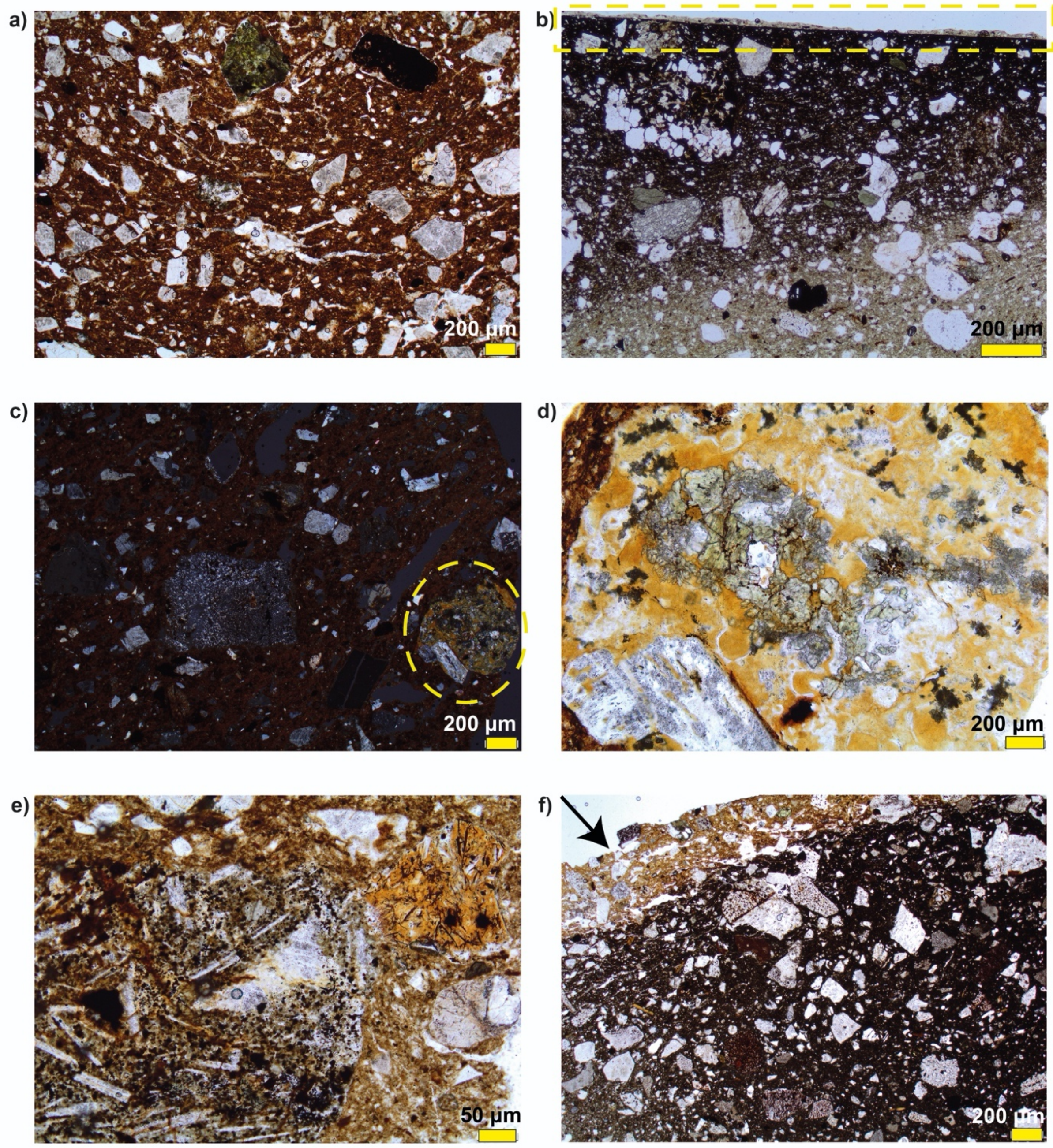


Figure 3. 29. (a) MG31 in PPL, x2 magnification. (b) MG10 in PPL, x4 magnification, indicating a possible slip on the top layer (yellow dashed lines); inclusions slightly aligned in a concentric motion. (c) MG31 in XP, x2 magnification; (d) in PPL close-up, x10 magnification. (e) MG3 in PPL, x10 magnification. (f) MG23 in PPL, x2 magnification. Scale on the lower right of each photomicrograph.

Aplastic inclusions in fabric 5 are complex igneous rock fragments that vary in composition, primarily andesites, dacites, and granodiorites. A possible sideromelane inclusion, transformed to orange palagonite in tuff and palagonite andesite (Stoops *et al.*, 2018) is visible in potsherd MG3 and MG31, which is green and orange in PPL (see Figure 3.29); however, it is possible that these inclusions might be characteristic of ore minerals (including by-products of metal production, such as slag). Further analyses on SEM-EDS can confirm the iron opaques and ore minerals present in this fabric.

Potsherds MG19 and MG46 have been fired in a reducing environment. The rest of the sherds are fired in an oxidised environment; however, sherds MG10 and MG22 exhibit a slip fired in a reduced atmosphere (Figure 3.29). Inclusions are aligned in a circular pattern in MG3 and MG46, implying evidence of the coiling technique performed by the potter(s) regarding manufacturing and forming techniques (also Figure 3.29).

3.3.7 Talin Tombs (n=10)

The general geological association of Talin Tombs is dominated by volcanic rocks. Iserlis *et al.*, (2015: 11), state that "the hilly volcanic Talin plateau is dominated by the extrusive dome of Arteni. The plateau contains large deposits of Neogene and Pleistocene rocks: basalt, dacite, andesite, rhyolite, obsidian, perlite and tuffobreccia; the highest point of Armenia, Mt. Aragats (4090 m) is an andesitic to dacitic stratovolcano with parasitic cones and fissures." Based on the stereomicroscopy results, most sherds exhibit an oxidised layer and reduced core. Potsherd T9 is constructed with an interior and exterior oxidised layer with a black core (reduced/unoxidised). Overall, the assemblage from Talin Tombs is unburnished. Thus, the reconstruction of technology and potting traditions are interesting to uncover, as they do not resemble the general consensus of 'black-burnished' technology of KA pottery. Three fabric groups were identified, based on the minerals and rock fragments, including evidence for manufacturing and treatment of the raw material (Table 3.29).

Table 3. 29. List of fabrics identified in the potsherd samples from Talin Tombs.

Fabric group	Characterisation	Number of potsherds	Potsherd samples
Fabric 1	Fine- and medium-grained grog and argillaceous rock fragments	4	T3, T4, T8, T10
Fabric 2	Fine- and medium-grained volcanic glass	2	T1, T5
Fabric 3	Medium-grained igneous rock fragments	4	T2, T6, T7, T9

3.3.7.1 Fabric 1 – Fine- and medium-grained grog and argillaceous rock fragments (n=4)

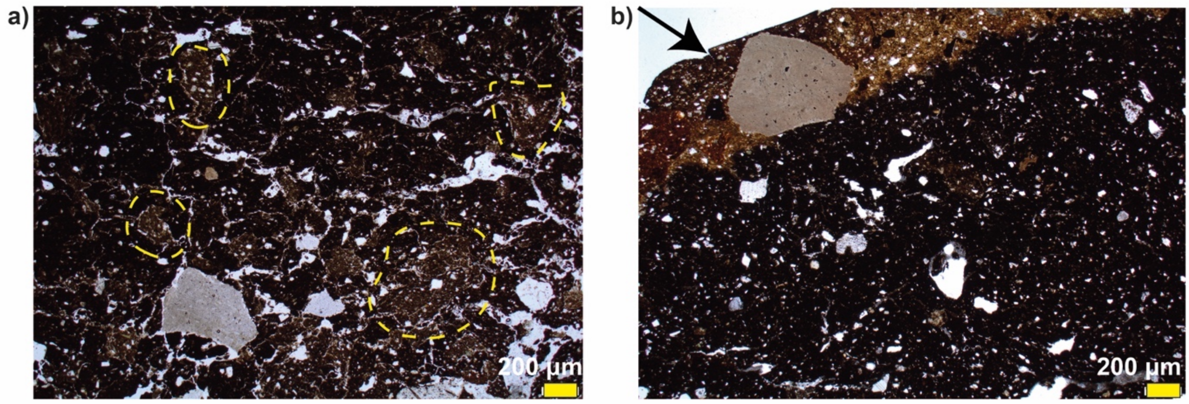


Figure 3. 30. (a) T3 in PPL, x2 magnification; sub-angular to angular grog inclusions circled in yellow dashed lines. (b) T8 in PPL, x2 magnification, illustrating a slipped oxidised layer and tuffaceous inclusion. Scale on the lower right of the photomicrograph.

Table 3. 30. Summary of fabric 1 at Talin Tombs.

Categories	**Fabric 1**: T3, T4, T8, T10
Sorting	Moderately to poorly sorted.
Inclusion frequency (average %)	20-30%
Dominant inclusions (average %)	Aplastic inclusions (15-20%): • Grog and argillaceous fragments (sub-angular to angular, 20%)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant sub-angular to angular, 5-10%) • Feldspar (plagioclase, weathered and sub-angular, 5%) • Biotite mica (2%) • Iron opaque (sub-angular to sub-rounded, 2-4%) • Andesite (sub-angular, equant, in potsherd T8, 1%) • Clinopyroxene (1%)

	• Orthopyroxene (sub-rounded, 1%) • Hornblende • Volcanic glass (sub-angular, 2%) • Muscovite (elongate and angular, 1%)
Matrix	• Calcareous (moderate) • Optically active and inactive (uneven) • Grog fragments within the optically inactive clay are optically active
Voids (shape and abundance, average %)	Planar, channels and some presence of vughs (micro and meso) (5-10%).
Textural features/comments	Fine- to medium-grained.

Similar to observations by Iserlis *et al.*, (2010; 2015) and Hovsepyan and Mnatsakanyan (2011), grog is identified due to sub-angular inclusions (Quinn, 2013). They are the main medium-coarse-grained inclusions (Figure 3.30; Table 3.30). Presence of plant matter with planar voids are visible, burnt off due to firing. Potsherds from this group were fired in a reducing atmosphere, but slightly irregularly fired. All potsherds exhibit an oxidised slip and/or layer, with a black core. In potsherd T4, there is evidence of one plant matter inclusions (burnt off), but it is not possible to suggest the source of this.

It appears that the clay is calcareous and optically active in some areas of the potsherd matrix. For instance, in potsherd T3, the clay alters between optically inactive and active in various areas. Regarding potsherd T10, the main clay body is optically active, and the slip (black, reduced slip) is optically inactive; this observation is similar in potsherd T4. Potsherd T8 can be considered as a sub-fabric within this group, due to the addition of a slip interior and exterior (Figure 3.30b). This is the only sherd within this assemblage corresponding to such an example. The slip itself is volcanic/glassy textured, but the main clay body is associated with the rest of the potsherds of the grog fabric group. Thus, it is possible to suggest the mixing of clay sources for the sole purpose of pottery technology. While the clay is optically inactive for the grog fabric, the slips applied to T8 are optically active for both interior and exterior of the sherd. This provides additional evidence that the clay provenance is different for both clays used in the production process of this particular vessel.

3.3.7.2 Fabric 2 – Fine- and medium-grained Volcanic glass (n=2)

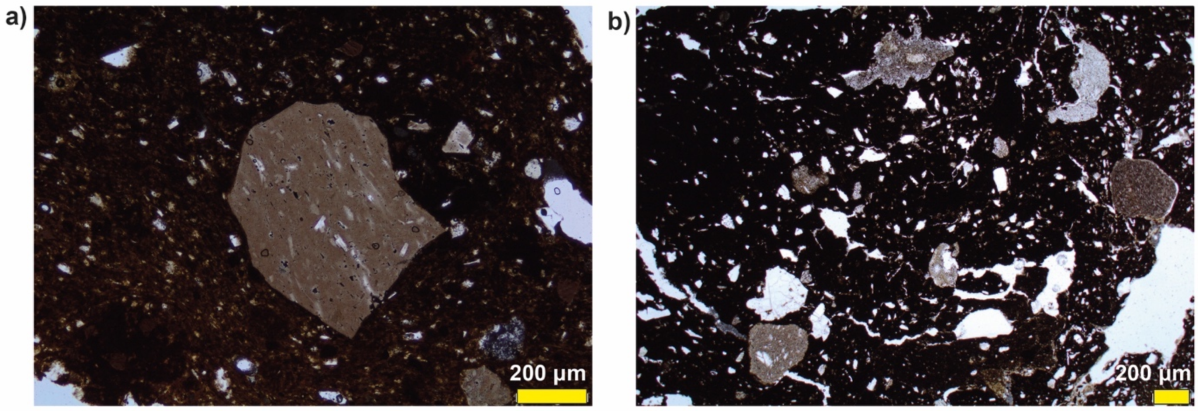


Figure 3. 31. (a) T1 in PPL, x4 magnification; displaying an angular volcanic lithic fragment inclusion with micro-phenocrysts of quartz and iron opaques. (b) T5 in PPL, x2 magnification. Scale on the lower right of each photomicrograph.

Table 3. 31. Summary of fabric 2 at Talin Tombs.

Categories	**Fabric 2**: T1, T5
Sorting	Moderately sorted
Inclusion frequency (average %)	20-30%
Dominant inclusions (average %)	Aplastic inclusions (<10-20%): • Volcanic glass (tuff and pumice, angular, sub-angular and sub-rounded)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant) • Feldspar (plagioclase) • Iron opaques • Clinopyroxene • Hornblende • Biotite
Matrix	• Calcareous (moderate) • Optically active (moderate)
Voids (shape and abundance, average %)	Micro- to meso-vughs, elongate planar, and micro-channels (1-3%)
Textural features/comments	Fine- and medium-grained.

Rare volcanic lithic fragments are visible in this group (Figure 3.31; Table 3.31). Voids resemble air pockets perhaps derived from the burn-out of former organic inclusions that occurred naturally in the clay, but not deliberately added for T1 potsherd. Regarding T5 potsherd, there are more elongate planar voids (10%) in addition to a small number of vughs and channels (1-2%). It is possible to suggest some clay mixing with Fabric 1, as this is the main volcanic tuff and pumice group. The inclusions are similar, but sorting varies. The angularity of volcanic glasses within the clay suggests that it was naturally present in the clay paste.

3.3.7.3 Fabric 3 – Medium-grained Igneous rock fragments (n=4)

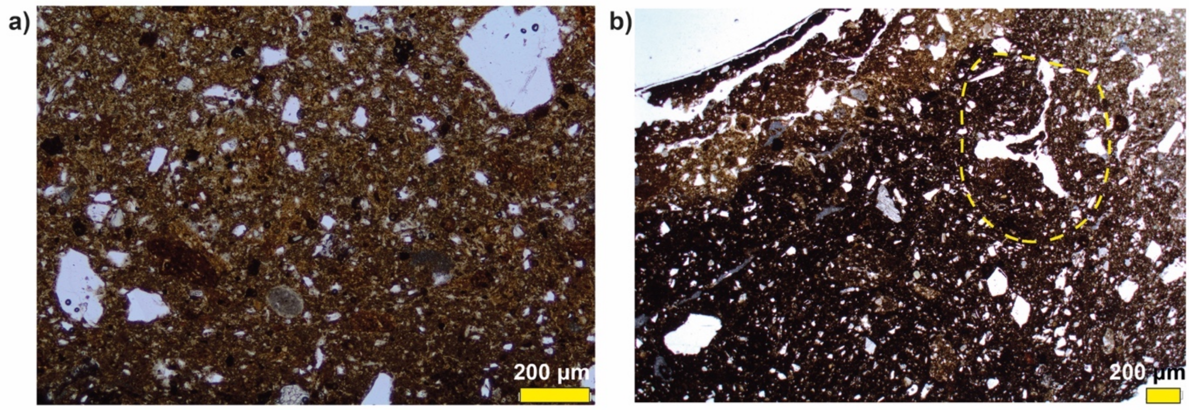


Figure 3. 32. (a) T9 in PPL, x4 magnification. (b) T2 in PPL, x2 magnification; plant matter (600-800 µm) circled in yellow dashed lines. Scale on the lower right of each photomicrograph.

Table 3. 32. Summary of fabric 3 at Talin Tombs.

Categories	**Fabric 3**: T2, T6, T7, T9
Sorting	15-20%
Inclusion frequency (average %)	Moderately sorted
Dominant inclusions (average %)	Aplastic inclusions (10-15%), angular to sub-rounded: • Andesite (10-15%) • Dacite (10%) • Basalt (5-10%)
Rare and finer inclusions (average %)	Silty component (>1-5%): • Quartz (equant sub-angular) • Iron opaque • Clinopyroxene

	• Biotite mica • Clay pellet (rounded) •
Matrix	• Non-calcareous • Optically inactive • Optically active exterior slip: T2, T6, and T9.
Voids (shape and abundance, average %)	Micro- to meso-planar and meso-vughs (1%).
Textural features/comments	Medium-grained.

Rock fragments associated with this fabric are slightly sub-rounded, which indicate residual clay from sedimentary rock sourcing clay (Figure 3.32; Table 3.32). While this suggests clay mixing, the main non-plastic component of this fabric (<15%) is rock fragments corresponding to igneous mineralogy. Clay pellets (rounded to well-rounded) are plastic inclusions surrounded by ring void (Quinn, 2013: 60).

In potsherds T2, T6, and T9, the visible slip exterior to the vessels (oxidised) is optically active (Figure 3.32b). The general firing regimen for the core and main body is a reducing environment. Voids and organic matter are quite limited. There is no evidence of organic matter deliberately added as aplastic inclusions, apart from one possible plant matter evident in potsherd T2 (Figure 3.32b).

3.4 Results: Scanning electron microscopy energy dispersive spectroscopy (SEM-EDS)

Regarding published data and literature, microscopic and chemical analyses of Kura-Araxes pottery from the Caucasus are limited. Where discrimination was beyond the abilities of thin section analysis, it was supplemented by scanning electron microscopy (SEM). This technique combines the benefits of a much higher magnification with the ability to perform discrete quantitative chemical analysis on individual minerals: both greatly assist with the identification of problematic inclusions and microtextural features. SEM-EDS was conducted on a selection of fine-ware samples (fine-grained and thin-walled), to investigate the surface/burnish technology, presence of a possible exterior slip/layer, body composition and general fabrics associated with fine-wares (i.e., notable inclusions and semi-quantitative analysis of ceramics; Pollard *et al.*, 2017: 118-120).

For Kura-Araxes pottery, burnishing is a bright metallic/highly glossed surface, almost non-porous. The identification of several major inclusions was possible through SEM, specifically due to the chemistry and morphological characteristics (i.e., volcanic ash). The instrument used in this study was a Jeol 5910 SEM fitted with an Oxford Instruments energy dispersive analyser (EDA) running INCA software. A semi-quantitative, energy dispersive analysis for a number of major and minor elements (Si, Al, K, Na, Fe, Mg, Ca and Ti) was undertaken and data was processed using AzTec Oxford Instruments Software. Due to the semi-quantitative analysis, SEM-EDS was mainly used to examine inclusions, the fabric paste and any notable differences between the surface of the sherds and clay body.

Typical operating conditions were 15kV, beam current 1-2nA and a 100 seconds live-time. The target region of each potsherd was the rim and clay matrix. Backscattered images are reported below. Tabulated data in this section includes the normalised results in oxide compound % based on spot and map analyses.

3.4.1 Selection of potsherds

Fine-wares (n = 17) were selected for SEM-EDS analyses in total from the following sites: Mokhra-Blur (n = 3), Shengavit (n = 3) and Norabak-1 (n = 11). As mentioned in Chapter 2.2, sample selection for SEM-EDS was conducted to closely examine black or buff burnished fine-wares and sherds with a possible slip and/or metallic/lustre finish, and to further assess the surface technology. Moreover, these potsherds were selected for SEM-EDS, due to their reduced firing nature, as the clay textural features are somewhat difficult to examine using thin-section petrography, especially for fine-ware (thin-walled) sherds. While the bulk of the samples are fired in a reduction environment (see Figure 3.1), SEM-EDS analysis allows a closer look at fine-ware potsherds, unable to characterise certain features macroscopically and through thin-section petrography. This technique achieves higher magnification and enables more detailed examination of pottery fabrics, composition of the body and/or surface, and surface treatment techniques (Froh, 2004). It is possible to suggest the raw materials used for pottery production and provenance the clay through (1) bulk chemical composition of selected areas of the fabric per sample, and (2) minerals present in the fabric and their distribution. Chemical compositional analyses were interpreted through published geological references (Adams and MacKenzie, 1998; Yardley *et al.*, 1990; MacKenzie *et al.*, 1982; Adams *et al.*, 1984; for reference chemistry mineral data: www.mindat.org).

All potsherds from Norabak-1 were analysed *via* SEM-EDS in this thesis (n = 11). At the site of Mokhra-Blur, only three samples were fine-wares and were selected. Other potsherds from Gegharot, Karnut-1, and Margahovit were not selected, as most of the sherds were analysed through thin-section petrography. Talin Tombs' potsherds were not burnished; thus, all potsherds were analysed through thin-section petrography (Section 3.3).

3.4.2 Shengavit fine-wares

A total of three samples were prepared as stub mounts (SH34) and resin polished blocks (SHEN4 and SHEN5). These potsherds were mainly to screen and test whether there was a presence of a slip or surface feature to achieve high-quality 'silver sheen' burnish. Resin blocks of SHEN4 and SHEN5 were analysed to record chemical compositions of notable inclusions, the clay matrix, and any other textural features (Figures 3.33). One sample potsherd (SH34) from Shengavit was prepared as a stub mount to test the surface features of burnishing and/or slipping, etc., and no elemental chemistry was recorded for this sample (see Figure 3.34). These potsherds are black-burnished fine-wares and preliminary observations through stereomicroscopy conclude that the surface slip and body are the same clay.

Through SEM-EDS, it is possible to conclude that the surface clay and clay matrix are compositionally similar. While there is a clear slip added during the manufacturing process, there is no chemical difference between body and surface clay, which means that burnishing is the common surface technology employed by KA potters. The abundance of pumice fragments in Shengavit potsherds is over 60%, poorly sorted. Pyroxenes are also present in Shengavit potsherds, typically characterised due to their low aluminium content $(Ca,Mg,Fe)Si_2O_6$, as well as olivines $(Mg,Fe)_2SiO_4$ (Hatch *et al.*, 1972). Augites are abundant in andesitic rocks, which are quite common in the Shengavit and Mokhra-Blur potsherds. These rock fragments are found locally across the Ararat Plain area, where both settlements are located (see geological map and descriptions, Figure 3.3; Table 3.1; Appendix B).

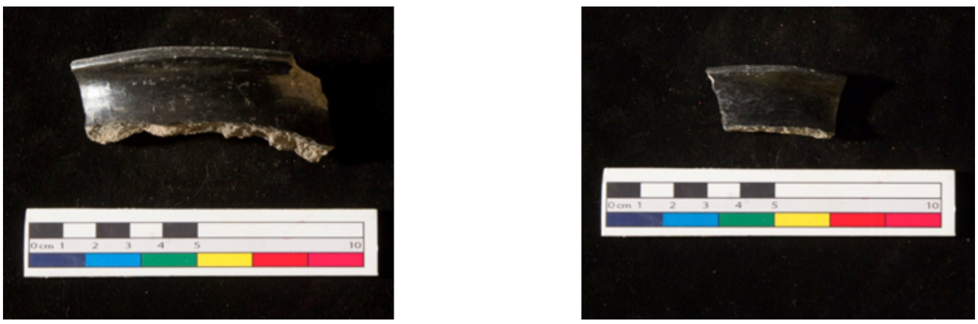


Figure 3. 33. SHEN4 (left) and SHEN5 (right) potsherds from Shengavit, highly burnished and classified as fine-wares.

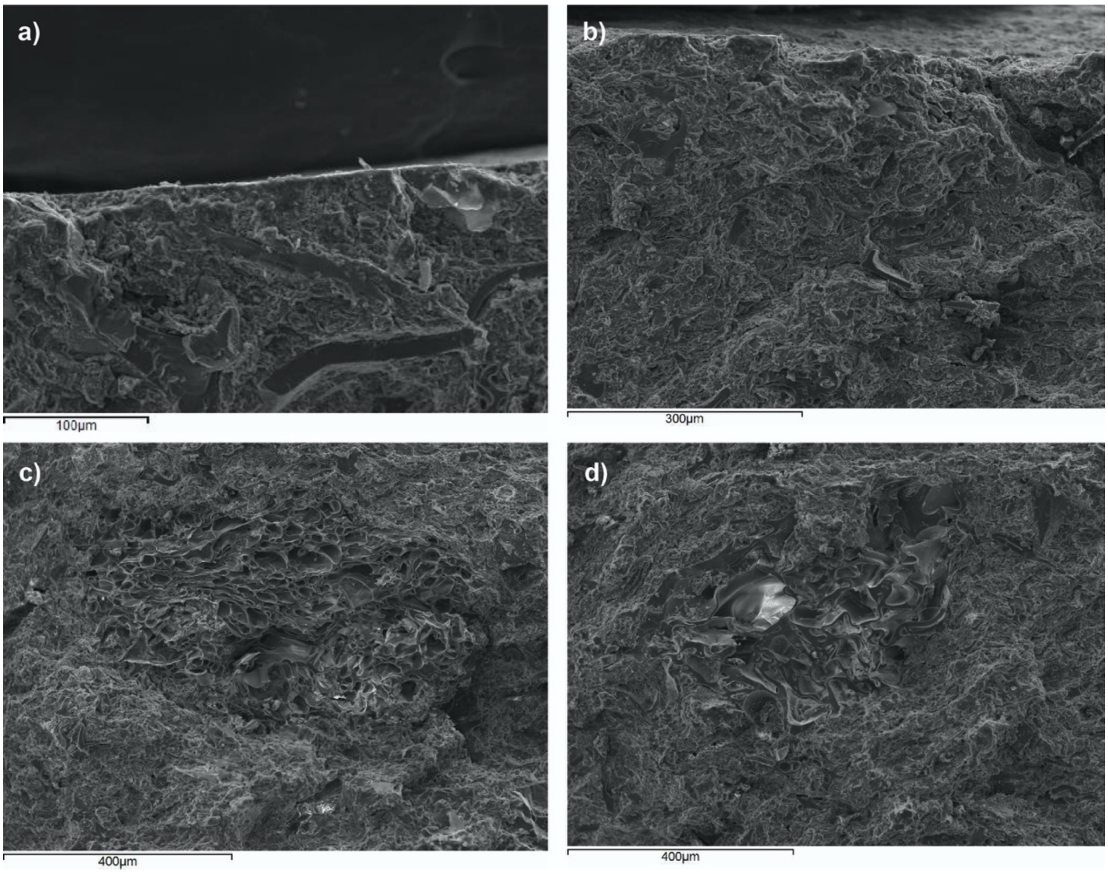


Figure 3. 34. SH34; BSE images of tuffaceous inclusions; (b-d) display inclusions of pumice and tuff. (a) and (b) exhibit the surface. BSE image (a) displays a welded tuff inclusion. Scale bars are located on the bottom left of each image.

Notable inclusions in Shengavit fine-ware potsherds include sub-angular to sub-rounded volcanic glass (tuff and pumice) (60-70%), sub-angular quartz (40%), and various igneous rock fragments (10%) (Figure 3.35 and 3.36; Table 3.33). Micro-xenolith inclusions within pumice fragments and within the clay body (Figure 3.35d and 3.66a) are common constituents of complex volcanic processes. Micro-xenoliths are essentially fragmentary pyroclastic rock fragments and lamprophyres are "holohyaline (vitroclastic) tuffs—a variety of atypical alkaline lamprophyres" specifically in the region of Armenia (Satian *et al.*, 2009: 438). These tuffs contain high-pressure crustal and mantle xenoliths (e.g., chrome diopside) indicating a high-pressure (upper mantle) origin. The sequence studied by Satian *et al.*, (2009) is near the archaeological sites of Mokhra-Blur and Shengavit. In general, volcanic glasses are the main component of these alkaline lamprophyric tuffs (Satian *et al.*, 2009: 401). Common minerals in alkaline lamprophyre tuffs include diopside, augite, orthopyroxenes, hornblende, basalt, biotite, apatite, magnetite, garnet, zircon, etc. (Satian *et al.*, 2009: 402). Inclusion (Table 3.33) measurement readings indicate high MgO-composition, which is characteristic in tuffs (Khosrov group data) (Satian *et al.*, 2009). More specifically, the inclusions (Mg-olivine fayalite and weathered gabbro) in Figure 3.35(d) are characteristic compositions of a micro-xenolith due to the enclosed groundmass, exhibiting gas vesicles (Figure 3.35d). The vesicular groundmass is an indicator of these lamprophyric tuffs, allowing this study to provenance (Satian *et al.*, 2009; Rock, 1987). It is possible to suggest that these tuff inclusions are local to the Ararat Plain, indicative of local Shengavit clay sources.

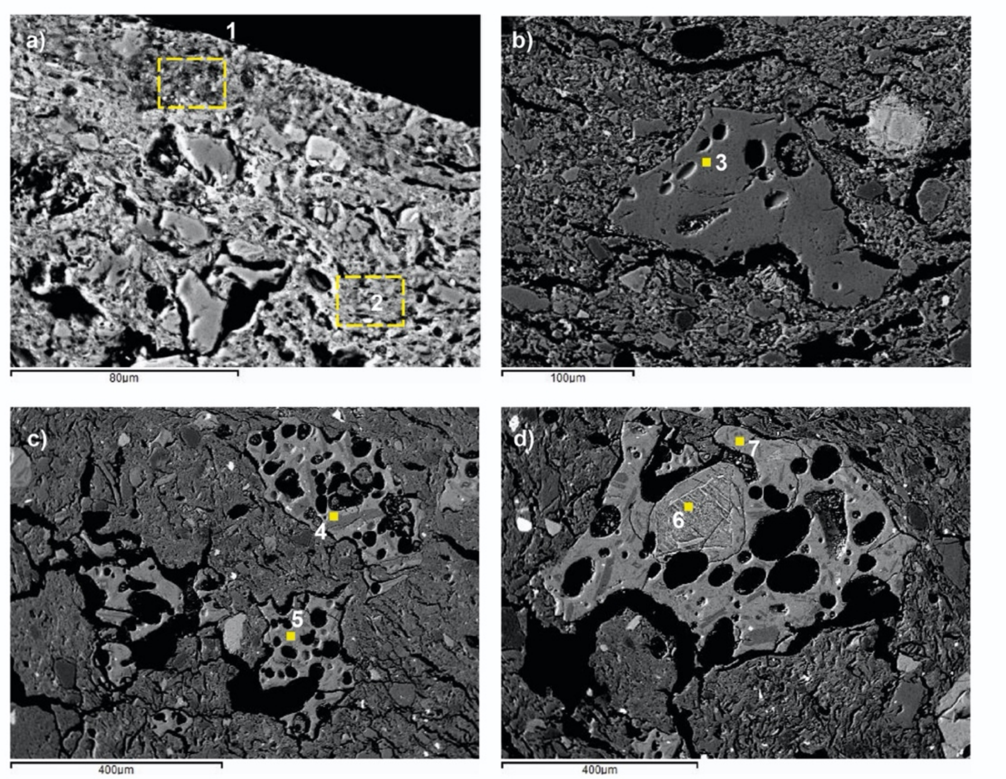


Figure 3. 35. BSE SEM photomicrographs; SHEN4 is a) and b); SHEN5 is c) and d); a) surface clay (1), and clay body (2); b) and c) pumice inclusions; d) micro-xenolith inclusion. Scale bars are located on the bottom left of each image.

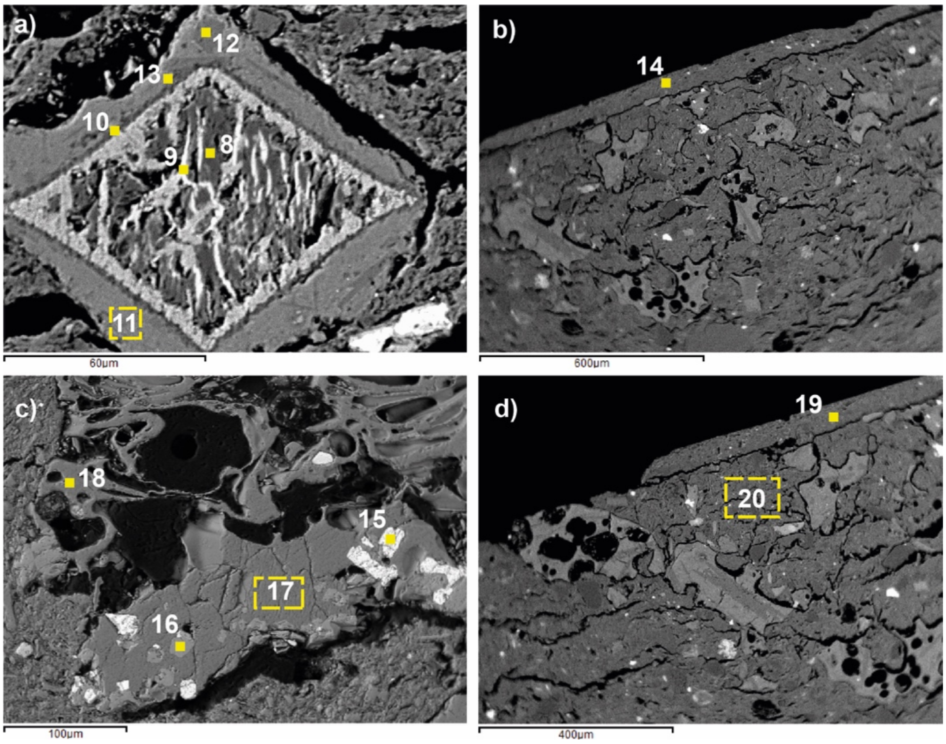


Figure 3. 36. BSE SEM photomicrographs; SHEN5 potsherd; a) close-up of a micro-xenolith inclusion; b) surface clay chemistry; c) pumice inclusions and other notable inclusions, including pyroxenes; d) surface clay chemistry, and below surface clay. Scale bars are located on the bottom left of each image.

Table 3. 33. SEM-EDS results in oxide compound %; Potsherds SH34, SHEN4 and SHEN5. Inclusions and analyses numbered; refer to Figures 3.35 and 3.36 for spot point analyses. ND; not detected, below detection limits.

%	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	CoO	Total	Classification
Surface Clay (1)	1.44	1.90	23.16	52.89	ND	7.54	3.51	1.04	ND	8.50	ND	99.98	K_2O enrichment
Clay body (2)	1.23	4.55	15.84	57.41	ND	4.91	7.55	1.72	ND	6.80	ND	100.01	Non-calcareous
Inclusion (3)	2.22	ND	13.25	75.26	ND	7.08	1.16	ND	ND	1.03	ND	100.00	Rhoylitic tuff
Inclusion (4)	3.86	1.44	24.63	54.50	ND	0.58	12.29	0.36	ND	2.34	ND	100.00	Pumice inclusion
Inclusion (5)	3.03	3.14	15.03	57.21	0.95	4.36	7.01	1.81	ND	7.46	ND	100.00	Serpentinised olivine
Inclusion (6)	ND	40.20	ND	41.47	ND	ND	0.22	ND	ND	18.11	ND	100.00	Mg-olivine fayalite
Inclusion (7)	3.31	5.12	14.42	55.86	ND	3.52	8.74	1.43	ND	7.60	ND	100.00	Weathered gabbro
Inclusion (8)	ND	55.15	ND	44.10	ND	ND	ND	ND	ND	0.75	ND	100.00	Micro-xenolith
Inclusion (9)	ND	39.31	ND	46.30	ND	ND	ND	ND	ND	14.25	0.13	99.99	Micro-xenolith
Inclusion (10)	ND	27.60	0.95	43.64	ND	ND	0.63	ND	0.48	26.69	0.45	100.44	Micro-xenolith
Inclusion (11)	4.61	6.07	15.30	56.75	1.07	2.68	5.19	1.32	ND	7.03	ND	100.02	Micro-xenolith
Inclusion (12)	4.56	ND	26.91	55.13	ND	0.37	10.62	ND	ND	1.65	ND	99.24	Micro-xenolith
Inclusion (13)	ND	26.50	9.35	47.32	ND	8.28	0.29	0.45	ND	1.78	ND	93.97	Micro-xenolith
Surface clay (14)	0.50	2.02	19.64	53.31	1.15	6.53	3.48	1.59	ND	11.78	ND	100.00	K_2O enrichment
Inclusion (15)	ND	2.72	ND	0.65	ND	ND	ND	13.19	0.76	78.76	1.42	97.50	Magnetite
Inclusion (16)	ND	14.25	3.54	51.06	ND	ND	16.79	1.79	ND	12.58	ND	100.01	Clinopyroxene
Inclusion (17)	5.32	ND	25.24	58.84	ND	0.62	8.74	ND	ND	1.23	ND	99.99	Plagioclase feldspar
Inclusion (18)	4.13	0.53	14.57	70.89	ND	5.36	1.32	0.97	ND	2.23	ND	100.00	Pumice inclusion
Surface clay (19)	1.50	2.40	17.13	61.41	0.96	4.75	3.87	1.04	ND	6.93	ND	99.99	K_2O enrichment
Below surface clay body (20)	2.86	2.39	18.31	63.30	ND	2.74	3.38	0.86	ND	6.01	ND	99.85	Non-calcareous; alluvial clay

3.4.3 Mokhra-Blur fine-wares

Three fine-ware potsherds from Mokhra-Blur were analysed through SEM-EDS: (1) MB2, (2) MB3-1, and (3) MB11. These potsherds contain inclusions characteristic of medium- to coarse-grained volcanic ash, rhyolite tuff, andesite and sandstones (chert and arkosic quartz). In particular, potsherd MB3-1 contains coarse inclusions of plagioclase feldspars. In general, the presence of volcanic ash varies between the three sherds. Compared to MB2, MB3-1 displays less abundance of volcanic ash (5-10%). However, through thin-section analyses, this sherd has been classified as 'coarse-grained volcanic ash, andesite and sandstones' (see fabric 3, Section 3.3.3).

Potsherd MB11, similar to MB2, contains pumice fragments (rhyolitic and andesitic) over 60% abundance, moderately to poorly sorted. Through thin-section petrographic data, amphibole and plagioclase feldspars are common in the fabrics pastes reported. The surface spot analysis and clay matrix of these potsherds display little to no chemical differentiation (Tables 3.34 and 3.35). Furthermore, organic matter and inclusions are lacking in these sherds, similar to the fabric paste characterisation through thin-section petrographic analyses.

Potsherd MB11 contains elongate and planar pumice fragments. Other inclusions include plagioclase feldspars (some with high Al_2O_3, due to weathering), with apatite inclusions, chert, quartz, rhyolite, hornblende, titanomagnetite, andesite, etc. Inclusion (11) Ca-amphibole is common in the alkaline basaltic tuffs with a similar composition from published datasets (Satian *et al.*, 2009; Rock, 1987).

There are slight dense areas near the surface, indicating burnishing, most likely prepared with a tool (i.e., stone/pebble) (Ionescu and Hoeck, 2020; discussed in Section 3.4 and Chapter 5). Voids are planar and elongate channels (Figure 3.39a), displaying 2-3% porosity estimation. Additionally, characteristic vesicular pumice fragments are visible (Figure 3.37d) (MacKenzie *et al.*, 1982). Other inclusions include plagioclase feldspars, quartz/chert, and rhyolite. A small percentage of inclusions (>1-5%) include epidote, albite, hornblende, andesite, as well as titanomagnetite. The compositions of these fine-wares are quite similar, suggesting the use of similar raw materials.

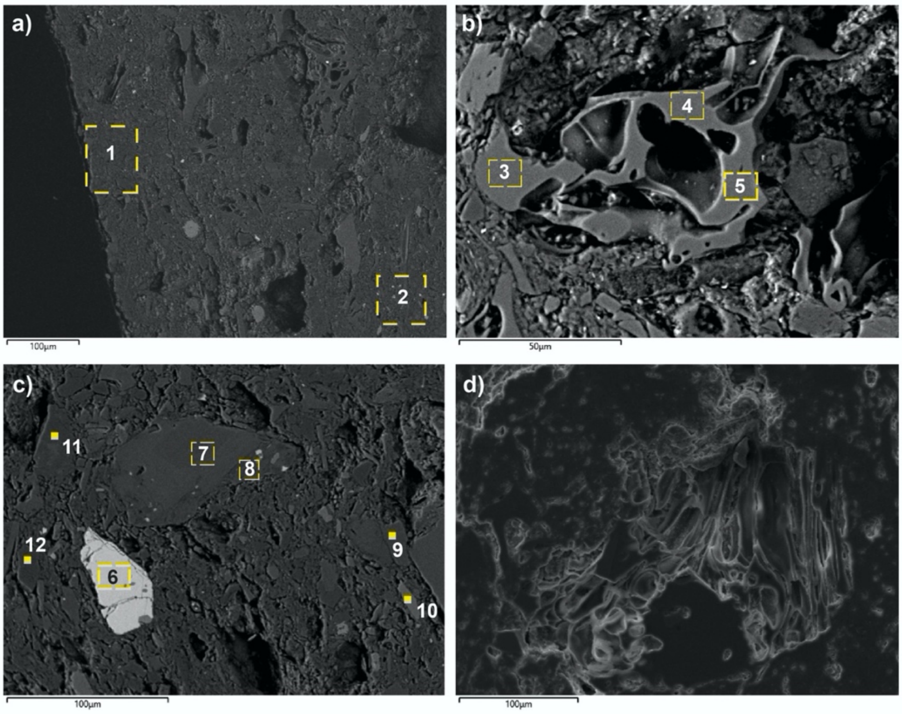


Figure 3. 37. MB2; BSE photomicrographs, indicating a) bulk composition of surface clay body (1) and interior clay matrix (2); b) pumice inclusion with three measurements; c) typical inclusions in MB2 include titanomagnetite (6), plagioclase feldspars (7), andesine plagioclase feldspar (8), plagioclase feldspars (9), albite (10), Ca-amphibole (11), and quartz (12). Chemistry of inclusions in Table 3.34. Spot analyses as yellow squares. Photomicrograph d) Secondary electron (SE) image of volcanic ash/pumice, 20% abundance in clay matrix of MB2. Scale bars are located on the bottom left of each image.

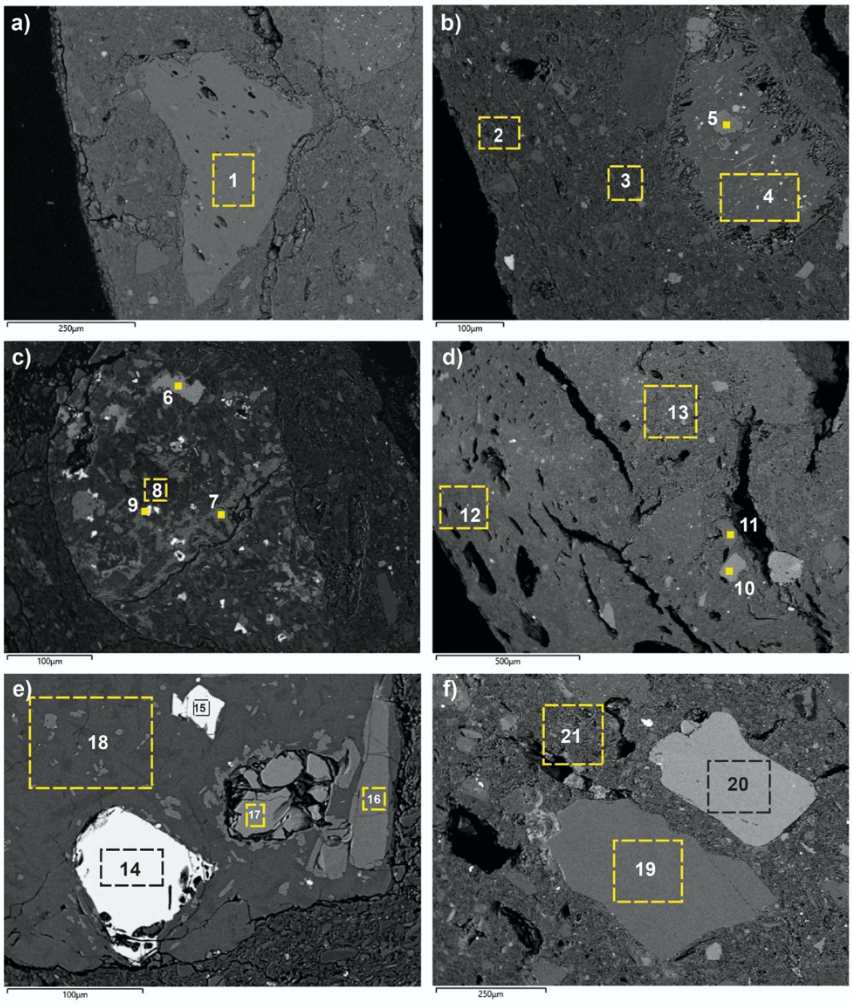


Figure 3. 38. MB3-1; BSE photomicrographs, indicating volcanic inclusions, a) rhyolite (1); b) bulk analysis near potsherd's surface (2), bulk analysis of clay matrix (3), trachytic groundmass inclusion (4), altered diopside (5); c) complex coarse inclusion within potsherd, comprising sphene (6), Mg-chlorite (7), chert and quartz (8), and ilmenite (9); d) clay matrix displaying planar voids and shrinkage, diopside (10), intermediate plagioclase feldspar (11), clay body displaying increase in phosphate (12 and 13); e) inclusions of opaque minerals: ilmenite (14 and 15), olivine/fayalite (16), diopside (17), and inclusion groundmass (18).; f) intermediate plagioclase feldspar (19), diopside clinopyroxene (20), and inclusion groundmass (21). Chemistry of inclusions in Table 3.35. Spot analyses as squares. Scale bars are located on the bottom left of each image.

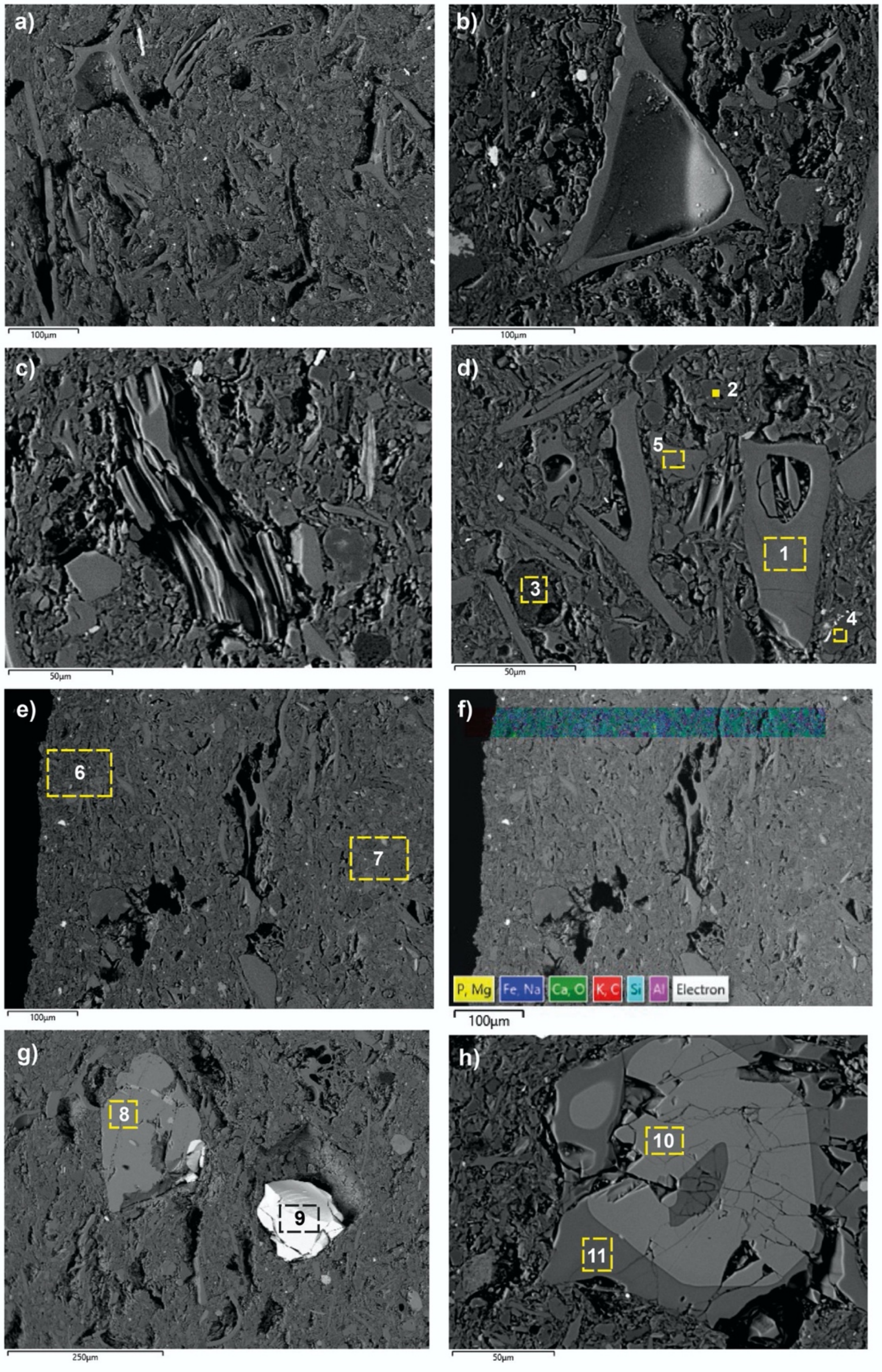


Figure 3. 39. MB11; BSE photomicrographs, indicating volcanic inclusions, primarily pumice (a) to (d); a) general view of clay body, with Y-shaped pumice inclusions, x200 magnification; b) detailed Y-shaped pumice fragment; c) rhyolite inclusion; d) rhyolite (1), and quartz/chert (2-5); e) and f) map from surface to clay body; g) hornblende (8), titanomagnetite (9); h) hornblende (10) and Ca-amphibole (11). Chemistry of inclusions in Table 3.36. Spot analyses as squares. Scale bars are located on the bottom left of each image.

Table 3. 34. SEM-EDS results in oxide compound %; Potsherd MB2. Inclusions and analyses numbered; refer to Figure 3.37. ND; not detected, below detection limits.

%	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total	Classification
Surface Clay (1)	1.29	2.03	15.84	65.87	1.78	3.78	2.23	0.67	ND	6.50	99.99	Clay body and surface clay exhibit similar chemistry.
Clay body (2)	1.38	2.55	19.62	61.54	ND	3.48	2.28	1.79	ND	7.13	99.77	
Inclusion (3)	2.85	0.59	15.70	70.05	ND	6.24	1.19	0.81	ND	2.58	100.01	Rhoylitic tuff
Inclusion (4)	2.99	0.50	15.60	70.02	ND	6.22	1.08	0.89	ND	2.70	100.00	Rhoylitic tuff
Inclusion (5)	2.98	0.56	15.19	70.55	ND	6.61	1.10	0.59	ND	2.42	100.00	Rhoylitic tuff
Inclusion (6)	ND	1.55	2.23	0.38	ND	ND	ND	10.29	1.03	84.52	100.00	Titanomagnetite
Inclusion (7)	5.26	ND	26.97	56.36	ND	0.30	10.12	ND	ND	0.99	100.00	Plagioclase feldspar
Inclusion (8)	4.59	0.81	18.29	65.96	ND	1.95	4.45	0.58	ND	2.01	98.54	Andesine plagioclase feldspar
Inclusion (9)	6.20	ND	26.11	59.19	ND	ND	8.49	ND	ND	ND	99.99	Plagioclase feldspar
Inclusion (10)	9.49	0.31	18.28	70.42	ND	0.62	ND	ND	ND	0.88	100.01	Albite
Inclusion (11)	1.90	9.60	14.43	42.00	ND	0.96	12.0	0.74	ND	18.38	100.00	Ca-amphibole
Inclusion (12)	ND	ND	1.01	98.99	ND	ND	ND	ND	ND	ND	100.01	Quartz

Table 3. 35. SEM-EDS results in oxide compound %; Potsherd MB3-1. Inclusions and analyses numbered; refer to Figure 3.38. ND; not detected, below detection limits.

%	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total	Classification
Inclusion (1)	4.45	0.63	15.39	68.48	ND	5.21	1.76	0.99	ND	3.10	100.01	Rhyolite
Surface clay (2)	0.92	1.89	19.47	64.02	0.73	3.37	2.11	0.83	1.48	5.18	100.00	Clay body and surface clay exhibit similar chemistry.
Clay body (3)	1.48	3.12	19.74	62.10	ND	3.20	3.61	0.82	ND	5.92	99.99	
Inclusion (4)	4.10	1.33	16.64	64.32	ND	4.12	4.39	1.00	ND	4.09	99.99	Trachytic groundmass inclusion
Inclusion (5)	0.33	14.73	4.22	50.70	ND	ND	21.19	1.26	ND	7.58	100.01	Altered diopside
Inclusion (6)	0.19	0.18	5.88	32.84	ND	0.21	28.59	29.83	ND	2.29	100.01	Complex coarse inclusion comprising sphene
Inclusion (7)	ND	13.39	18.33	41.95	ND	1.61	0.67	ND	ND	24.05	100.00	Mg-chlorite
Inclusion (8)	ND	0.66	2.92	94.34	ND	ND	ND	ND	ND	2.08	100.00	Quartz/chert
Inclusion (9)	ND	0.86	2.78	3.94	2.11	0.74	0.70	11.46	ND	77.41	100.00	Ilmenite
Inclusion (10)	ND	14.72	2.13	51.07	ND	ND	19.86	1.30	ND	10.92	100.00	Diopside
Inclusion (11)	2.48	ND	31.53	49.11	ND	ND	15.80	ND	ND	1.08	100.00	Intermediate plagioclase feldspar
Clay body (12)	1.54	2.20	18.04	60.49	2.92	4.12	2.67	ND	ND	8.01	99.99	Increase in phosphate
Clay body (13)	1.15	2.34	17.65	60.75	2.27	3.60	3.37	1.18	ND	7.68	99.99	Increase in phosphate
Inclusion (14)	ND	2.95	ND	ND	ND	ND	ND	14.40	ND	75.55	92.90	Ilmenite
Inclusion (15)	ND	3.52	ND	ND	ND	ND	ND	16.87	ND	77.26	97.65	Ilmenite
Inclusion (16)	ND	15.27	2.95	51.03	ND	ND	20.27	0.95	ND	9.53	100.00	Olivine/fayalite
Inclusion (17)	ND	31.56	ND	36.64	ND	ND	ND	ND	0.88	30.62	99.70	Diopside
Clay body (18)	3.95	1.21	15.48	66.10	ND	4.96	2.87	0.86	ND	4.57	100.00	Inclusion groundmass
Inclusion (19)	4.46	ND	27.74	56.38	ND	0.60	10.83	ND	ND	ND	100.01	Intermediate plagioclase feldspar
Inclusion (20)	ND	14.93	0.86	53.90	ND	ND	22.10	ND	ND	8.21	100.00	Diopside clinopyroxene
Clay body (21)	1.47	2.59	18.88	61.34	ND	3.88	4.24	1.00	ND	6.60	100.00	Inclusion groundmass

Table 3. 36. SEM-EDS results in oxide compound %; Potsherd MB11. Inclusions and analyses numbered; refer to Figure 3.39. ND; not detected, below detection limits.

%	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total	Classification
Inclusion (1)	2.93	0.60	15.13	69.78	ND	6.15	1.93	0.86	ND	2.62	100.00	Rhyolite
Inclusion (2)	ND	ND	0.84	98.27	ND	0.39	0.49	ND	ND	ND	99.99	Quartz/chert
Inclusion (3)	0.29	ND	5.97	85.20	1.67	1.72	2.50	ND	ND	2.65	100.00	Quartz/chert
Inclusion (4)	ND	ND	0.50	99.50	ND	ND	ND	ND	ND	ND	100.00	Quartz/chert
Inclusion (5)	2.01	0.58	15.95	70.80	ND	5.14	1.52	0.76	ND	3.07	99.83	Quartz/chert
Surface clay (6)	2.28	1.61	18.25	62.78	1.38	3.29	3.51	0.96	ND	5.93	99.99	Quartz/chert
Clay body (7)	2.92	1.38	21.74	62.46	ND	3.12	2.88	0.62	ND	4.88	100.00	Clay body and surface clay exhibit similar chemistry.
Surface clay and body map	1.88	1.58	19.27	64.81	ND	3.09	3.01	0.80	ND	5.55	99.96	
Inclusion (8)	ND	24.45	1.12	53.13	ND	ND	1.29	0.36	1.25	18.14	100.00	Hornblende amphibole
Inclusion (9)	ND	2.87	2.32	0.51	ND	ND	ND	11.50	0.84	81.45	99.49	Titanomagnetite
Inclusion (10)	ND	24.30	0.91	53.80	ND	ND	1.32	ND	1.32	18.34	99.99	Hornblende amphibole
Inclusion (11)	3.67	0.48	15.30	69.37	ND	6.12	1.53	0.66	ND	2.86	99.99	Ca-amphibole

3.4.4 Norabak-1 fine-wares

Norabak-1 fine-wares have been analysed, as most of the site yielded black-burnished fine-wares, characteristic of the Kura-Araxes pottery repertoire. For potsherds analysed, see Table 3.37. All inclusions and points of analyses have been numbered in Figures 3.40 to 3.43. These points are numbered in tables and the map analyses are indicated (Tables 3.38).

Table 3. 37. Norabak-1 potsherd samples for SEM-EDS. All potsherds are fired in a reduction environment, except potsherd NB6 (N13-337 – oxidised and organic and chaff tempered).

Laboratory code	**Trench C, Unit #**	**Locus**	**Surface feature**	**Width of sherd (mm)**	**Munsell**
NB1	Unit 3 (upper layer)	N13-295	Burnished (black)	8.13	2.5 Y 3/0
NB2	Unit 3 (upper layer)	N13-312	Burnished (black)	9.38	2.5 Y 3/0
NB3	Unit 3 (upper layer)	N13-322	Burnished (black)	6.06	2.5 Y 5/0
NB4	Unit 3 (upper layer)	N13-332	Burnished (grey)	9.74	2.5 Y 5/0
NB5	Unit 6	N13-336	Burnished (black)	10.78	2.5 Y 3/0 exterior, 10 YR 5/3 interior and rim
NB6	Unit 6	N13-337	Unburnished (brown/beige)	15.56	7.5 YR 6/4
NB7	Unit 3 (lower layer)	N13-347	Burnished (black)	6.85	2.5 Y 5/0 to 2.5 Y 4/0
NB8	Unit 3 (lower layer)	N13-353	Burnished (black)	4.21	10 YR 5/2 rim, 2.5 Y 3/0 body
NB9	Unit 3 (lower layer)	N13-354	Burnished (black)	9.15	2.5 Y 4/0
NB10	Unit 4	N13-358	Burnished (black)	5.90	2.5 Y 3/0 exterior, 10 YR 4/2 interior
NB11	Unit 6	N13-365	Burnished (grey)	8.79	10 YR 5/1 exterior and interior

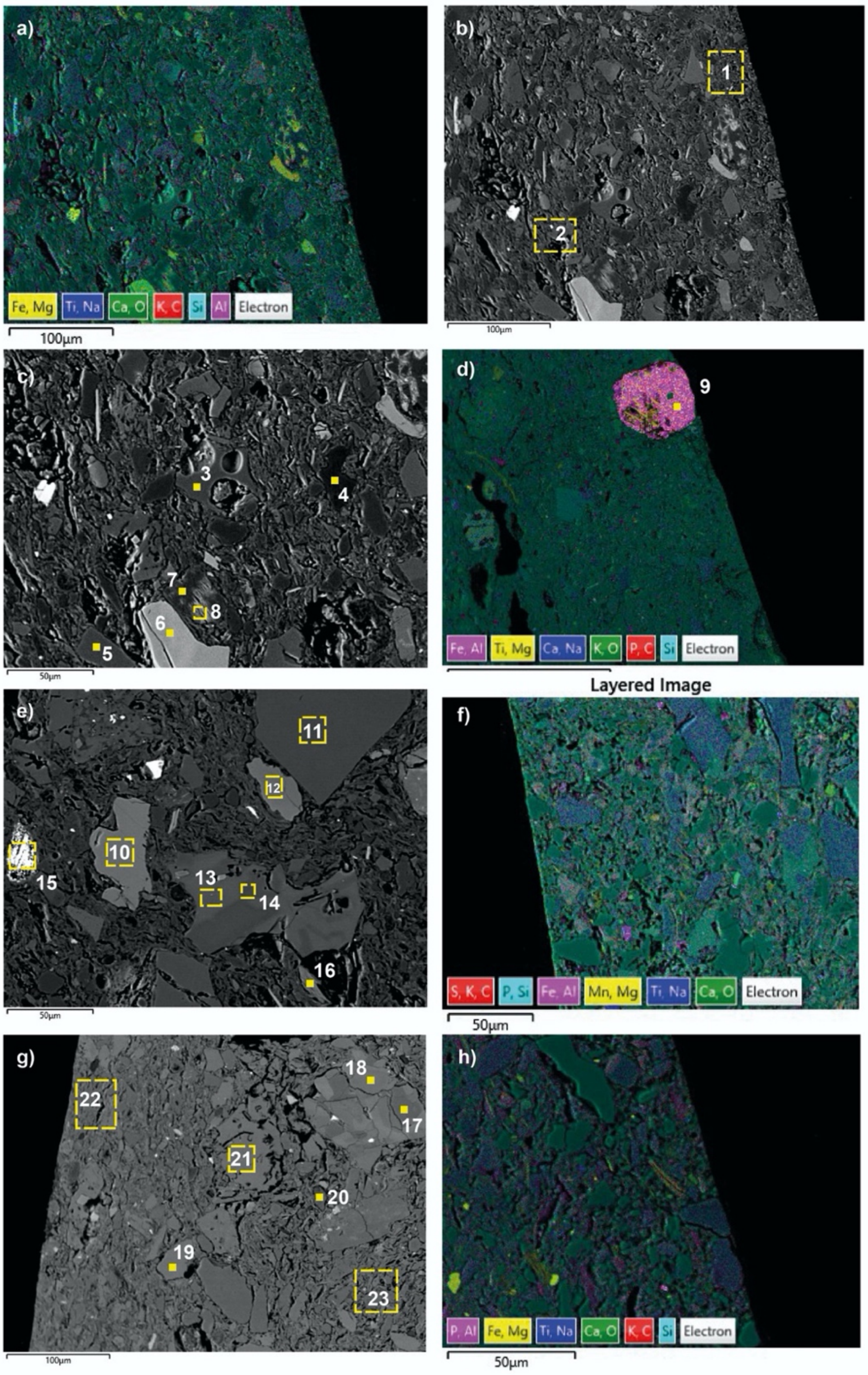


Figure 3. 40. BSE photomicrographs of potsherds NB1 (a, b and c), NB2 (d and e), NB3 (f), and NB4 (g and h). Chemistry and characterisation of inclusions in Table 3.38. Spot analyses as yellow squares. Scale bars are located on the bottom left of each image.

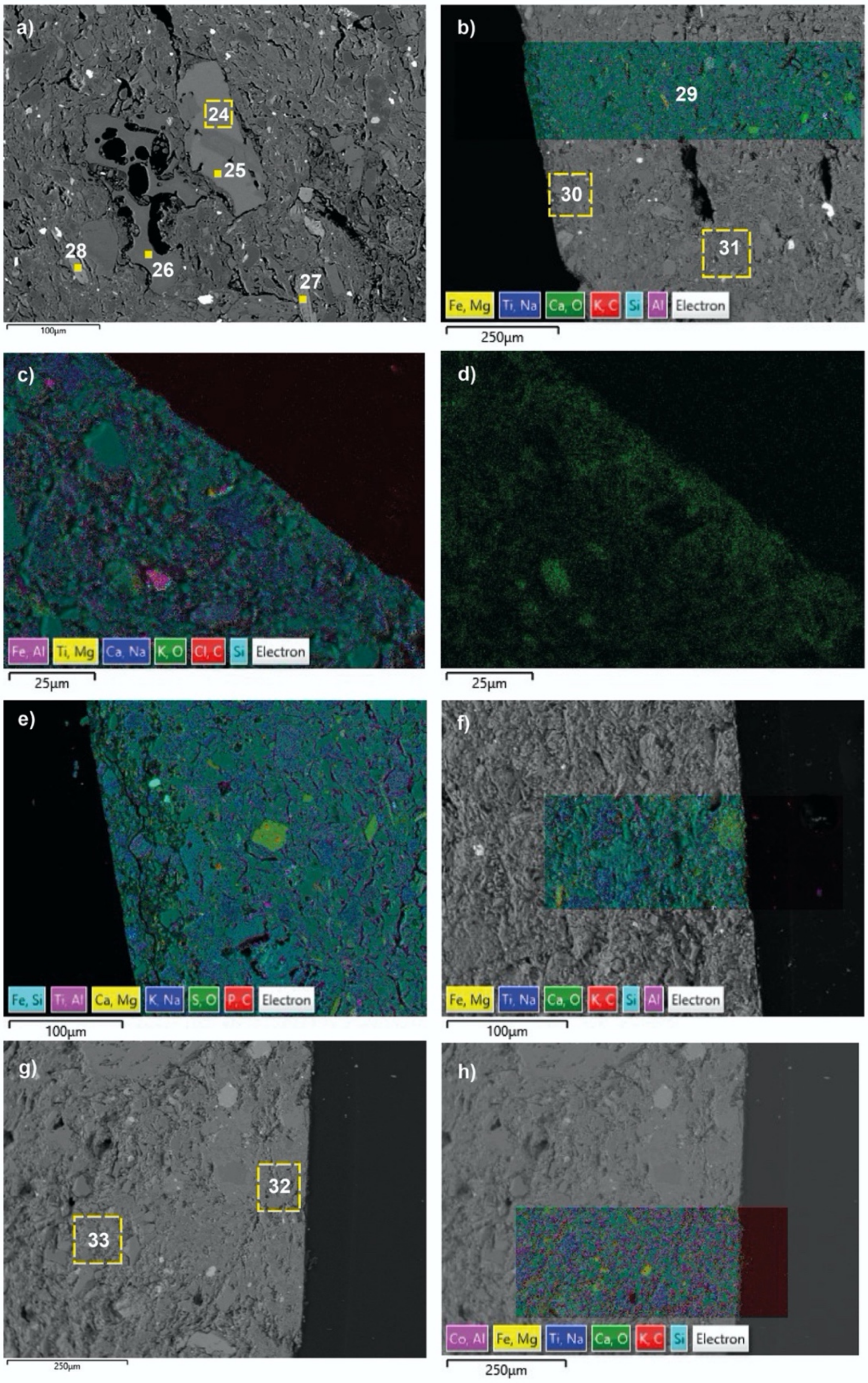


Figure 3. 41. BSE photomicrographs of potsherds NB5 (a), NB7 (b), NB8 (c-d), NB19 (e), NB10 (f) and NB11 (g-h). Chemistry and characterisation of inclusions in Table 3.38. Spot analyses labelled as yellow squares. Scale bars are located on the bottom left of each image.

Table 3. 38. SEM-EDS results in oxide compound %; Inclusions and analyses numbered; refer to Figures 3.40 and 3.41. ND; not detected, below detection limits.

%	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total	Classification
NB1												
Map of section	1.46	1.96	17.64	65.57	ND	3.20	3.84	0.79	ND	5.54	100.00	Slight increase of K_2O and CaO towards edge compared to clay body
Surface clay (1)	0.72	1.85	15.13	66.39	ND	4.48	4.40	1.01	ND	6.02	100.00	
Clay body (2)	1.54	1.63	18.95	64.62	ND	3.00	3.66	1.16	ND	5.43	99.99	
Inclusion (3)	1.12	ND	12.43	78.67	ND	6.36	0.79	ND	ND	0.63	100.00	Rhyolitic pumice
Inclusion (4)	ND	0.37	ND	99.02	ND	ND	ND	ND	ND	ND	99.39	Quartz
Inclusion (5)	6.08	25.71	ND	58.61	ND	0.57	8.38	ND	ND	0.65	100.00	Intermediate plagioclase
Inclusion (6)	0.39	14.13	2.95	50.66	ND	ND	20.51	0.93	ND	10.44	100.01	Diopside
Inclusion (7)	ND	0.48	3.72	93.32	ND	0.32	ND	ND	ND	2.16	100.00	Chlorite
Inclusion (8)	ND	4.88	17.81	56.84	ND	1.87	1.69	ND	ND	16.92	100.01	Biotite
NB2												
Map of section	1.28	2.03	17.21	58.58	0.52	3.82	4.02	1.92	ND	10.56	99.94	Non-calcareous
Inclusion (9)	ND	0.73	ND	0.71	ND	ND	0.22	38.37	ND	59.71	99.74	Ilmenite
Inclusion (10)	0.25	15.01	1.83	52.14	ND	ND	21.62	0.71	ND	8.44	100.00	Diopside
Inclusion (11)	5.58	ND	26.07	58.59	ND	0.75	8.45	ND	ND	0.57	100.01	Intermediate plagioclase
Inclusion (12)	1.83	14.38	14.42	ND	ND	1.34	12.95	2.03	ND	10.54	100.00	Ca-amphibole
Inclusion (13)	2.18	0.71	12.12	71.57	ND	5.22	2.47	1.26	ND	4.46	99.99	Andesitic groundmass
Inclusion (14)	4.72	ND	27.17	56.05	ND	0.25	10.92	ND	ND	0.89	100.00	Intermediate plagioclase
Inclusion (15)	ND	0.77	6.09	5.75	ND	0.72	0.38	5.48	ND	80.81	100.00	Hematite
Inclusion (16)	ND	17.87	19.04	40.20	ND	1.07	1.50	ND	0.38	19.94	100.00	Mg-chlorite
NB3												
Map of section	1.36	1.60	18.14	61.91	ND	5.28	5.47	0.86	0.37	4.96	99.95	Non-calcareous
NB4												
Inclusion (17)	ND	ND	ND	100.00	ND	ND	ND	ND	ND	ND	100.00	Quartz
Inclusion (18)	5.87	ND	25.95	58.25	ND	0.58	8.50	ND	ND	0.85	100.00	Intermediate plagioclase
Inclusion (19)	5.44	ND	26.64	57.29	ND	0.26	9.79	ND	ND	0.57	99.99	Intermediate plagioclase
Inclusion (20)	ND	ND	1.11	97.70	ND	0.37	0.82	ND	ND	ND	100.00	Chlorite
Inclusion (21)	2.02	0.24	12.45	77.04	ND	6.57	0.26	0.26	ND	1.16	100.00	Andesitic groundmass
Surface clay (22)	0.63	1.50	15.84	70.11	ND	3.91	2.52	0.61	ND	4.89	100.01	Non-calcareous

Table 3.38. *Continued.*

%	Na_2O	MgO	Al_2O_3	SiO_2	SO_3	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total	Classification
NB4													
Body clay (23)	0.98	1.27	12.30	75.68	ND	ND	2.26	2.23	0.89	ND	4.38	99.99	Non-calcareous; alluvial clay
NB5													
Clay body and surface map section	1.55	2.29	17.74	63.84	0.20	ND	4.30	2.98	0.68	ND	6.41	99.99	No visible difference between clay body and surface clay chemistry
Inclusion (24)	2.90	0.79	12.50	70.46	ND	ND	4.54	2.59	1.26	ND	4.96	100.00	Rhyolitic pumice
Inclusion (25)	2.25	0.66	12.25	71.27	ND	ND	4.59	2.63	1.43	ND	4.91	99.99	Rhyolitic pumice
Inclusion (26)	1.90	ND	13.28	76.48	ND	ND	6.37	0.65	ND	ND	1.31	99.99	Rhyolitic pumice
Inclusion (27)	ND	15.66	3.49	52.12	ND	ND	ND	22.92	ND	ND	5.13	99.32	Diopside
Inclusion (28)	0.51	14.88	3.68	50.25	ND	ND	ND	21.26	1.13	ND	8.29	100.00	Diopside
NB6													
Map of section	2.04	2.21	20.17	61.76	ND	ND	3.60	3.15	0.74	ND	6.33	100.00	Non-calcareous
NB7													
Surface to clay body (29)	1.81	2.09	20.35	61.59	ND	ND	2.98	3.62	0.96	ND	6.61	100.01	Slight K_2O and CaO enrichment towards surface.
Surface clay (30)	1.63	1.39	15.39	65.59	ND	ND	3.99	5.62	ND	ND	5.40	99.01	
Body clay (31)	1.69	1.80	19.68	64.61	ND	ND	3.08	2.47	ND	ND	6.88	100.01	
NB8													
Map of surface clay to body	1.51	2.20	20.29	59.39	ND	ND	4.55	3.32	1.11	ND	7.55	99.92	
NB9													
Map of surface clay to body	1.52	1.82	20.71	60.08	ND	0.43	4.50	4.85	0.83	ND	5.26	100.00	
NB10													
Map of surface clay to body	1.79	1.82	19.07	62.34	ND	ND	3.59	4.57	0.79	ND	6.03	100.00	
NB11													
Map of surface clay to body	1.59	1.82	20.61	59.08	ND	ND	5.28	3.88	1.06	ND	6.68	100.00	
Surface analysis (32)	1.25	1.32	20.97	57.15	ND	ND	7.13	5.83	0.75	ND	5.59	99.99	
Clay body (33)	1.33	2.13	22.03	57.61	ND	ND	3.92	4.47	0.93	ND	7.58	100.00	

Potsherd NB1 contains inclusions of pumice and volcanic ash (over 70% in abundance). In contrast, potsherd NB2 does not contain pumice, but there are sub-angular rhyolite inclusions and few opaques (5-10%) evident throughout the potsherd. Other inclusions include ilmenite, orthopyroxene, basalt and andesitic groundmass, diopside and clinopyroxenes, intermediate plagioclases, Mg-olivines, Ca-amphibole, and occasional iron opaques (magnetite/hematite). Other inclusions include Mg-chlorite and trachytic groundmasses. Furthermore, NB3 contains highly fragmented pumice.

Based on map chemistry (see Figures 3.40 and 3.41; Table 3.38), there is no differentiation between the surface clay and body clay. These fine-wares do not exhibit a slip or any visible treatment to the highly polished burnished. There is an indication of calcium leaching near the surface for most of the sherds analysed from Norabak-1, but this is most likely due to post-burial environment and/or sample preparation (Maritan, 2020). Other notable inclusions include andesite, groundmass, and intermediate plagioclase. Potsherd NB4 is a rim section, with the presence of medium- and coarse-grained inclusions. Such inclusions include quartz, intermediate plagioclase, pumice, olivine (fayalite), orthopyroxene, Ca-amphibole, titanomagnetite, biotite, potassium feldspar, and albite. Potsherd NB5 (N13-336) contains inclusions such as quartz, biotite, olivine, pyroxenes, intermediate plagioclases, Ca-Mg amphiboles, K-feldspars, rhyolitic groundmass, pumice inclusions, and diopside. The geochemical data suggests that these inclusions are indicative of deep-sourced volcanic rocks, common in the geology of Armenia (Satian *et al.*, 2009). Based on the mineralogy and rock fragments locally available, it is possible to suggest that these potsherds were produced locally near the site of Norabak-1.

All potsherds display a non-calcareous source of clay, including the potsherd labelled as oxidised with possible organic inclusions. There is no observable effect on composition between surface and clay.

Potsherd NB7 (N13-347) contains a clay body of fine ash particles (volcanic glass, tuff and with vesicular pumice). Other inclusions include trachytic groundmass, intermediate plagioclases, apatite, diopside, etc. Moreover, potsherd NB8 (N13-353) exhibits a volcanic ash-rich body. There is a slight increase of K_2O towards the surface of the potsherd (Table 3.38); perhaps this is due to post-depositional processes and the natural burial environment, which is highly variable (Maritan, 2020). However, it is also possible that the K_2O enrichment might be due to high-quality burnishing. Inclusions include pumice, intermediate plagioclases, Ca-Mg amphibole, biotite, chlorite, garnet and apatite. Potsherd NB 9 (N13-354) contains vesicular pumice fragments. Other inclusions include rhyolite/groundmass with titanomagnetite, intermediate plagioclase, potassium feldspar, and quartz. There is no observable change in chemistry between the surface and clay body. Furthermore, potsherd NB10 (N13-358) exhibits no differentiation in chemistry between the map/surface and clay body. Most common inclusions are pumice and tuff. Potsherd NB11 (N13-365) exhibits a volcanic ash-rich body, but with silty-sand inclusions matrix. Other notable inclusions are rhyolite and diopside. In general, all sherds at Norabak-1 exhibit volcanic rock fragments and ash, with similar chemical compositions (Figures 3.40 and 3.41; Table 3.38).

3.4.5 Summary of SEM-EDS results

There is no observed difference between the clay matrix and surface of these potsherds. The main difference observed is the slight increase in K_2O and CaO towards the surface of the sherd. This is most likely caused by post-depositional processes and lime leaching characteristic of the burial environment (Maritan, 2020). SEM-EDS results suggest that there is no applied surface coat on the black-burnished pottery. However, thin slips are evident for some potsherd samples, particularly SHEN4 and SHEN5. No other slips were observed at Mokhra-Blur and Norabak-1. Organic materials and other applications suggested by scholars were not observed in the chemistry (i.e., graphite-burnished; Edens 1995).

These results indicate that KA vessels were burnished after the pottery forming procedure, primarily before or after the firing process, in order to achieve a high surface gloss. Upon mapping the surface of a black-burnished sample, clay bodies and the vessel surfaces have similar chemical compositions. When comparing the 'burnish' to high gloss phenomenon to Greek attic ware, it is significant to note that there is a difference between the surface and body composition, as Tite *et al*., (1982) analysed fresh breaks and polished sections. They conclude that "the compositions of the intentional red and black surface finishes differed from that of the body in having higher Al_2O_3 to SiO_2 ratios, higher FeO contents and lower MgO and CaO contents: there were, however, no systematic differences in the K_2O contents" (Tite *et al*., 1982: 121). The surface treatment is discussed more in Section 3.4 – 3.4.4.

Results from all three settlements indicate that volcanic ash and pumice are naturally occurring within the clay, suggesting that volcanic ash and glass are not necessarily used as tempering sources. At all sites, the clay matrix is high in MgO and SiO_2, where volcanic ash is naturally present in the clay. Furthermore, the Al_2O_3 composition of all clay bodies examined at Norabak-1, Shengavit and Mokhra-Blur was quite high, at around 20 wt%. Ferruginous minerals comprising high abundance of FeO and TiO_2 were also common within the clay matrix. Throughout all fine-wares analysed here from Mokhra-Blur, Shengavit, and Norabak-1, CaO content is relatively low, suggesting non-calcareous clay sources. Findings reported through stereomicroscopy and SEM-EDS will be compared with thin-section petrography results in Chapter 3.4 and discussed in Chapter 3.6.

3.5 Discussion: reconstructing production and *chaîne opératoires* of Kura-Araxes pottery from settlements in Armenia

The primary focus of this chapter was to examine and investigate the raw data for each pottery assemblage at Kura-Araxes settlements introduced in the preceding sections of this chapter. Furthermore, the main aim was to describe the compositional and fabric variability within the assemblage and consider the selection and manipulation of raw materials and paste preparation. This section will combine these results with a particular emphasis placed on the questions concerning forming, firing, and surface modification. This discussion section will synthesise the data presented in the preceding sections and discuss the overall *chaîne opératoire* of the Kura-Araxes assemblage. As mentioned in Chapter 1, Leroi-Gourhan (1964: 164) coined *chaîne opératoire* describing "techniques are at the same time gestures and tools, organised in sequence by a true syntax which gives the operational series both their stability and their flexibility." The *chaîne opératoire* is a series of actions that transform raw material into finished product (Cresswell, 1976: 13).

The macroscopic/microscopic groups were classified based on the percentage and abundance of inclusions, size of inclusions (fine-, medium-, and coarse-grained), paste texture (percentage), porosity (voids), approximate firing temperature, surface treatment (and/or slip composition), and visible forming techniques. Findings reported here are based on qualitative and semi-quantitative data following published petrographic instructions (Quinn, 2013; Whitbread, 1995; Riederer, 2004; Degryse and Braekmans, 2016). Published methodologies and case studies were consulted in order to characterise rock fragments (plastic and aplastic inclusions), determine fabric classes and technological attributes (Rice, 1987; Roux *et al*., 2018; 2020). These observable technological attributes provide data to form the *chaîne opératoires* and interpret the potting technology and choices made through the selection of raw materials, manufacturing and production processes (Rice, 1987; Quinn, 2013; Roux *et al*., 2018). As suggested (Chapter 1), regional and local diversity in the technical skills and production of pottery manufacturing (including production methods) has been discussed to a limited extent in terms of Kura-Araxes pottery analyses, particularly in the South Caucasus region (i.e., Armenia[4], Georgia[5], and Iran/Azerbaijan[6]). Furthermore, the aim of this thesis is to compare and contrast pottery technology across coeval Kura-Araxes settlements, including the use of the landscape and natural resources in various regional areas of Armenia, in order to understand regional differences and/or similarities (on the themes of transformation and transmission).

Material analyses have led archaeologists to devise and reconstruct the very nature of technological processes, from the procurement of raw materials, manipulation of such materials, to the shaping and final product. The order of pottery production is as follows: raw materials and paste preparation, forming of the vessel and shape, firing, surface treatment, use, and discard (Figure 3.42; Roux *et al.*, 2018; Degryse and Braekmans, 2016: 234). The *chaîne opératoire* step concerning 'use' of pottery are thoroughly discussed in Chapter 5, and results are presented in Chapter 4, organic residue analyses. The following next sections are organised based on the order of the *chaîne opératoire* process.

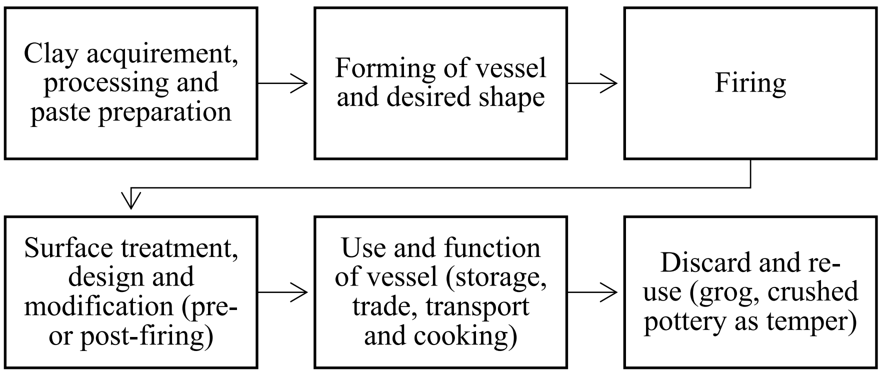


Figure 3. 42. *Chaîne opératoire* sequence and the pottery technology scheme.

[4] Published petrographic studies will be compared with the findings reported here.
Hayrapetan, 2008; Hovsepyan and Mnatsakanyan, 2011; Hovsepyan, 2014; Iserlis *et al.*, 2010; Iserlis *et al.*, 2015
[5] Babetto *et al.*, 2021; Randazzo *et al.*, 2020
[6] Mason and Cooper, 1999; Khazaie Koupar *et al.*, 2015; Heydarian *et al.*, 2020

3.5.1 Raw materials and paste preparation

In terms of the provenance of raw materials, this is difficult without clay samples in the project; however, from geological reasoning it is possible to suggest that most clays were attained from alluvial deposits (river-bed clays), locally produced, apart from one possible non-local sherd at Shengavit (Sample SH48). The medium to coarse fraction suggests natural rock fragments as aplastic inclusions, and possibly added by potters in certain circumstances. River-bed clay is recognised due to the sub-rounded to rounded inclusions in various fabric recipes, depicting sandy inclusions (Shengavit Fabric 4; Mokhra-Blur Fabrics 2 and 3).

As confirmed through SEM-EDS, Kura-Araxes pottery clays are generally non-calcareous, which indicates a low CaO concentration. In the archaeological literature, calcareous clays are about >15 wt% of CaO concentration (Fabbri *et al.*, 2014: 1903). Furthermore, fabrics containing microfossils are indicative of marine origin and useful for provenance (Fabbri *et al.*, 2014). The KA clay bodies chemically analysed through SEM-EDS from Norabak-1, Mohkra-Blur and Shengavit display non-calcareous sourcing. Four fabrics contain slightly calcareous clays (Fabric 3 – Mokhra-Blur; Fabric 4 – Shengavit; Fabric 1 and 2 – Talin Tombs). The identification of such clay types is due to the speckled optical activity caused by a calcitic and limestone content.

Paste preparation involves the use of igneous-rich rock fragments and minerals, heavily distinguished during the EBA compared to Neolithic/Chalcolithic and post-EBA pottery (post-EBA, pottery is oxidised and red-slipped; see Khatchadourian, 2019). Based on the results reported in Sections 3.2, 3.3 and 3.4, KA potters preferred coarse clay with igneous-rich sources, absent of organic inclusions. Through macroscopic analyses, one potsherd appears to contain organic chaff inclusions (NB6 from Norabak-1); however, SEM-EDS analyses illustrate that the clay body is also characterised as non-calcareous clay and similar in composition with the other sherds examined (Table 3.38). Sedimentary rock-derived inclusions do not dominate the KA pottery raw materials, as 7 % (n = 10) of potsherds are classified as sandy siltstones fabric pastes (Figure 3.43). The rest are igneous-rich sub-angular to angular, indicating a non-sedimentary source clay. This is consistent with the predominance of volcanic rocks in the region. Evidence of clay mixing, and refining is assessed by the fabric inclusions' sizes, colouration of clay and fine-paste suggesting a form of levigation (Quinn, 2013: 120, 154; Santacreu, 2014: 68; Abbink, 1999: 49).

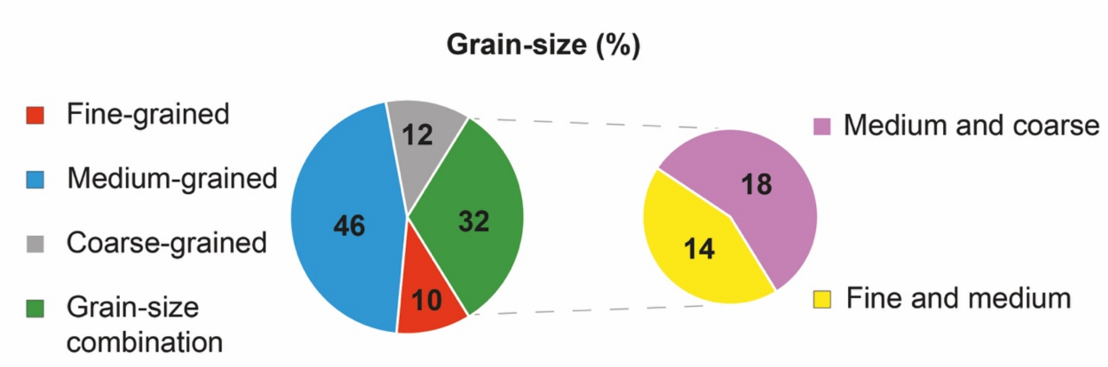


Figure 3. 43. Grain-size estimation (%) across all KA settlements examined (Karnut-1, Gegharot, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs).

Abbink (1999: 49) describes levigation as "potters can improve the properties of raw clays in a number of ways: homogeneity is increased by rotting and kneading, by sieving or levigation—letting the clay settle in water and separating finer and coarser silts—or by simply picking out the larger impurities." Fine-grained fabrics recorded at Margahovit, Gegharot and Shengavit suggest an extra step in refining the clay and removing coarse aplastic inclusions. However, the percentage (10 %, n = 14) of fine-paste fabrics is low compared to medium- and coarse-grained fabrics. According to Santacreu (2014: 75-78), the presence of clay pellets might suggest the mixing of clay sources. Furthermore, "clay pellets or 'porphyroclasts' are common type of plastic inclusion that are generally equant and well-rounded and may have an elongate punched-out tail from their deformation during clay working and forming"

(Santacreu, 2014: 58) (Figure 3.44). Clay pellets were reported in most sites examined, particularly common at Mokhra-Blur and few at Margahovit.

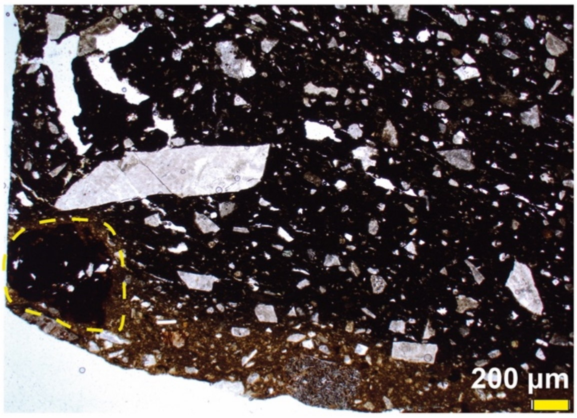


Figure 3. 44. MG24 in PPL, x2 magnification; Fe-rich pellet in yellow dashed lines. Scale on the lower right of each photomicrograph.

In terms of medium- and coarse-grained vessels, fabric pastes of volcanic origin were common across all KA sites, as suggested by the local clay sources and geological characterisation (Figure 3.3 and Table 3.1). Volcanic ash and glass morphologies, such as rhyolite, rhyolitic tuff, dacite, trachyte, and andesitic rocks were present at most sites, including ferruginous minerals (magnetite and titaniferous magnetite) as impurities and aplastic inclusions. Amphiboles, micaceous inclusions such as biotite, quartz, feldspars, pyroxenes (orthopyroxene and clinopyroxene) and apatite were also identified. There is some level of standardisation in paste preparation across settlements (discussed in Chapter 5). Standardisation of pottery production is difficult to assess (Roux, 2015); however, it can be suggested that within each site, potters were producing pottery using a variety of clay sources, specifically preparing the paste using medium-grained igneous rock fragments (20-50 % poorly sorted, angular to sub-rounded).

It is clear that some differentiation in paste preparation is evident across sites, but varies in scale; for instance, at Gegharot, medium-grained igneous fabrics dominate. However, at Shengavit, pastes vary between fine- to coarse- and various temper sources. This differentiation is discussed more in Chapter 5. Based on findings reported here, it is possible to suggest that most vessels were hand-made, with techniques visible such as slab-building, drawing, and coiling (Rice, 1987: 124-125). Wheel-made pottery is detected with "rhythmic ridges and grooves that spiral around the vessel walls" (Rice, 1987: 129), this is impossible to detect on KA pottery, as most vessels are burnished post-forming, and such technological features are obliterated. While Iserlis *et al.*, (2010) have suggested wheel-made KA vessels, to conclude this unequivocally requires further investigation on larger datasets of KA pottery, including whole vessels as opposed to fragments. The common paste preparation techniques recorded through thin-section petrographic analyses suggest that KA potters used readily available clay, rich in medium- to coarse-grained igneous rock fragments. Furthermore, potters refined clay by plucking impure medium- to coarse-grained igneous rock fragments to form fine-paste vessels. Levigation and clay refining might have been an important step for potters to undertake such refinement for fine pastes. Lastly, the combination of some fabrics suggests some clay mixing (i.e., Fabric 1 at Talin Tombs; Fabric 2 at Karnut-1; Fabric 3 at Mokhra-Blur, Fabric 3 at Shengavit; Fabrics 1 and 2 at Gegharot).

Most vessels exhibit 'compact clay' and 'sintered' (Quinn, 2013). This means that there is relatively low porosity recorded across all sites, 2-4%. The voids are mostly micro (<0.05 mm) to meso (0.05-0.5 mm), with minimal macro (0.5-2 mm) and mega (>2 mm) voids. The low porosity most likely aided potters with consumption and use of this pottery and provided a longer use-life. Erosive processes affect fabrics with abundant pottery, and the use-life of cooking pots is substantially reduced (Santacreu, 2014: 160).

3.5.1.1 Aplastic inclusions and temper

Aplastic inclusions are 20-40 % in abundance estimation. It is possible to suggest some addition of aplastic inclusions as temper (i.e., grog and coarse inclusions), which produce a bimodal distribution. As mentioned, grog (crushed recycled pottery) is a common temper source recorded at KA settlements in the published literature (Mason and Cooper, 1999; Iserlis *et al.*, 2010; 2015; Hovsepyan and Mnatsakanyan, 2011; Hovsepyan, 2014; Hayrapetyan, 2008). However, grog is not the common temper source reported here, as 14 % (n = 19) of potsherds contained grog. The low quantity of human-made temper (i.e., grog) suggests KA potters did not prefer to temper. The main aplastic inclusions are sub-angular volcanic inclusions that most likely represent the local geological sources. This means that potters preferred local volcanic sources for the production and manufacturing of KA vessels. Grog was mainly common at Talin Tombs, Karnut-1, Shengavit and Gegharot. There are difficulties in distinguishing between rock fragments, textural features and grog (Whitbread, 1986), and the addition of aplastic inclusions requires further analyses, possibly more accurate chemical characterisation rather than thin-section petrography.

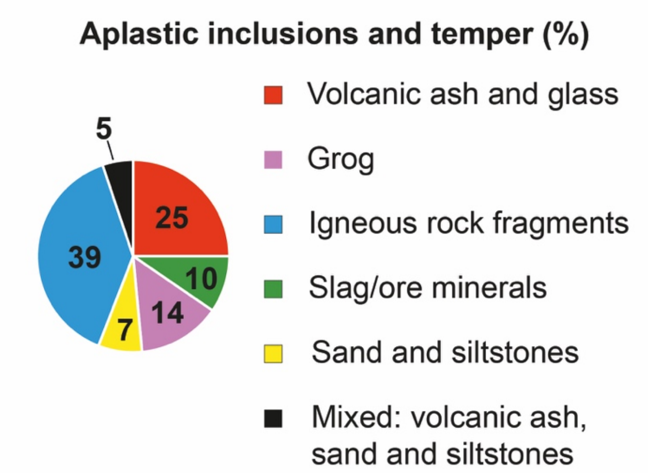


Figure 3. 45. Aplastic inclusions and temper (%) across all KA settlements examined (Karnut-1, Gegharot, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs).

A subset of potsherds contained possible slag inclusions, compared with published datasets (Martin *et al.*, 2013; Quinn, 2013). However, these sherds require additional experimental tests using SEM-EDS to confirm the presence of slag. The recorded inclusions characteristic of slag/ore-minerals are evident at Gegharot and Margahovit (i.e., potsherd MG31). These inclusions comprise iron opaques (magnetite/fayalite), olivine and serpentinised olivine, etc. They exhibit morphological characteristics to Martin *et al.*, (2013) and Quinn (2013) references to slag temper inclusions. Olivine crystals show a variety of textures, namely skeletal and dendritic olivine (Martin *et al.*, 2013: 3783). Further investigations are required to determine the extent of slag inclusions in KA pottery, as well as the general chemistry. The quantity of slag and ore minerals constitutes 10 % (n = 13) of the overall assemblage. Slag can be extremely beneficial to produce strong vessels (Stahl *et al.*, 2008; Ben-Shlomo, 2019; Tropper *et al.*, 2019; Martin *et al.*, 2013). Even in modern times, new cement studies have been published indicating the use of slag and ore minerals for high compact designs and strong durability (Jóźwiak-Niedźwiedzka *et al.*, 2020). Furthermore, it is possible to suggest that slag impurities and ore minerals might be unintentionally present in the clay or craft production area of pottery and other crafts (i.e., metal). The presence of such inclusions might resemble by-products of craft manufacturing processes. Given the metal production evident at Margahovit (Gevorgyan *et al.*, 2021), including the close proximity to native copper mines, it is possible that potters were producing pottery using clay near such outcrops.

Organics were not used for temper; the absence of intentional organic temper suggests the conservatism and specific choices of KA potters, primarily preferring to use clay sources rich in igneous rock fragments. It is shown, archaeologically in other contexts and regions, that volcanic temper has been used as a tempering material (Barone *et al.*, 2010), decoration and surface finishing (Grifa *et al.*, 2021). The most abundant temper recorded across Kura-Araxes sites is volcanic ash combined with igneous rock fragments (25 % and 39 % of the assemblage). The pumice fragments contain oval and circular vesicles. As Chung and Song (2014: 157) note, "the oval form of the pumice fragments indicates the ash accumulated to reach some depth and was then pressed by weight." It is unclear that obsidian is one of the main tempers; the most common form of volcanic ash is rhyolite, dacite, and other morphologies. These are characteristic of fine-grained volcanic igneous rocks that solidified from magma and cooled rapidly (rhyolite, andesite, basalt and trachyte) (Reedy, 2008: 9). Pumice and tuff are also quite common. The former is fine-grained with a frothy or foamy texture (Reedy, 2008: 10). Tuff, and in particular welded tuff, are sometimes called ignimbrites (Reedy, 2008: 11). These temper and aplastic inclusions are available locally at settlements across Armenia (Table 3.1).

3.5.2 Pottery forming methods

Forming techniques from small fragments are difficult to interpret as part of the *chaîne opératoire* process; due to the incomplete size of sherds, voids and inclusion alignment were recorded in order to make inferences on forming methods (slab-building, paddle/anvil, coiling, pinching and drawing; wheel-thrown, etc.; see Rice, 2015). Coiling was the principal primary forming method macroscopically and microscopically visible through thin-section analyses (Quinn, 2013). Coil joins and relic coils between 5-20 mm wide were identified in seven fabrics at four KA settlements (Gegharot, Margahovit, Mokhra-Blur, and Shengavit). Coils were identified mainly in medium-grained fabrics.

Other pottery forming techniques were suggested in the results section of Chapter 3.4. For instance, based on the randomly oriented inclusions, it is possible to suggest that almost all KA vessels examined are hand-built, without a wheel. However, further examination into whole vessels on-site should complement these interpretations. Macro-traces can provide exorbitant information on such manufacturing processes. The inclusions which appeared directional are most likely associated with slab-building, as the clay is drawn upwards (Quinn, 2013).

The application of a slip (additional layer of clay) is evident at some of the settlements; for example, at Shengavit, Gegharot[7], Talin Tombs[8], Margahovit[9] and few at Mokhra-Blur. However, through further SEM-EDS analyses in Section 3.4, the clay composition and surface of clay with a clear slip indicate similar chemistry. Slipped sherds were only recorded at Shengavit, as Mokhra-Blur and Norabak-1 black-burnished fine-wares did not exhibit slips.

3.5.3 Firing

Based on the macroscopic analyses (Figure 3.1), it is possible to suggest that the firing technology was variable (oxidised and irregularly fired) and that a reduced environment was preferred for the black-burnished vessels, in order to achieve a grey/black surface. While not all vessels were fired to achieve this, the bulk of the potsherds from each site are associated with this type of firing regimen. As kilns are absent in the archaeological record at EBA Kura-Araxes settlements (see background on KA archaeological context – Chapter 1), it is possible that potters were pit-firing or producing small-scale bonfires (discussed in Chapter 5).

Very few fabrics were labelled as ‘slightly’ calcareous clays: Fabric 1 and 2 at Talin Tombs, Fabric 3 at Mokhra-Blur, and Fabric 4 at Shengavit. They vary in terms of grain-size and inclusions are variable as well, but the fabrics at Mokra-Blur and Shengavit are classified with aplastic inclusions of sandstones; limestone and other carbonates are most likely present in the clay. However, lime spalling can be prevented by achieving a reducing atmosphere (Rice, 2015: 81), and this is most likely a step followed by KA potters.

The variability of firing across the entire assemblage studied here in (Sections 3.1 and 3.2) suggests that this step of the *chaîne opératoire* was conducted without the use of kilns. There is a discontinuation of firing atmospheres (irregularly fired, oxidised and unoxidised).

[7] Potsherd sample G19
[8] Potsherd samples T2 and T8
[9] Potsherd samples MG10 and MG22

The oxygen flow and temperature control are not necessarily regulated by KA potters. Further studies on mineralogical and chemical analyses can provide estimates regarding firing temperatures. Smudging (applying organic matter on pots to prevent oxygen flow) or other organic features (Rice, 2015: 117) were not evident on the studied assemblage here. This means that the surface treatment is most likely pre- or post-firing treatment (Lepère, 2014; Bonilla *et al.*, 2020; Ionescu and Hoeck, 2020).

3.5.4 Surface treatment

The quality of burnish allows archaeologists to interpret practical skills required to obtain such attractive and highly functional pottery (Ionescu and Hoeck, 2020). Once the vessel is formed and leather-hard, potters most likely scraped the interior and exterior surface of vessels (burnish is also visible interior of vessels), using a tool, as striations on sherds are visible via stereomicroscopy. Based on experimental archaeological studies published recently over the past decade, burnishing is most likely completed using various tools, such as rocks (pebbles) (Lepère, 2014). All potsherds analysed via SEM-EDS displayed a similar composition between the surface clay and the body, both visually and chemically. It is possible to conclude that the black-burnished samples were not slipped with an organic material (Section 3.4). Although a few samples displayed a slight enrichment in potassium (Norabak-1; Table 3.38), it is not enough to suggest a human-made component, as such enrichment can be due to post-depositional activity (Maritan, 2020).

The surface finish presents a significantly high-gloss finish, as exemplified in Figure 3.3. Experimental archaeological work suggests that high burnishing can be attained when pots are leather-hard, using various tools (Lepère, 2014; Bonilla *et al.*, 2020; Ionescu and Hoeck, 2020). Lepère (2014) noted differences between 'soft leather-hard', 'stiff leather-hard', and 'bone-dry' stages within the burnishing technique (Figure 3.46).

3. 46. (a) Soft leather-hard and (b) stiff leather-hard paste, reproduced from Lepère (2014: 147, Figure 2).

Striations have been recorded on pottery, visible only under high magnifications. Given the alignment of inclusions in SEM and thin-section photomicrographs, it is possible to suggest a 'compact' burnished surface, when compared with published data (Ionescu and Hoeck, 2020). Some potsherds appear highly metallic, suggesting hard tools (i.e., pebbles); oftentimes, broken potsherds have been recorded as abrading tools in various case studies, such as use-wear analysis of Neolithic ceramic tools from Bulgaria (Vieugué, 2015: 98). The patterns of burnishing in all KA potsherds depicts linear lines in motion. Based on Ionescu and Hoeck (2020), the burnishing features recorded macroscopically agree with the features of hand-burnishing (Ionesco and Hoeck, 2020; Table 3.39). Most KA vessels are described with a homogeneous burnished surface, depicting luster and quality. The BSE images in this Chapter (Section 3.4) are indicative of burnished as opposed to smoothed surfaces. Even and compact layers appear brighter on back scattered electron images (Ionescu and Hoeck, 2020). Furthermore, isotropic spinel-like phases are evident across some potsherds, identified through thin-section petrography (see Section 3.3.6 – Margahovit, Fabric 5). These layers are indicative of burnishing peels, which act as a "barrier for oxygen and favour reducing conditions in the ceramic's core and eventually lead to the formation of Fe(III)-phases" (Ionescu and Hoeck, 2020: 9). Based on the intensity of the shine and the surface flaws (including the traces left by the implements), burnishing quality was intensely practiced for KA vessels, suggesting (1) hand-burnishing, (2) plain-, linear- and pattern-burnishes in terms of style, and (3) medium to high-burnishing quality (Table 3.39).

Table 3. 39. Adapted from Ionescu and Hoeck, 2020: 4, Table 3). The common burnishing features associated with KA vessels.

Criteria	**Term**	**Main features**
Procedure	**Hand-burnishing**	- Generally low to medium gloss - Homogeneity on restricted areas - Short burnishing streaks - Random orientation of the burnishing streaks
Style	**Plain-burnish**	- Covers the whole surface or large areas
	Linear-burnish	- Singular, or group of a few straight or curved (including spiral) lines Combined with smoothed areas
	Pattern-burnish	- Straight or curved lines composing various patterns e.g., network, zig-zag, hatches, floral, geometric, etc. - Combined with smoothed areas
Quality	**Medium-burnish (average-burnish)**	- Average gloss - Reflections with burred margins - Areas of high or low gloss, mixed - Visible but rare traces (scratches, ridges) left by the burnisher along the streak - Short streaks left by lifting of the burnisher during rotation - Flaws (pits and scratches) on large parts of the burnished areas - Rare smoothing striations popping out of the burnished surface
	High-burnish (good-burnish)	- Bright, mirror-like gloss - Reflections with sharp margins - No visible or extremely rare traces of burnisher streaks - Virtually flawless surface, with scarce pits and scratches

3.6 Conclusion

This chapter presented results of macroscopic and microscopic analyses of KA pottery undertaken as part of this project and discussed the main *chaîne opératoire* elements of pottery production at the sites examined. It introduced the potsherds analysed, the analytical procedure undertaken, and discussed the findings. Findings reported here emphasise the importance of thin-section petrography in combination with other complementary methods to define pottery traditions and understand choices potters made in order to produce the Kura-Araxes vessels, as well as reconstruct the *chaîne opératoires*. Significant features of forming methods, raw material processing, and paste preparation were recorded. Where possible, provenance was suggested. Of particular importance was pointing the broad and diverse technological traditions within each settlement, indicating the presence of various fabrics, surface treatments and firing procedures. Moreover, these findings suggest there is some technological similarity and variability among KA settlements, further discussed in Chapter 5.

Despite the fact that obsidian appears to be suggested as temper across various petrographically studied reported in this region (Palumbi *et al.*, 2014; Hovsepyan and Mnatsakanyan, 2011; Hayrapetyan, 2008; Hovsepyan, 2014), this dataset did not report obsidian as a 'primary' temper source. While potsherds contained inclusions characteristic of volcanic glass and ash (rhyolite, dacite, etc.) the absence of obsidian inclusions suggests that it is not a main KA technological marker (temper). The primary temper and aplastic inclusion of interest concern various morphologies of volcanic ash and igneous rock fragments.

In order to make inferences on pottery production, resource procurement, technological innovation, social organisation and other factors in reconstructing potting communities as well as the overall socio-economic structure of settlements, it is imperative to examine pottery through a multi-analytical approach. Limitations in this study imply the importance of understanding the overall geology of the region, as well as the clay availability within the studied settlements and beyond. Future studies can embark on a thorough study of the local clay in order to compare and contrast the petrographic findings reported here, as well as published data from other neighbouring coeval settlements.

CHAPTER 4

Lipid Residue Analysis of Kura-Araxes Pottery: Dietary, Culinary, and Pottery Use Inferences

4.1 Introduction

The absorbed lipid residues embedded in archaeological pottery provide invaluable information pertaining to the life history of vessels, specifically on vessel use through the identification of various commodities, including terrestrial and aquatic fats, plants, waxes, tars and resins (Table 4.1; see Chapter 2 – Table 2.2). Lipid residue analysis of archaeological potsherds has become an essential tool to investigate direct evidence of production, trade, subsistence, food processing and dietary inferences (Evershed, 2008; Roffet-Salque *et al.*, 2017). More specifically, absorbed lipid residues can also provide direct evidence of diet and culinary practices, specifically in identifying and differentiating non-ruminant, ruminant and aquatic fats. Extracted lipids can be radiocarbon dated (Casanova *et al.*, 2020a; Casanova *et al.*, 2020b) and analysed via gas chromatography (GC), GC-mass spectrometry (GC-MS) and GC-compound-isotope-ratio MS analysis (GC-C-IRMS), to differentiate between ruminant and non-ruminant adipose fats. Ruminant dairy fats are distinguished from the carcass fats due to biosynthetic differences between the major fatty acids (Evershed, 2008; Roffet-Salque *et al.*, 2017; Dudd and Evershed, 1998; Evershed *et al.*, 2002; Copley *et al.*, 2003; Copley *et al.*, 2005).

To date, dietary studies on Kura-Araxes inhabitants are lacking, with only a few studies on stable carbon isotopes of post-KA human and animal bones (post-KA: periods after EBA, which include the MBA and LBA covered in Chapters 1 and 2); as such, organic residue analyses regarding the EBA have not been conducted thus far. This chapter aims to build a detailed model for the subsistence patterns across coeval Kura-Araxes settlements in Armenia, by employing the lipid biomarker approach to determine the nature and origins of organic residues preserved in the fabric of pottery vessels. Results presented here will be discussed in Section 4.5, and alongside archaeological information from other KA sites in Chapter 5.

Table 4. 1. Commodities of interest in organic residue analysis investigations.

Commodities of interest	**References**
Terrestrial animal fats	Evershed *et al*., 2002
Resins and tars	Charters *et al*., 1993; Urem-Kotsou *et al*., 2002; Rageot *et al*., 2015; Rageot *et al*., 2019; Regert, 2004
Beeswax	Evershed *et al*., 1997; Charters *et al*., 1995; Evershed *et al*., 2003; Heron *et al*., 1994; Roffet-Salque *et al*., 2015; Dunne *et al*., 2021
Plant products	Reber and Evershed, 2004; Stern *et al*., 2003; Colonese *et al*., 2017; Dunne *et al*., 2016; Dunne, 2021; Heron *et al*., 2016
Aquatic biomarkers	Copley *et al*., 2004; Cramp and Evershed, 2014; Cramp *et al*., 2014a; 2014b; 2019; Hansel *et al*., 2011; Lucquin *et al*., 2016; Shoda *et al*., 2017; Admiraal *et al*., 2020; Bondetti *et al*., 2020

4.2 Aims and Objectives

The onset of the EBA denotes the start of a cultural phenomenon described by a ‘material cultural package’, yet little is known about the relationships between the EBA people and their natural environment, including food resources and culinary practices. Scholars claim that KA communities are characterised as non-hierarchical (Sagona, 2018; Alizadeh *et al.*, 2018; Samei and Alizadeh, 2020). The structure of these communities is rather unknown, in terms of the dietary inferences. Diet and cuisine are a driving force of the development of cultural and social values within societies (Wilkinson, 2014b; Kerner *et al.*, 2015; Hastorf, 2017). As mentioned in Chapter 1, zooarchaeological research to date suggests that the KA subsistence economy is based on secondary products (Summers, 2014; Wilkinson, 2014b; Greenfield, 2010), agricultural resources (Hovsepyan, 2015), and wine production (Batiuk, 2013). Movement of communities and groups suggests that subsistence practices appear to be based on transhumant pastoralism (Piro and Crabtree, 2017; Hammer and Arbuckle, 2017; Arbuckle and Hammer, 2018) although a dearth of zooarchaeological data has precluded direct isotope analysis of animal bones (Chazin *et al*., 2019; Herrscher *et al.*, 2018). A vast and previously unexplored archaeological area, lipid residue analysis of KA pottery can enhance our understanding of cultural human behaviour, as food traditions are culturally intrinsic (Hastorf, 2017; Evershed, 2008). Moreover, investigating whether KA vessels were used for dairy products can contribute to our understanding of dairying in the region compared to other regional areas in the Ancient Near East and Eurasia (Sherratt, 1983; Jeong *et al.*, 2018; Warinner *et al.*, 2014; Wilkin *et al.*, 2020; 2021). Questions pertaining to this culture's social organisation, overall economy, pottery production and use, are still extensively discussed (Sagona, 2018; Smith, 2005; Rothman, 2015).

Scholars claim that the KA is built on a distinct cultural identity (Kushnareva, 1997; Sagona, 2018; Rothman, 2015) but whether this identity translates to dietary and cuisine-based practices remains to be established. If the KA was a homogeneous cultural phenomenon, it is likely that lipid residue analysis will provide corroborating evidence of a uniform diet, as culinary practices are culturally intrinsic (Kerner *et al.*, 2015; Hastorf, 2017). These results hold implications for understanding the socio-economic structure of Kura-Araxes communities.

Based on the research questions set out in Chapter 1, the specific aims of this chapter are:

1. To reconstruct diet and culinary practices spatially across coeval EBA Kura-Araxes settlements by performing molecular and isotopic analyses on absorbed lipid residues.
2. To investigate what Kura-Araxes vessels were used for—primary or secondary production?
3. To determine whether aquatic commodities contributed to the diets of inhabitants of settlements close to the river-beds and estuarine environment (and Lake Sevan) through

the analysis of aquatic biomarkers from absorbed lipid residues in KA pottery (APAAs, IFAs and dihydroxy fatty acids).

4. To investigate the interactions of humans with their environment through evidence of plant exploitation.
5. To investigate whether 'burnished' vessels were used for the consumption, cooking and processing of commodities.
6. To assess any observed changes or continuity in subsistence patterns spatially across Kura-Araxes settlements.

The following hypotheses will be tested:

1. The $\delta^{13}C$ values of lipid residues will reflect a consistently C_3 terrestrial diet throughout the EBA Armenia (as attested by archaeobotanical evidence; Hovsepyan, 2015; Herrscher *et al.*, 2018; Martin *et al.*, 2021).
2. Analysis of organic residues in pottery vessels will indicate that dairying was intensively practiced during the EBA.
3. Biomarkers deriving from the exploitation of aquatic resources will be detected in lipid residues in pottery from most settlements near rivers and Lake Sevan (Sotk-2, Gegharot, Karnut-1, Shengavit, and Mokhra-Blur).
4. Similar subsistence practices will be observed across KA sites, given the similar archaeobotanical and zooarchaeological profiles, including the homogeneous 'material culture package' .

To achieve this task, 164 potsherds from seven sites have been investigated using the lipid biomarker approach involving GC, GC-MS and GC-C-IRMS to determine the nature and origins of organic residues preserved in the fabric of pottery vessels (Table 4.2). Full details of the potsherd samples are available in Appendix D (Tables 1 and 2), and the analytical protocols are outlined in Chapter 2. Comparative archaeozoological and archaeobotanical data alongside lipid residue results provide an imperative lens into the socio-economic lifestyle of prehistoric populations attested in various studies (Roffet-Salque *et al.*, 2017). The extent of agricultural consumption, ruminant, non-ruminant meat, and dairy production in the context of KA communities, is not known to date (Wilkinson, 2014b).

4.3 Materials and methods

Lipid residue analysis of ceramic-related materials is increasing in application in archaeological research. It is mainly used to determine the nature and origins of organic residues preserved in the fabric of pottery vessels. While charred deposits can be analysed, this thesis specifically focuses on the absorbed lipid residues, due to the overall multiple cooking events recorded through the analysis of absorbed residues (Miller *et al.*, 2020). Miller *et al.*, (2020) state that charred residues represent a single cooking event and absorbed residues represent the combination of multiple cooking events. Where possible, rim and upper body sherds from cooking vessels were selected for analysis, due to the high concentration of fatty acid lipids (Charters *et al.*, 1993). Cooking pots were recognised through the presence of sooting clouds on sherds (burnt areas), which indicate the use of fire and heating (Rice, 1987: 235-236).

4.2.1 Archaeological sites and pottery information

As mentioned in Chapter 2, potsherds were selected based on three factors; (1) rim profile availability, (2) sooting and presence of possible burning to high temperatures, indicative of cooking, and (3) large enough samples to cover both microscopy and organic residue analyses. Minor traces of sooting patterns are visible on a small subset of samples (i.e., potsherd MB12). Systematically, cooking wares are identified as unburnished wares, often identified as 'grit'-tempered sherds (see Palumbi *et al.*, 2014). However, this thesis investigates both unburnished and burnished vessels to determine the function of KA pottery. As mentioned in Chapter 3 (Figure 3.1), black-burnished vessels are prevalent across the Kura-Araxes assemblage and their direct function is unknown. Vessels are most likely medium-sized and open shaped (see Chapter 2).

Petrographic analyses assessed in Chapter 3 confirm local household production, indicating that the findings reported here represent local subsistence practices and dietary implications. Apart from one non-local sherd from Shengavit (potsherd SH48), KA pottery appears to be a symbolic local commodity serving local functions. As described in Chapter 3, Section 3.4 (petrographic analyses), potters from each settlement preferred various raw materials to produce the black-burnished wares.

All potsherds were analysed using the methodological framework outlined in Chapter 2, using the acidified methanolic extraction method (Correa-Ascencio and Evershed, 2014).

Table 4. 2. Pottery sherds chosen for organic residue analysis. KA phase I extends from 3600/3500-2900 BCE, while KA phase II ranges from 2900-2600/2500 BCE (Badalyan, 2014).

Site name	Period; ^{14}C radiocarbon dates	Total (out of 164 potsherds)	Rim and body	Body	Body and base	Base
Gegharot	KA I-II	35	20	15	0	0
Karnut-1	KA II	30	1	28	0	1
Margahovit	KA II	30	13	10	5	2
Mokhra-Blur	KA I-II?	13	12	0	0	1
Shengavit	KA I-II	48	32	11	5	0
Sotk-2	KA I-II?	4	2	0	1	1
Talin Tombs	KA I	4	4	0	0	0

4.3 Overall results

4.3.1 Lipid preservation overall and compound-specific stable isotopic results

The archaeological sites studied here reflect varied topographical terrains (i.e., mountainous and lowland zones in the Republic of Armenia, South Caucasus) and have been selected based on the ‘core’ KA cultural area, availability of well-contextualised potsherds spanning a wide array of pottery types and chronological data (Appendix D; Table 4.2). These settlements reflect a range of different environments, due to the nature of topography and altitude (Appendix D). A suite of different lipid classes was detected within the pottery vessels, the most abundant of which were degraded animal fats in the form of saturated fatty acids. Other lipid classes detected comprise aliphatic lipids including *n*-alkanes, α,ω-dicarboxylic acids, and *n*-alcohols. A summary of lipids detected is given in Table 4.3 and Appendix D. Analyses yielded interpretable lipid concentrations (>5 $\mu g\ g^{-1}$) from 91.5% of 164 sampled potsherds (Figure 4.1). Lipid preservation was remarkably high for all the sites examined, specifically at Mokhra-Blur (100%, *n*=13), Talin Tombs (100%, *n*=4) and Sotk-2 (100%, *n*=4) where all sherds sampled yielded lipids, and still quite high at the sites of Margahovit (73%, *n*=22), Karnut-1 (60%, *n*=18), Shengavit (66%, *n*=32), and Gegharot (61%, *n*=22) (Table 4.3). While the sample sizes for Sotk-2 and Talin Tombs are low, these sites will be discussed in combination with all sites to cover overall trends. Of these, the average concentration of extracted lipids was 244.3 mg g^{-1}, the highest being 3384.9 mg g^{-1}. A total of 115 (70.2%) sherds across all sites contained sufficient lipids for compound-specific isotopic analysis.

The percentage of animal products reported here are calculated based on the potsherds with compound-specific stable isotopic data. The compound-specific results were calculated based on the equations in Section 2.4 – 2.5.5.3. For all plots, $\delta^{13}C$ and $\Delta^{13}C$, the values of reference fats are represented by confidence ellipses (± 1σ) for animals raised on a strict C_3

diet, where the three annotated fields correspond to P = 0.684 confidence ellipses relating to modern fats (C_3 diet) in Britain (Copley *et al.*, 2003). All $\delta^{13}C$ values were adjusted for post-Industrial Revolution effects of fossil fuel burning by the addition of 1.2 ‰ (Friedli *et al.*, 1986). Ranges depicted in the $\delta^{13}C$ and $\Delta^{13}C$ plots represent the mean ($\pm 1\sigma$) of $\Delta^{13}C$ values for a global database published elsewhere comprising modern reference animal fats from various geographical settings that include Africa (Dunne *et al.*, 2012), UK (Dudd and Evershed, 1998), Kazakhstan (Outram *et al.*, 2009), Switzerland (Spangenberg *et al.*, 2006), and the Middle East (Gregg *et al.*, 2009).

Table 4. 3. Summary of occurrence of lipid classes detected in pottery vessels at each site. Average lipid concentration of sherds containing a significant lipid concentration (>5 µg g^{-1} of potsherd). NRA = non-ruminant adipose, RA = ruminant adipose, RD = ruminant dairy. Aquatic resources include the co-occurrence of C_{18}, C_{20}, and C_{22} APAAs and/or isoprenoid fatty acids (TMTD, phytanic and pristanic acids).

Site	% lipid recovery	Av. Lipid concentration (µg g^{-1})	Animal resources			Aquatic resources	Plant resources
			NRA	RA	RD		Aliphatic lipids
Shengavit	94	317.4	3	25	4	3	10
Mokhra-Blur	100	291.1	0	9	4	1	5
Margahovit	90	45.0	1	14	7	4	9
Gegharot	77	305.2	0	10	12	1	2
Karnut-1	100	95.3	10	4	4	0	6?
Talin Tombs	100	262.1	0	1	3	0	0
Sotk-2	100	116.9	0	2	2	0	2?

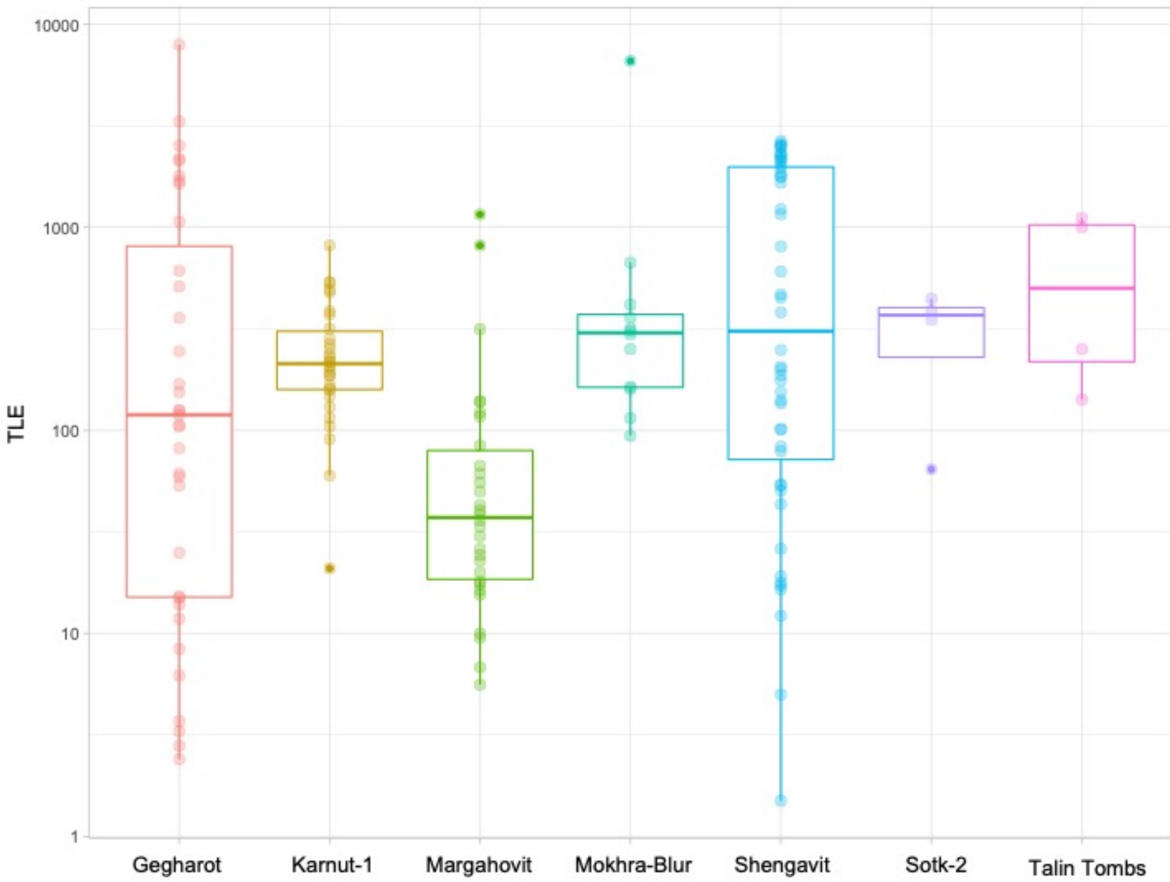


Figure 4. 1. Box plot of total lipid extract (TLE) concentration from each archaeological site (log10 scale), exhibiting the nature of lipids preserved in archaeological vessels.

4.3.2 Blank potsherds and contamination

Extracts with absolutely no lipids and contaminated samples were low (n = 11). Extracts which yielded no residues are categorised as blanks (i.e., SH15, SH30 and SH37) and a typical chromatogram for these samples is exhibited in Figure 4.2b. Regular blanks were prepared alongside potsherd batches to determine any contaminants in the extraction process (Figure 4.2a). Additionally, extracts with contamination (i.e., phthalates) and low concentration of fatty acid methyl esters (FAMEs) were not submitted to compound-specific stable isotopic analyses (i.e., SH58, SHK6, SH112 and MG7; Figure 4.3).

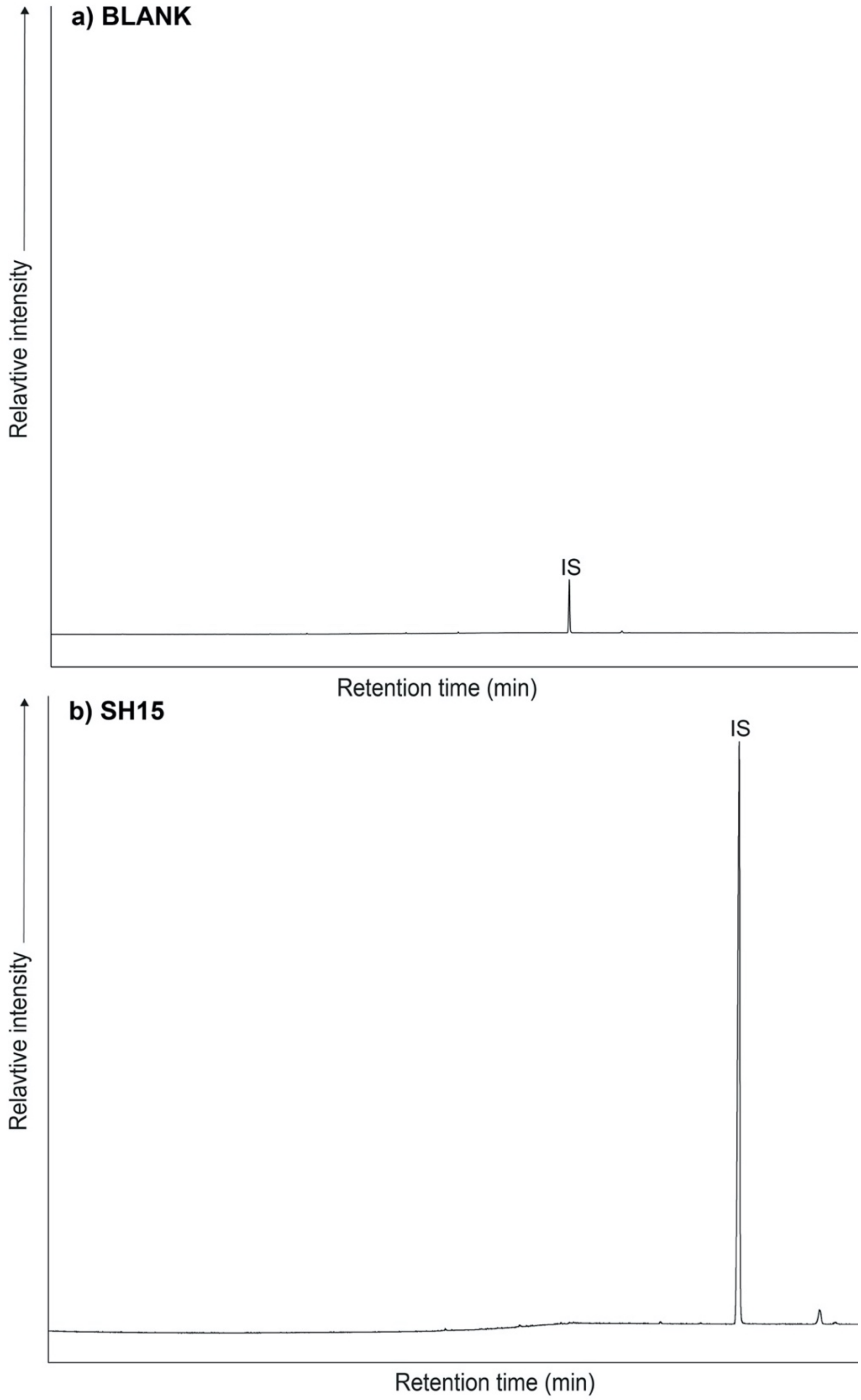


Figure 4. 2. (a) Full GC profile of an analytical blank extract prepared in batch; (b) Partial GC profile of potsherd SH15 (Shengavit), an extract labelled as blank with no residues detected. IS is the internal standard (C_{34} *n*-alkane).

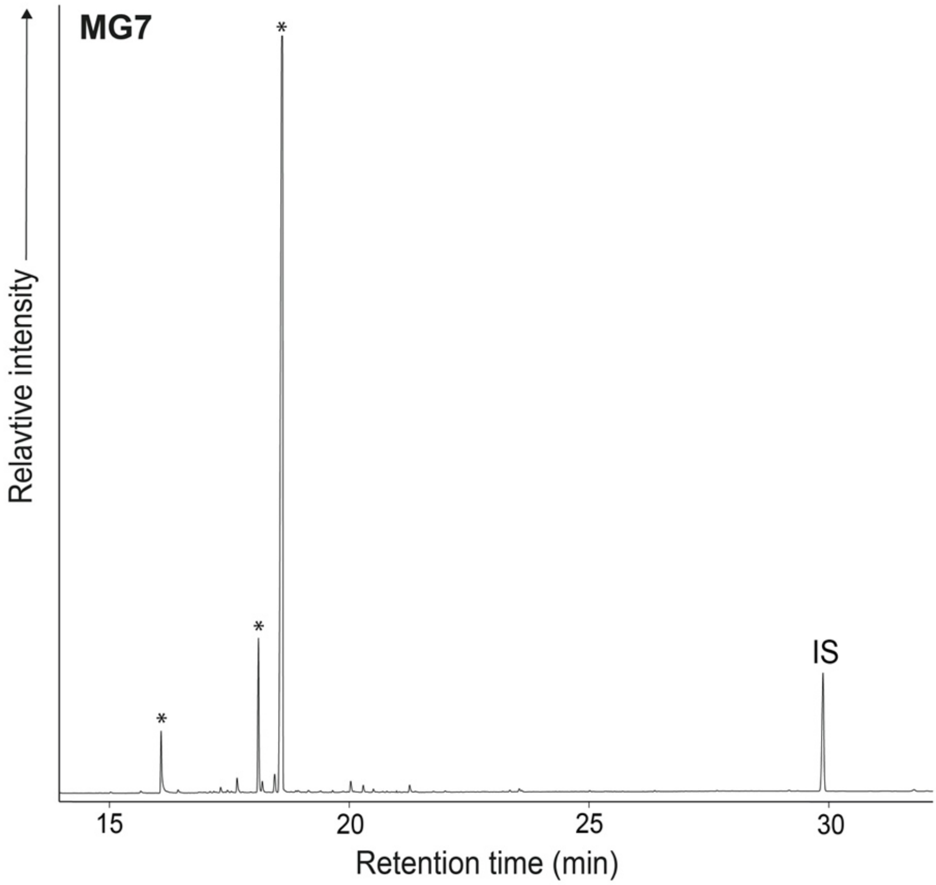


Figure 4. 3. Partial GC profile of an extract (MG7 from Margahovit) containing high concentrations of phthalates. IS is the internal standard (C_{34} *n*-alkane) and * denotes plasticiser contamination.

In addition to blanks and contaminated extracts, some extracts yielded sulfur, albeit in low in concentration (n = 13; G32, MG26, SH45, SH47, SH50, SH82, MB001, MB1 MB3, MB5, MB6, MB7 and MB10). Sulfur is indicative of waterlogging associated with microbial decay (Fors *et al.*, 2014; Monachon *et al.*, 2020). Furthermore, according to Pecci *et al.*, (2017: 54), it is possible that sulfur was applied as a waterproofing agent; however, further work is required to examine the prevalence of sulfur in archaeological potsherd extracts.

4.4 Results: site-by-site

The extracts from all sites were dominated by the free fatty acids, with palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$) as the most abundant components (refer to Table 4.3). A fewer number of extracts contained $C_{14:0}$ fatty acid. Long-chain monounsaturated fatty acids (> $C_{19:0}$)

were present across various extracts and sites as well. Furthermore, odd-carbon chain length saturated fatty acids (i.e., $C_{15:0}$ and $C_{17:0}$) were also present, including the straight and branched chain isomers (the latter recorded as C_{15}br and C_{17}br), which indicate the dominance of ruminant adipose fats (Evershed *et al.*, 1997).

4.4.1 Gegharot

The lipid residue recovery rate from the analysis of KA pottery from Gegharot was 77% of 35 sherds. The average concentration of lipids in the extracts was 305.2 µg g^{-1} with the highest concentration being 3384.8 µg g^{-1}. GC analysis of the extracts from Gegharot with significant concentrations of lipid (n = 22) demonstrates that the free fatty acids, palmitic (*n*-$C_{16:0}$) and stearic (*n*-$C_{18:0}$), are the most abundant components (Figure 4.4), including long-chain fatty acids (LCFAs, *n*-$C_{14:0}$ to *n*-$C_{30:0}$), odd-chained *n*-alkanes (C_{21} to C_{33}), even-chained *n*-alcohols (C_{16} to C_{30}), ω-hydroxy FAMEs (C_{20}, C_{22} and C_{24}) and hydroxy FAMEs (C_{24} to C_{26}), branched chain fatty acids (C_{17}) and occasional instances of unsaturated fatty acids ($C_{16:1}$, $C_{18:1}$, and $C_{22:1}$). Long-chain fatty acids (LCFA) up to *n*-$C_{30:0}$ in chain-length were identified in most potsherds from Gegharot (n = 11; G10, G11, G15, G19, G21, G22, G24, G26, G31, G32, and G35). Diacids (α,ω-dicarboxylic acids: C_{16}, C_{18}, C_{20}, C_{22}, C_{24}) were common in some potsherds (G11, G28, and G32).

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(*o*-alkylphenyl) alkanoic acids (APAAs) and other aquatic biomarkers, isoprenoid fatty acids (IFAs) and dihydroxy fatty acids. Only one potsherd (G31, Figure 4.4) yielded isoprenoid fatty acids. No APAAs were detected.

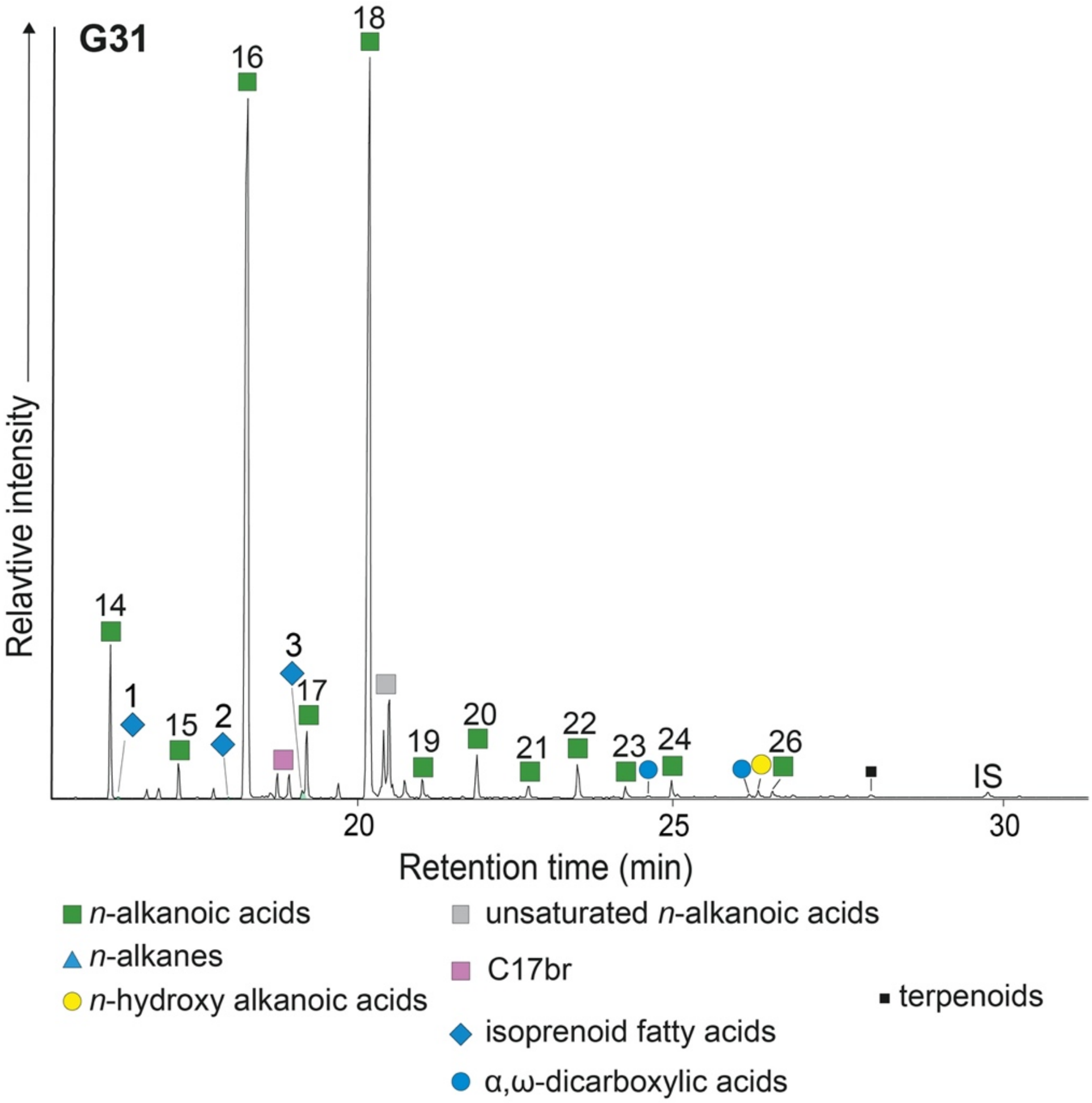


Figure 4. 4. Partial GC-MS chromatogram from Gegharot (G31) classified as a dairy residue with isoprenoid fatty acids, labelled blue triangles: (1) 4,8,12-trimethyltridecanoic acid (TMTD), (2) pristanic and (3) phytanic acids; IS is the internal standard, C_{34} *n*-tetratriacontane.

Plant biomarkers were detected in two extracts (G28 and G31), corresponding to terpenoids discussed in Section 4.4.2.2. Long-chain ketones (C_{29}, C_{31} and C_{33}) were present in two potsherds, G24 and G29 (Figure 4.5). Due to the presence of *n*-hydroxy alkanoic acids and *n*-alcohols, the presence of ketones is most likely to have derived from epicuticular leaf waxes (Evershed *et al.*, 1995; Raven *et al.*, 1997; Whelton *et al.*, 2021). Additionally, the $\delta^{13}C$ value of ketone C_{33} (-20.6 ‰) is enriched compared to the major fatty acids (Evershed *et al.*, 1995).

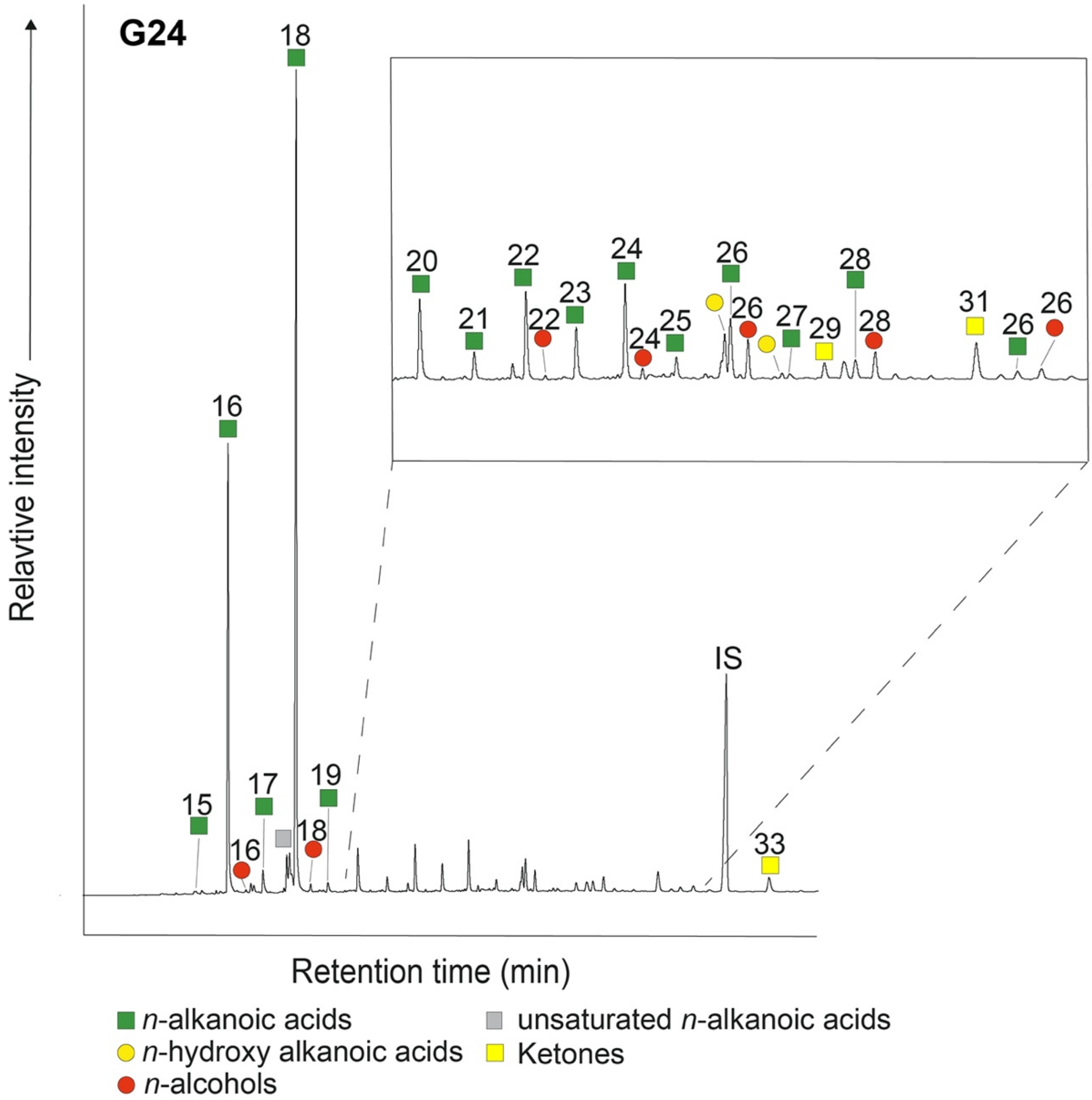


Figure 4. 5. Partial GC chromatogram from Gegharot (G24) classified as a dairy residue with ketones (C_{29}, C_{31} and C_{33}). The $\delta^{13}C$ value of Ketone C_{33} is -20.6 ‰. The major fatty acids exhibit $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values of 24.2 ‰ and 25.3 ‰. IS is the internal standard, C_{34} *n*-tetratriacontane.

Compound-specific stable carbon isotope analyses for the free fatty acids *n*-$C_{16:0}$ and *n*-$C_{18:0}$ were conducted to identify the origin of the animal fats recovered. Extracts with biomarkers indicating a mixture of plant and animal lipids are labelled. The $\delta^{13}C_{16:0}$ values range between -24.2 ‰ and -27.5 ‰. The $\Delta^{13}C$ values ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:}$) show that the majority of the extracts plot with the ranges expected for a ruminant dairy input (55%; Figure 4.6). The remaining extracts plot in the range for ruminant adipose fats (45%). Percentage calculations are calculated based on the number of potsherds submitted to compound-specific stable carbon isotope analyses.

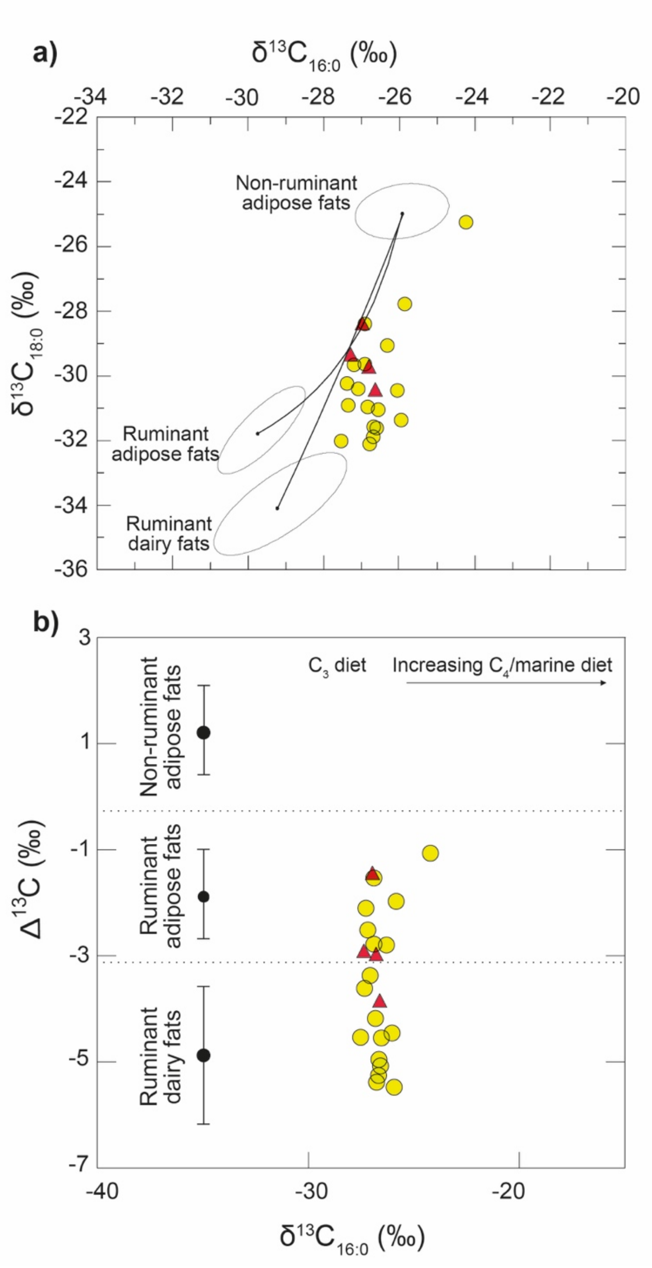


Figure 4. 6. (a) $\delta^{13}C$ values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Gegharot. (b) The difference in the $\delta^{13}C$ values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Red triangle symbols represent TLEs with evidence of plant processing with CPI values >2. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.2 Karnut-1

The lipid residue recovery rate from the analysis of KA pottery from Karnut-1 was 100% of 30 sherds. The average concentration of lipids in the extracts was 95.3 µg g^{-1} with the highest concentration being 296.7 µg g^{-1}. GC analysis of the extracts from Karnut-1 with significant concentrations of lipid (n = 18) demonstrates that the free fatty acids, palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$) are the most abundant components (Figure 4.7). LCFAs are common up to n-$C_{26:0}$, and even-chained fatty acids, n-$C_{16:0}$ to n-$C_{30:0}$. Hydroxy FAMEs of C_{23} and C_{24} are also common in most extracts. Unsaturated components ($C_{16:1}$ and $C_{18:1}$) are present in the extracts as well in high abundance; these potsherds were sampled directly in the field, and thus contamination is not caused by overtime or post-excavation handling. Branched chain fatty acids such as C_{15} and C_{17} have been reported in most extracts as well. In fewer extracts, odd-chained *n*-alkanes, *n*-alcohols, and hydroxy FAMEs (C_{23} to C_{25}) have been reported as well.

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(*o*-alkylphenyl) alkanoic acids (APAAs) and other aquatic biomarkers (IFAs and dihydroxy fatty acids). No IFAs, APAAs or dihydroxy fatty acids were detected.

Plant exploitation at Karnut-1 is dominated by one potsherd (KRT35), exhibiting the common triterpenoids corresponding to birch bark tar production. Diterpenoids are present in ten extracts, but in negligible amounts as dehydroabietic acid (KRT55, KRT57, KRT58, KRT59, KRT60, KRT61, KRT62, KRT63, KRT65 and KRT66). However, dehydroabietic acid alone is not a definitive marker for pine resin (Mills and White, 1994; Whelton *et al.*, 2021). Pine resin is identified through the presence of diterpenoid components such as abietic acid, dehydroabietic acid, primaric and isopimaric acids (Pollard and Heron, 2008; Reber and Hart, 2008). All potsherds exhibiting plant products were also dominated by a mixture of animal fats.

Furthermore, the P/S (palmitic/stearic) ratio is calculated for six extracts due to the low stearic n-$C_{18:0}$ fatty acid depicting some plant input (Table 4.4). Potsherd KRT64 extract is dominated by n-alkanes maximising at C_{29} carbon chain length.

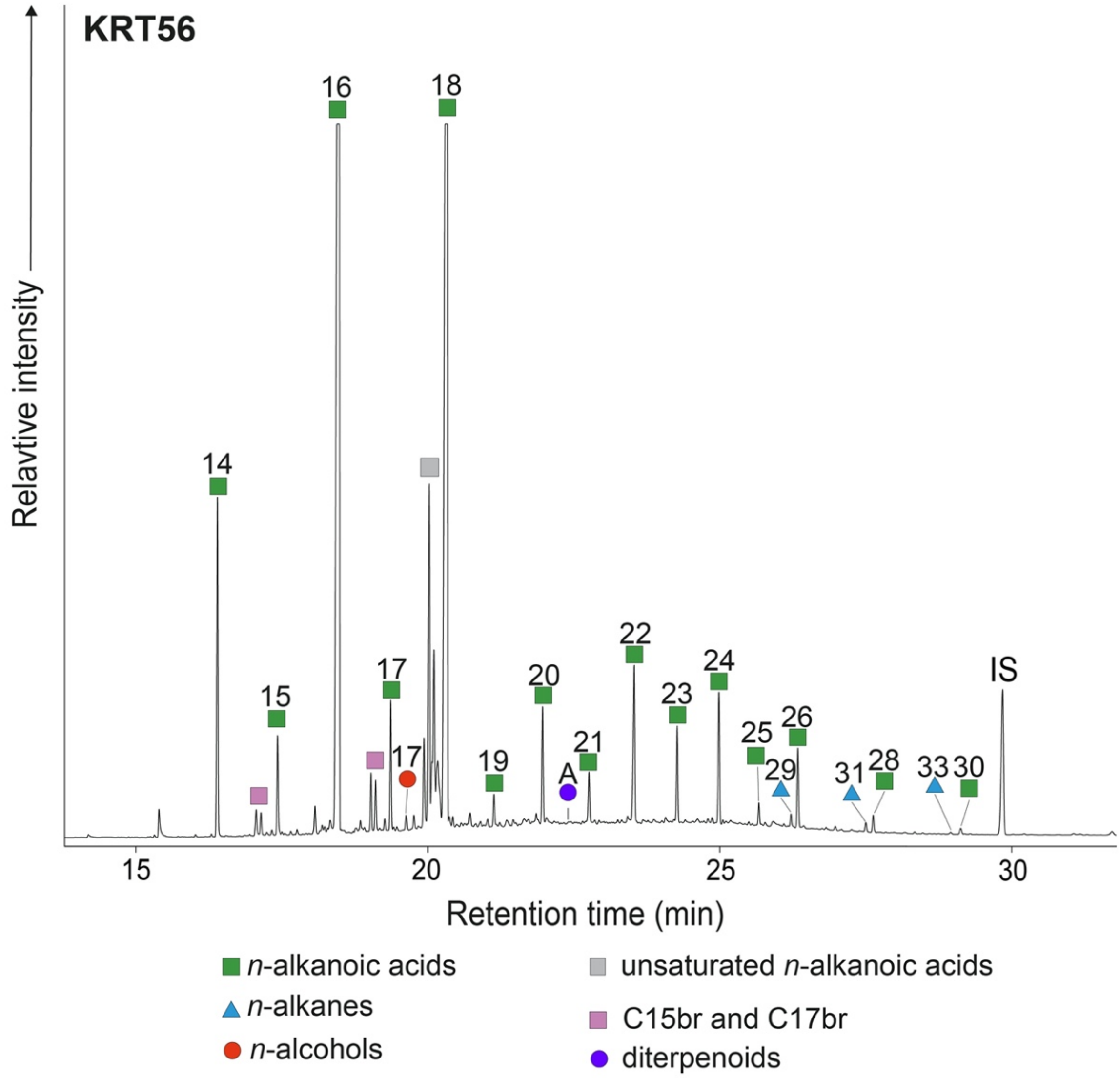


Figure 4. 7. Partial GC chromatogram from Karnut-1 (KRT56) classified as a dairy residue; diterpenoid (A) corresponds to dehydroabietic acid. IS is the internal standard, C_{34} n-tetratriacontane.

While lipid residues were yielded for all sherds sampled, only 18 potsherds were submitted to compound-specific isotopic analyses. The $\delta^{13}C_{16:0}$ values range between -26.6 ‰ and -28.4 ‰, and plot near the mixing lines (Figure 4.8a). The $\Delta^{13}C$ values show that the majority of the extracts plot within the non-ruminant adipose ranges, 55% of the potsherds analysed (Figure 4.8b). The rest of the extracts plot within the ruminant dairy input (22%) and ruminant adipose fats (22%).

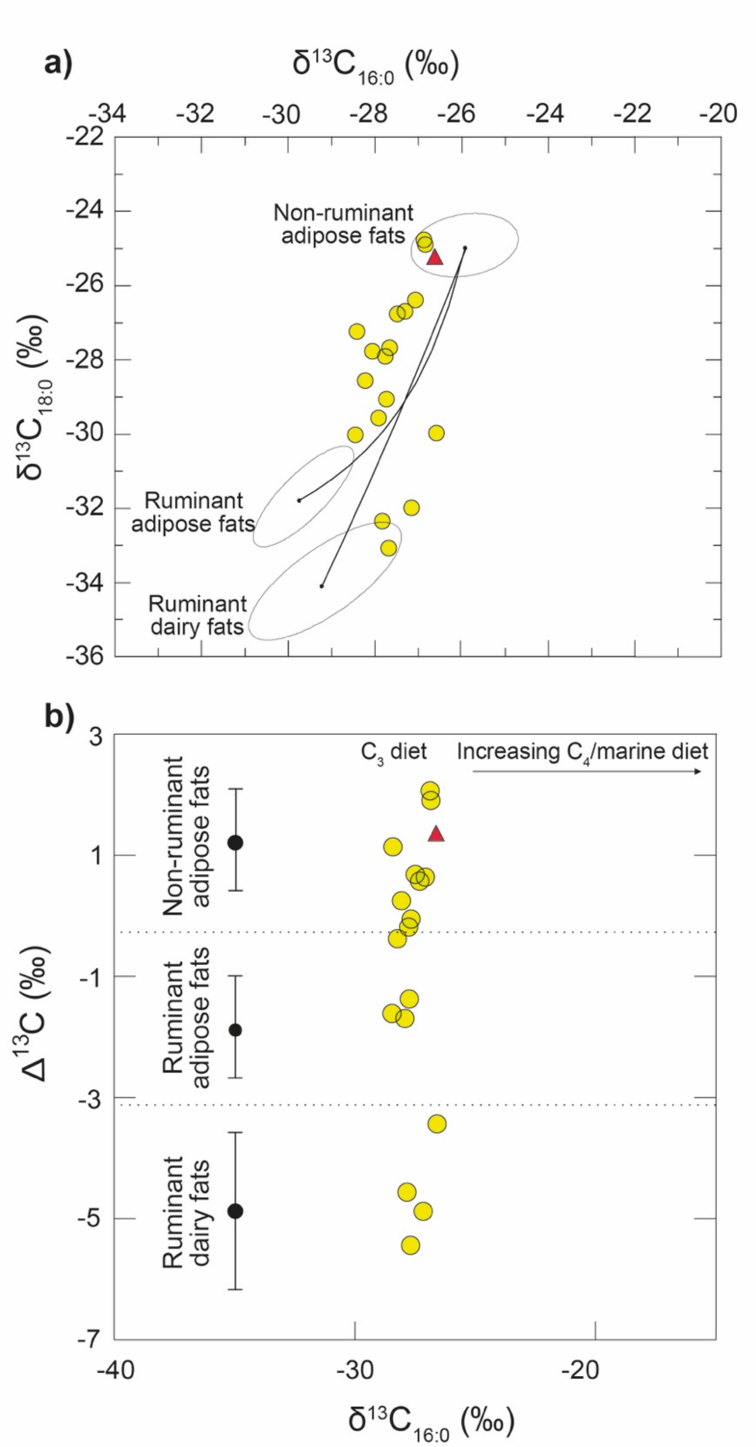


Figure 4. 8. (a) $\delta^{13}C$ values for the major fatty acid components (*n*-$C_{16:0}$ and *n*-$C_{18:0}$) prepared from lipid extracts from Karnut-1. (b) The difference in the $\delta^{13}C$ values of the *n*-$C_{18:0}$ and *n*-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the *n*-$C_{16:0}$ and *n*-$C_{18:0}$ fatty acids. Red triangle symbols represent TLEs with evidence of plant processing with CPI values >2. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.3 Margahovit

The lipid residue recovery rate from the analysis of KA pottery from Margahovit was 100% of 30 sherds. The average concentration of lipids in the extracts was 45.0 μg g^{-1} with the highest concentration being 431.5 μg g^{-1}. GC analysis of the extracts from Margahovit with significant concentrations of lipid (n = 22) demonstrates that the free fatty acids, palmitic (*n*-$C_{16:0}$) and stearic (*n*-$C_{18:0}$), are the most abundant components (Figure 4.9). FAMEs include *n*-$C_{14:0}$ to *n*-$C_{26:0}$, and *n*-$C_{28:0}$. For potsherd MG9, *n*-$C_{12:0}$ to *n*-$C_{14:0}$ FAMEs are also present. Other components include branched chain fatty acids (C_{15} and C_{17}), unsaturated fatty acids ($C_{16:1}$ and $C_{18:1}$), ω-hydroxy FAMEs (C_{22}), and *n*-hydroxy FAMEs (C_{15}, C_{16}, C_{20}, C_{24}). Other components of plant lipids are common in this assemblage (*n*-alkanes, *n*-alcohols, α,ω-dicarboxylic acids, and terpenoids).

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of *ω*-(*o*-alkylphenyl) alkanoic acids (APAAs) and other aquatic biomarkers (IFAs and dihydroxy fatty acids). No APAAs or dihydroxy fatty acids were detected. However, six potsherds (MG9, MG23, MG26, MG29, MG33, and MG43) contained IFAs. Only two potsherds (MG9 and MG33) contained all three IFAs (TMTD, pristanic and phytanic).

The $\delta^{13}C_{16:0}$ values range between -23.7 ‰ and -28.2 ‰. The mixing lines in Figure 4.11(a) indicate some non-ruminant sources (4%); the rest of the extracts plot within the expected ruminant adipose fats (64%) and ruminant dairy (32%). Potsherd MG2 plots as a mixture of plant and animal fat. The $\Delta^{13}C$ values show that this particular vessel was used for both plant and ruminant dairy fats, further discussed in Section 4.5.

Furthermore, through GC-MS, plant exploitation comprises 41% of the extracts (n = 9; MG2, MG3, MG19, MG20, MG26, MG30, MG31, MG43 and MG46), with the abundance of α,ω-dicarboxylic acids (even-chained carbon lengths C_{16}, C_{18}, C_{20} and C_{22}), even-chained *n*-

alcohols (C_{14} to C_{32}) and *n*-alkanes (C_{23}, C_{25} to C_{29}, C_{31} and C_{33}). The CPI of all extracts containing *n*-alkanes have been calculated (see Table 4.4 in Section 4.5.2). In particular, potsherd MG2 (Figure 4.9) contains a mixture of animal fats and plant products (birch bark components) identified through 11 triterpenoids. Identification of triterpenoids was conducted using GC-MS, as the components displayed base peaks at *m/z* 189 and molecular ions ($M^{+\bullet}$) at *m/z* 426, 498 and 468; comparisons with reference mass spectra identified the characteristic components of birch bark tar; lupeol, lupeol and betulin in conjunction with their degradation markers produced via oxidation and heating e.g., allobetul-2-ene, 3-oxoallobetulane, and 28-oxoallobetul-2-ene (Aveling and Heron, 1999; Colombini and Modugno, 2009; Rageot *et al.*, 2019; Perthuison *et al.*, 2020).

Additionally, long-chain ketones with carbon chain lengths C_{31}, C_{33} and C_{35} were detected in potsherd MG43 (Figure 4.10), with the presence of *n*-alkanes and *n*-alcohols, most likely resembling a vessel used to process leaf epicuticular wax (Evershed *et al.*, 1995; Raven *et al.*, 1997).

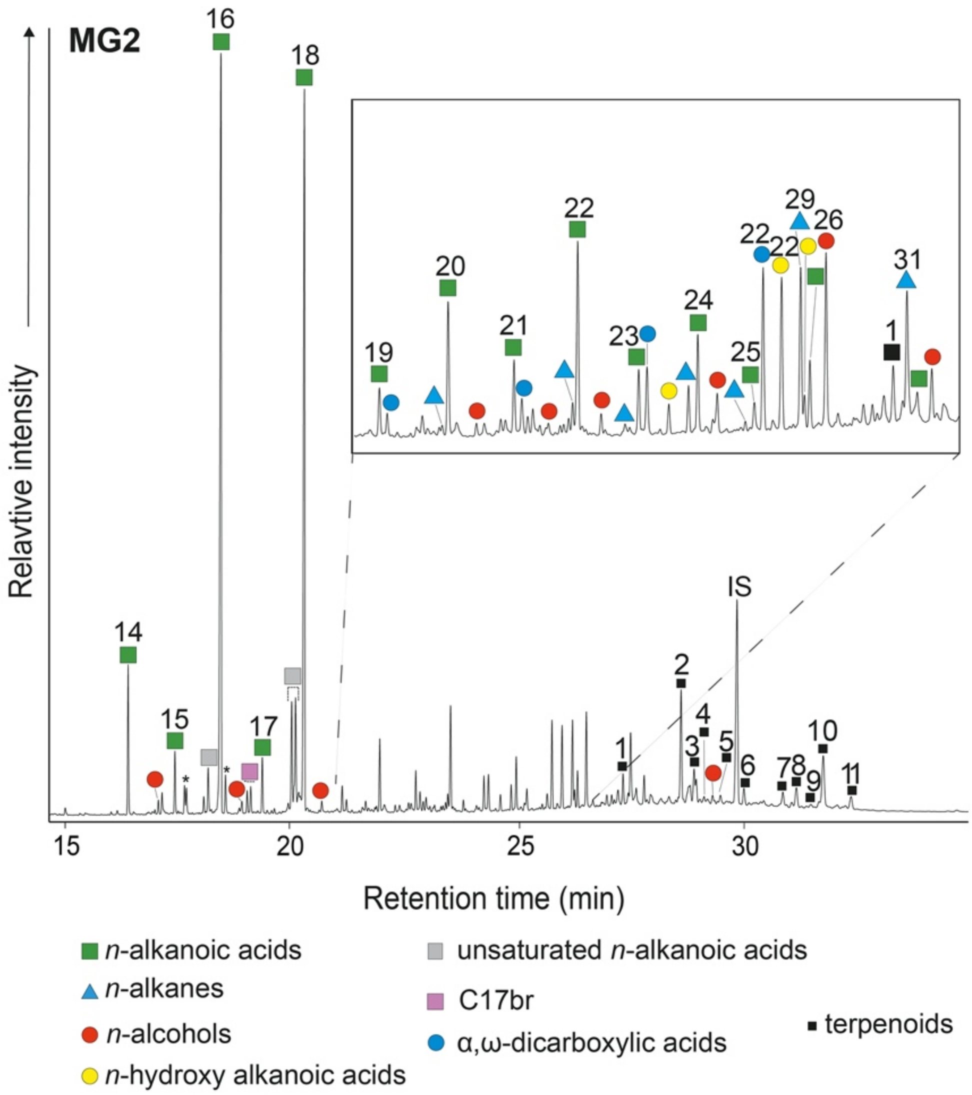


Figure 4. 9. Partial GC chromatogram from Margahovit (MG2) depicting birch bark tar biomarkers, numbered black squares; (1) Lup-2,20(29)-diene, (2) Lup-2,20(29)-dien-28-ol (TMS ether), (3) Allobetul-2-ene, (4) Lupeone, (5) Lupeol (TMS ether), (6) unknown terpenoid, (7) 28-oxoallobetul-2-ene, (8) Betulone (TMS ether), (9) 3-oxoallobetulane, (10) Betulin (TMS ether), and (11) Allobetulinol (TMS ether). IS is the internal standard, C_{34} *n*-tetratriacontane; * denotes plasticisers.

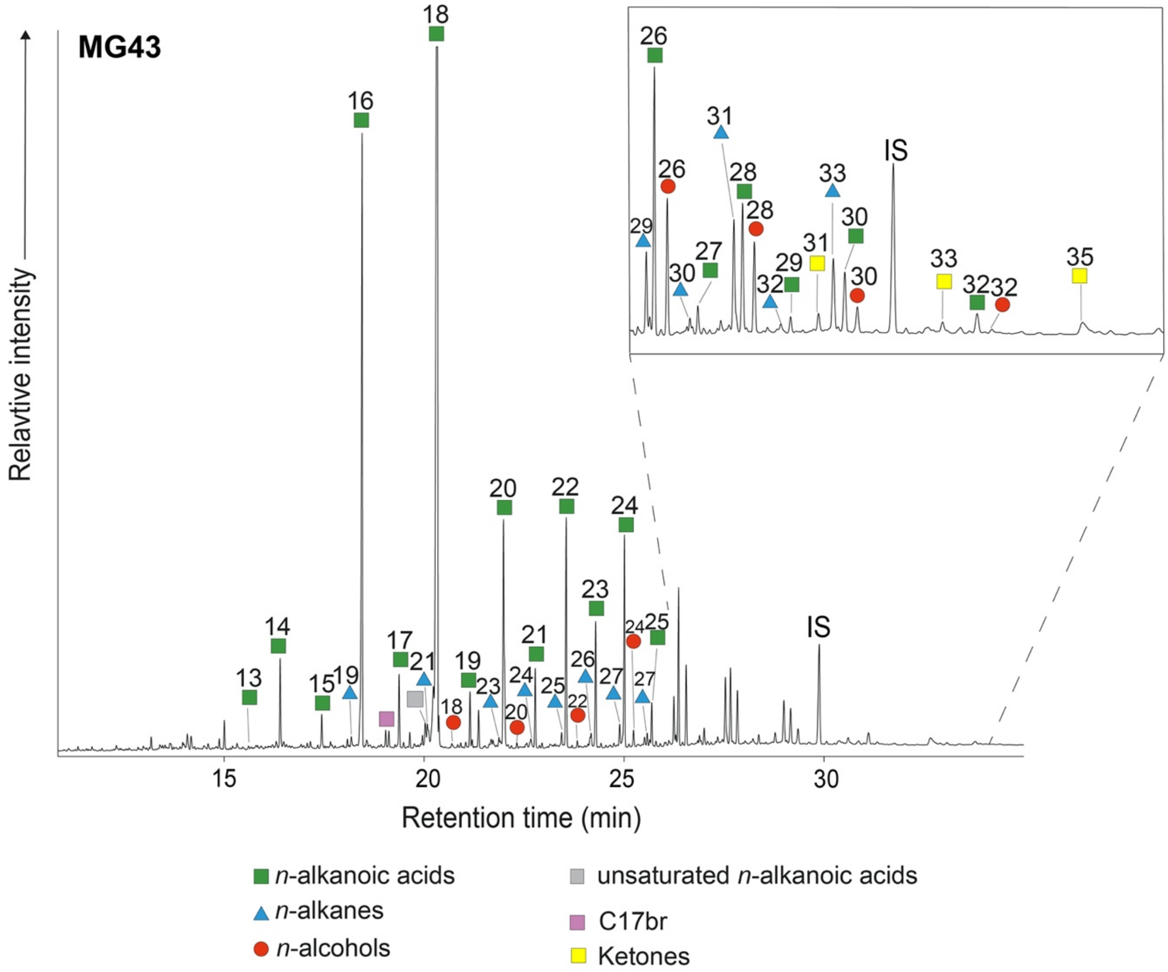


Figure 4. 10. Partial GC chromatogram from Margahovit (MG43) depicting a dairy residue and possible plant input (n-alkanes, n-alcohols and ketones). IS is the internal standard, C_{34} *n*-tetratriacontane; * denotes plasticisers.

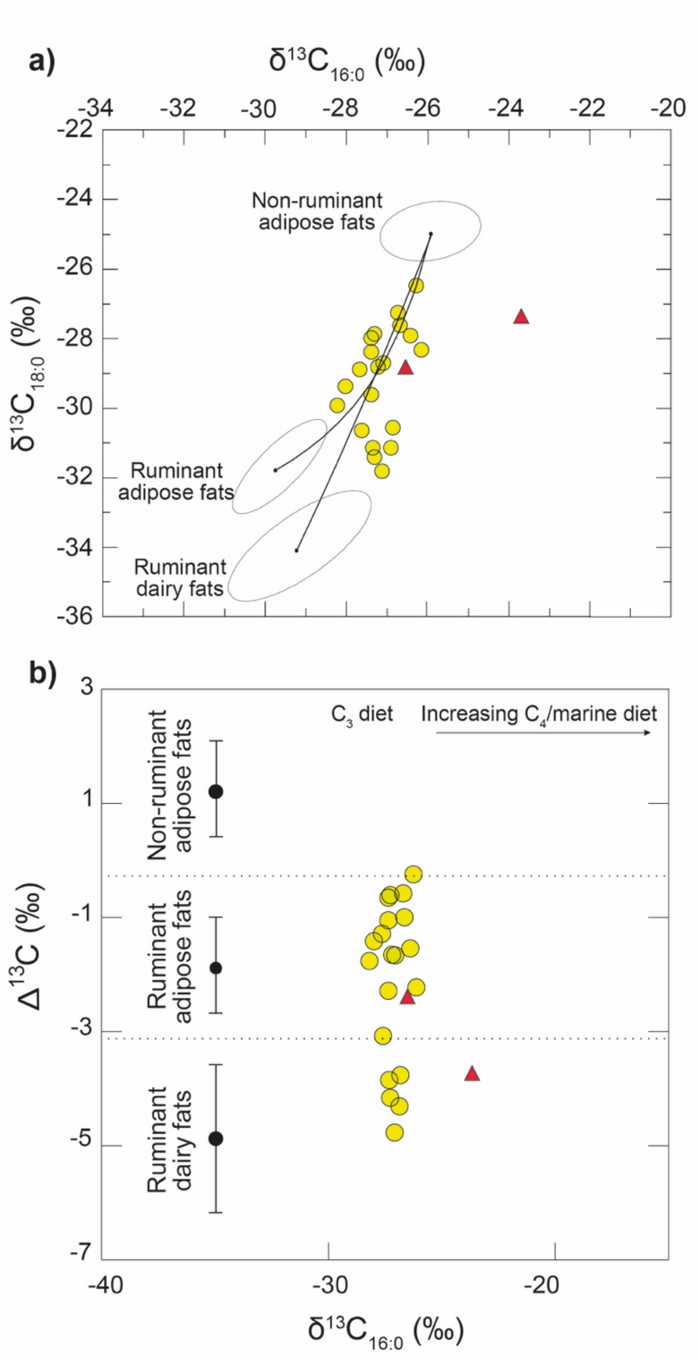


Figure 4. 11. (a) $\delta^{13}C$ values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Margahovit. (b) The difference in the $\delta^{13}C$ values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Red triangle symbols represent TLEs with evidence of plant processing with CPI values >2. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.4 Mokhra-Blur

The lipid residue recovery rate from the analysis of KA pottery from Mokhra-Blur was 100% of 13 sherds. The average concentration of lipids in the extracts was 291.1 µg g^{-1} with the highest concentration being 2510.4 µg g^{-1}. GC analysis of the extracts from Mokhra-Blur with significant concentrations of lipid (n = 13) demonstrates that the free fatty acids, palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$), are the most abundant components (Figures 4.12, 4.13 and 4.14), even-chained fatty acids (n-C_{14} to n-C_{32}), as well as hydroxy fatty acids (C_{24} to C_{26} and C_{28}), even-chained n-alcohols, and n-alkanes. LCFAs (C_{14} to C_{28}) are found in extracts MB1, and (C_{14} to C_{31}) in MB3. Long-chain n-alkanes (C_{17} to C_{33}) were detected in six potsherds.

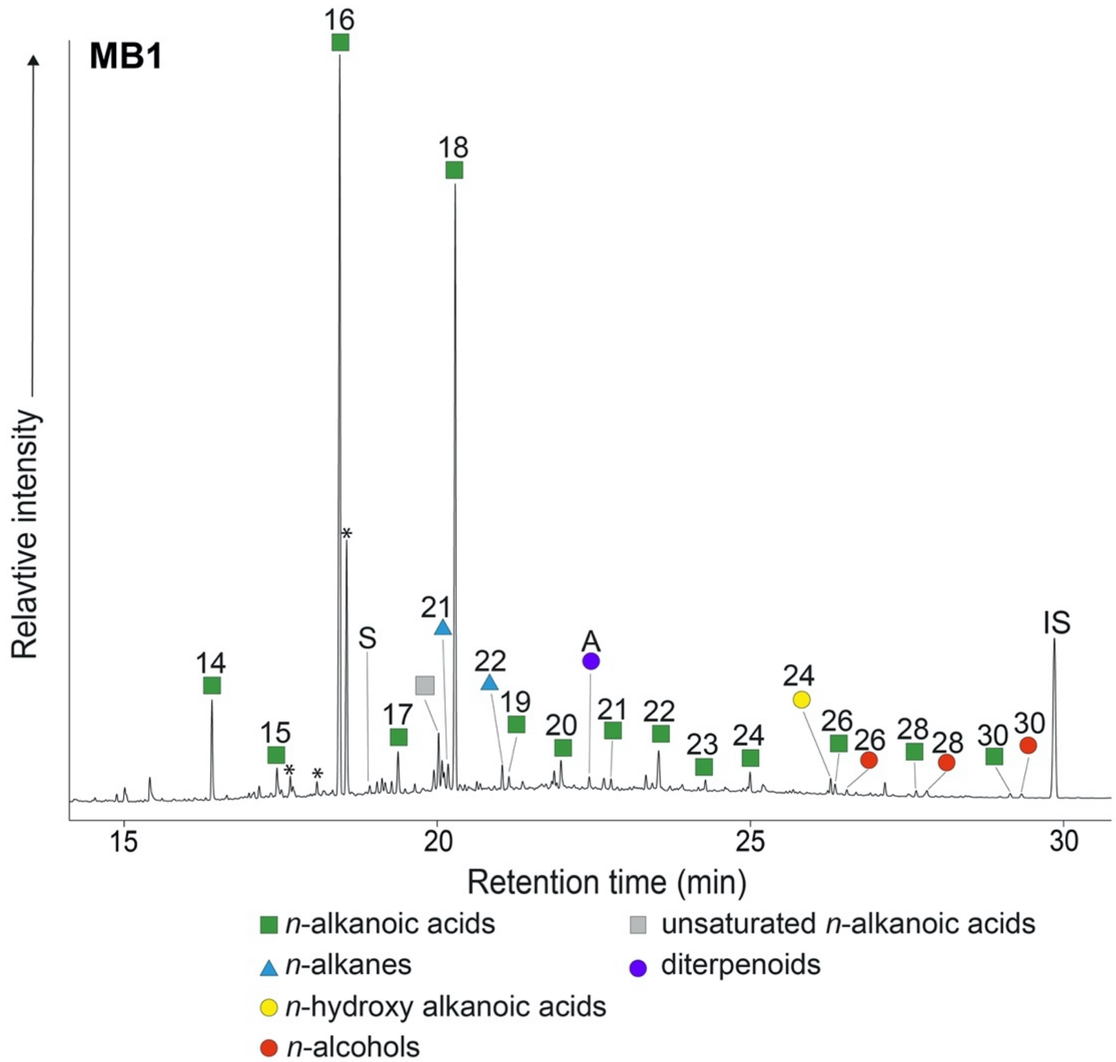


Figure 4. 12. Partial GC chromatogram from Mokhra-Blur (MB1) depicting a dairy residue and possible plant input (n-alkanes, n-alcohols and diterpenoid (A), dehydroabietic acid). IS is the internal standard, C_{34} n-tetratriacontane; * denotes plasticisers.

In particular, potsherd MB6 yielded a CPI of 5 (*n*-alkanes with carbon chain lengths of C_{20} to C_{33}, maximising at C_{29} and C_{31}). Plant lipids are evident in five extracts (38%; MB1001, MB1, MB6, MG9 and MB11; Figure 4.12) and two of them have been labelled as plant products mixed with animal fats (Figure 4.15; MB6 and MB11). Traces of pine resin are detected in potsherds MB1 and MB9, where dehydroabietic acid is present in MB1. Other components of pine resin are evident in extract MB11: dehydroabietic acid, 7-oxodehydroabetic acid, trimethylsilyl ester. Potsherd MB9 yielded both dehydroabietic acid and 7-oxodehydroabietic acid, methyl ester (Figure 4.13).

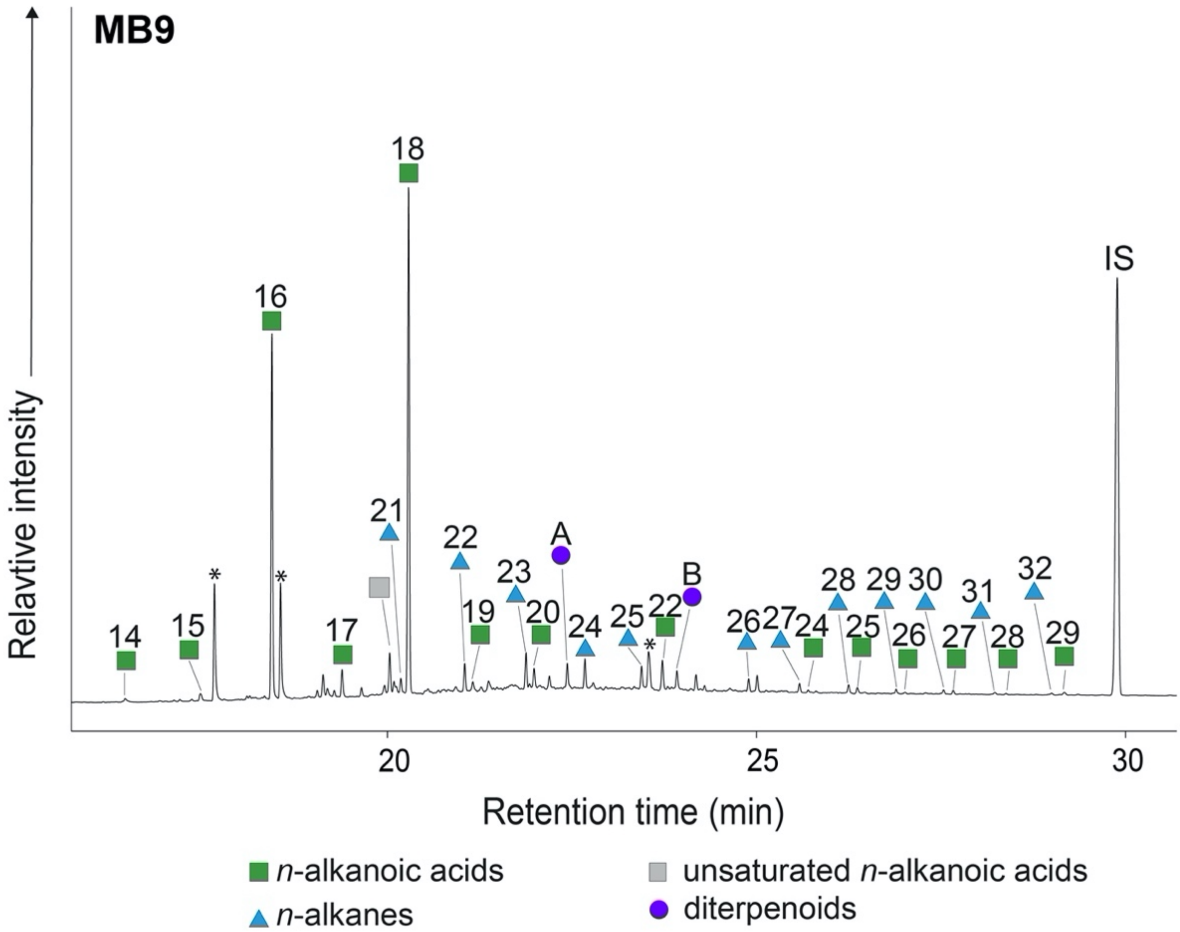


Figure 4. 13. Partial GC chromatogram from Mokhra-Blur (MB9) depicting ruminant adipose fats and plant input (n-alkanes and diterpenoids); diterpenoid (A) is classified as dehydroabietic acid and (B) is classified as 7-oxodehydroabietic acid. IS is the internal standard, C_{34} *n*-tetratriacontane; * denotes plasticisers.

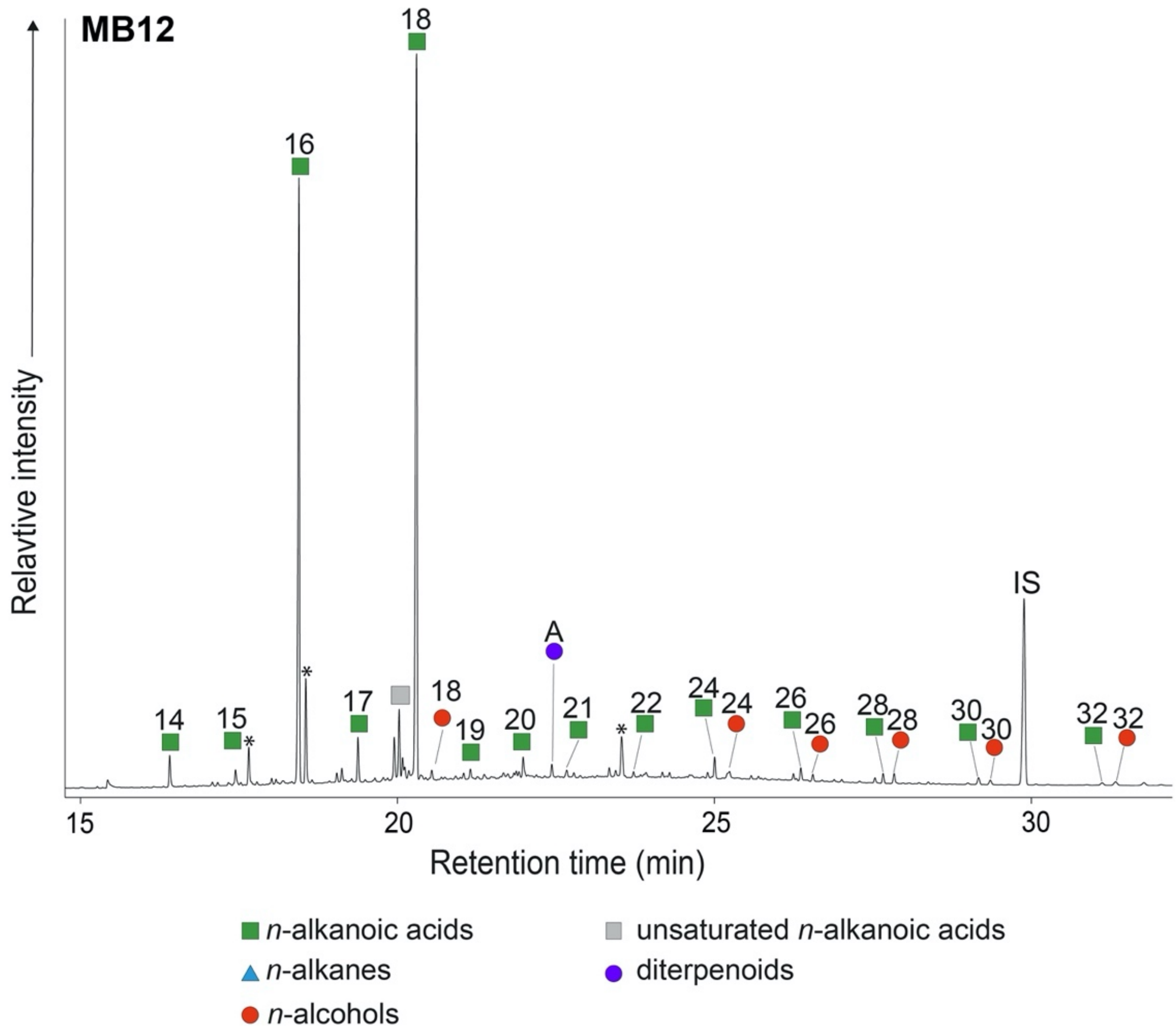


Figure 4. 14. Partial GC chromatogram from Mokhra-Blur (MB12) depicting a dairy residue; diterpenoid (A) is classified as dehydroabietic acid. IS is the internal standard, C_{34} *n*-tetratriacontane; * denotes plasticisers.

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs) and other aquatic biomarkers. Only one potsherd (MB3) yielded C_{18} APAA and traces of both C_{20} and C_{22} APAAs. In particular, this potsherd also contained all three isoprenoid fatty acids (TMTD, pristanic and phytanic).

The $\delta^{13}C_{16:0}$ values range between -21.5 ‰ and -27.2 ‰. The $\Delta^{13}C$ values are used to remove any exogenous factors linked to environment to categorise the animal fats (Figure 4.15b). The majority of the extracts plot within the expected range of ruminant adipose fats comprising (62%, Figure 4.15b). A small number of extracts plot within the expected range for ruminant dairy fats (31%). Due to the enrichment exhibited in the $\delta^{13}C_{16:0}$ values, it is possible to suggest that animals were grazing on C_4 vegetation. In the Ararat Plain region, salt marshes are common. This is discussed further in Section 4.4.

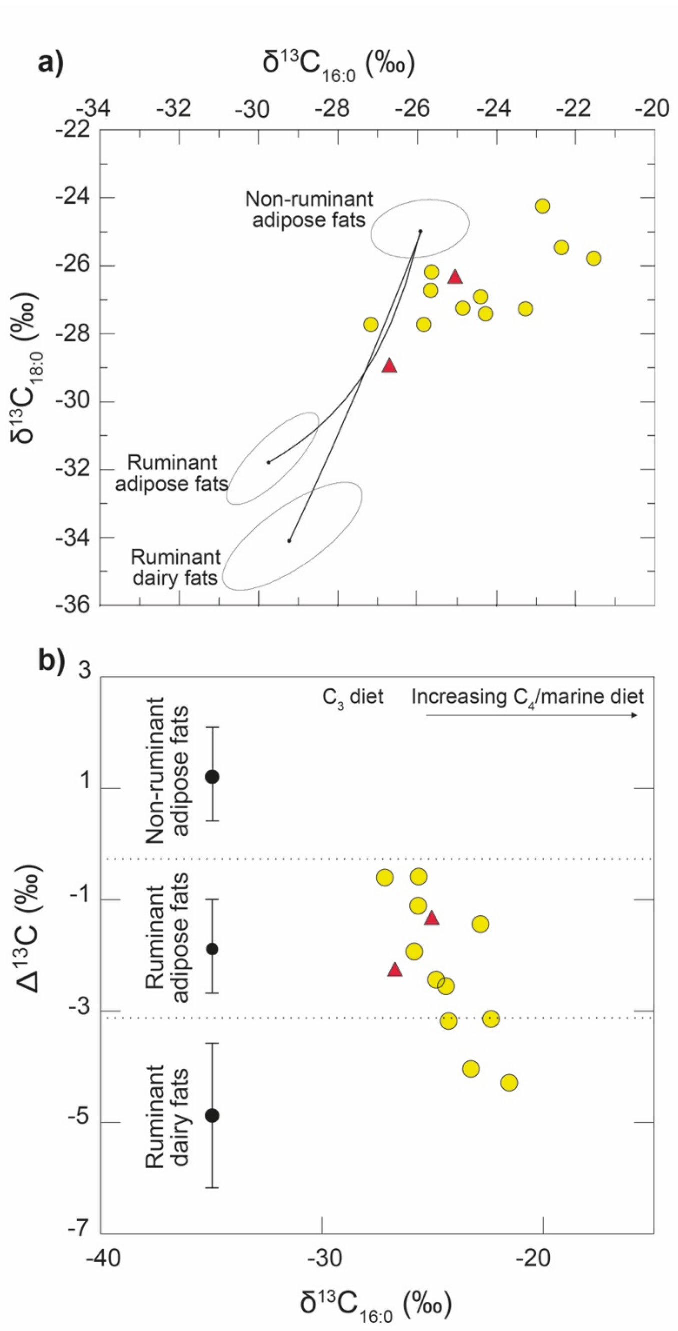


Figure 4. 15. (a) $\delta^{13}C$ values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Mokhra-Blur. (b) The difference in the $\delta^{13}C$ values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Red triangle symbols represent TLEs with evidence of plant processing with CPI values >2. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.5 Shengavit

The lipid residue recovery rate from the analysis of KA pottery from Shengavit was 94% of 48 sherds. The average concentration of lipids in the extracts was 317.4 $\mu g\ g^{-1}$ with the highest concentration being 1101.5 $\mu g\ g^{-1}$. GC analysis of the extracts from Shengavit with significant concentrations of lipid (n = 32) demonstrates that FAMEs, LCFAs, *n*-alkanes, *n*-alcohols, diacids (C_{20} and C_{22}), hydroxy FAMEs (specifically C_{22} and C_{24}), unsaturated fatty acids ($C_{16:1}$ and $C_{18:1}$) and branched fatty acids (C_{15} and C_{17}) are abundant. However, the free fatty acids, palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$), are the most abundant components (Figure 4.18). LCFAs ($C_{14:0}$ to $C_{30:0}$) are present in potsherds SH9 and SH48 (Figure 4.18).

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(o-alkylphenyl) alkanoic acids (APAAs) and other aquatic biomarkers (IFAs and dihydroxy acids). Aquatic commodities comprise 9% of the potsherds analysed. Potsherd SH68 revealed all three APAAs (traces of C_{22}) (Figure 4.17). Potsherd SH48 revealed traces of all three APAAs. Significantly, IFAs were found in five extracts; however, only one potsherd, SH9, contained all three and the rest contained some traces.

The $\delta^{13}C_{16:0}$ values range between -21.3 ‰ and -29.0 ‰. The $\delta^{13}C_{16:0}$ values range between -21.5 ‰ and -27.2 ‰ (Figure 4.19). The $\Delta^{13}C$ values are used to remove any exogenous factors linked to environment to categorise the animal fats. Based on the $\Delta^{13}C$ values, it is possible to suggest there is a lot of mixing of commodities within vessels, where non-ruminant fats (9%), ruminant adipose fats (78%), and ruminant dairy fats (12.5%).

Significantly, plant lipids and waxes correspond to 45% of the potsherds screened through GC and GC-MS. In particular, potsherd SH32 (Figure 4.16), contained *n*-alkanes maximising at C_{29}. Other potsherds exhibiting similar *n*-alkanes composition include SH21, SH97, and SH111. In potsherd SH105, the main *n*-alkanes are C_{23}, C_{25} and C_{27}, maximining at

C_{25}. Seven extracts contained plant lipids and waxes (discussed in Section 4.4.2; five of the extracts that have been calculated for CPI >2 are plotted in Figure 4.19). Potsherd SH132 demonstrated evidence of birch bark tar production through the identification of terpenoids.

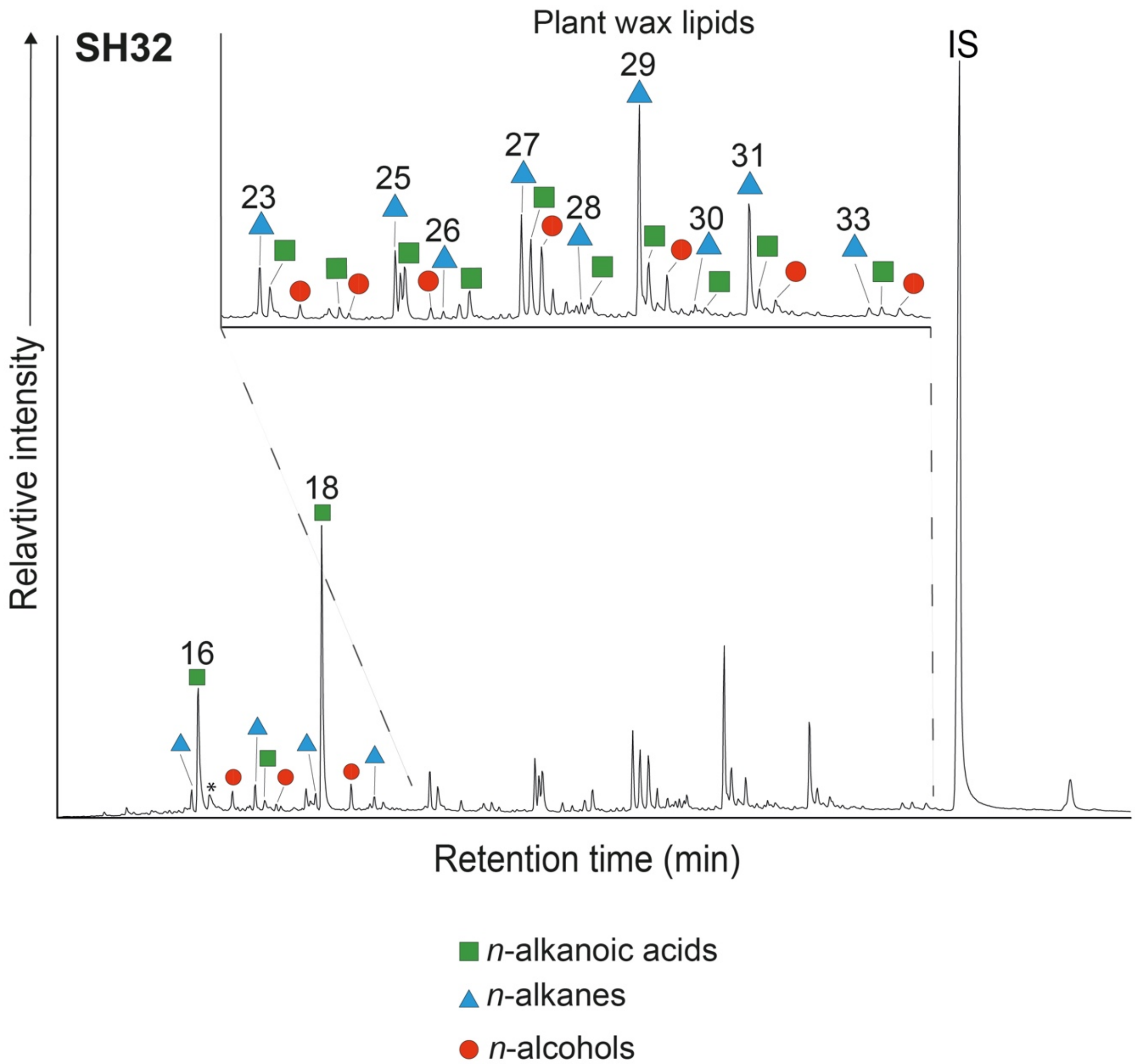


Figure 4. 16. Partial GC-MS chromatogram from Shengavit (SH32) illustrating the distribution of compounds characteristic of plant lipids with a CPI of 18.8. Plasticisers are marked with asterisks. IS is the internal standard, C_{34} *n*-tetratriacontane.

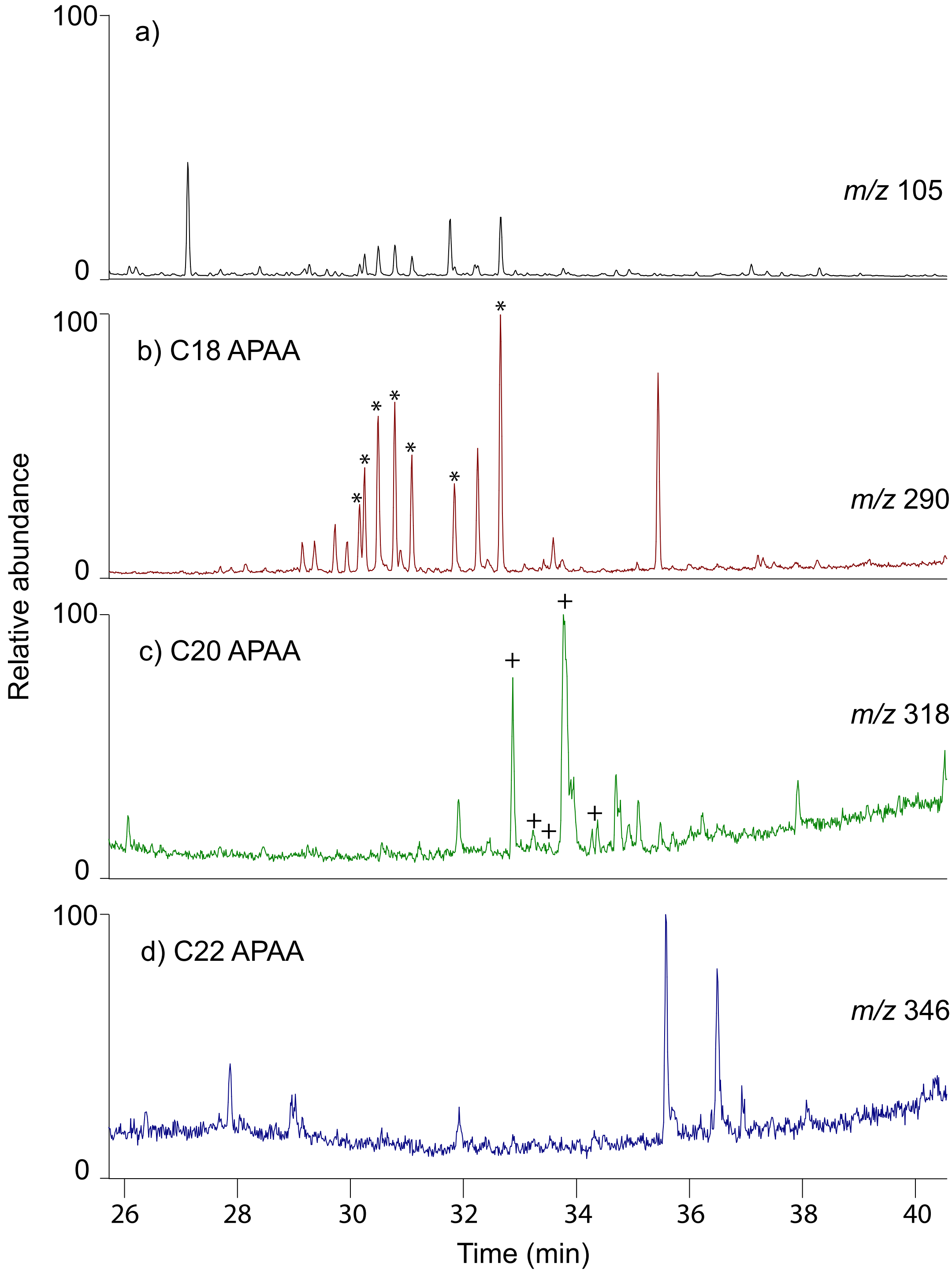


Figure 4. 17. Mass chromatograms of a) *m/z* 105, b) *m/z* 290, c) *m/z* 318 and d) *m/z* 346 of the acid extracted FAME from Shengavit (potsherd SH68) illustrating the presence of C_{18}, C_{20} APAAS, and traces of C_{22} APAAs.

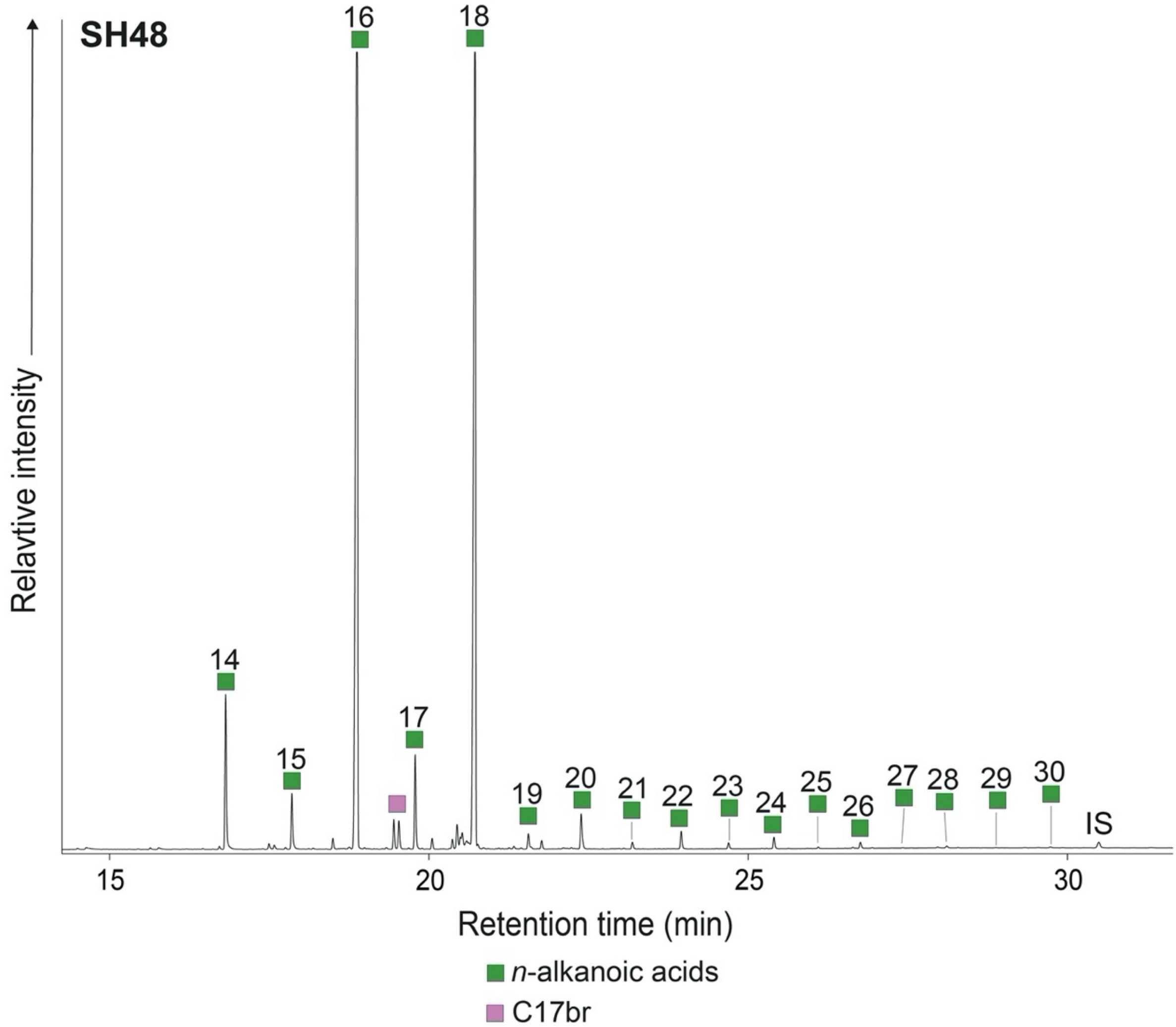


Figure 4. 18. Partial GC chromatogram from Shengavit (SH48) illustrating a high concentration of FAMEs (951 µg g^{-1}), classified as a dairy residue. IS is the internal standard, C_{34} *n*-tetratriacontane.

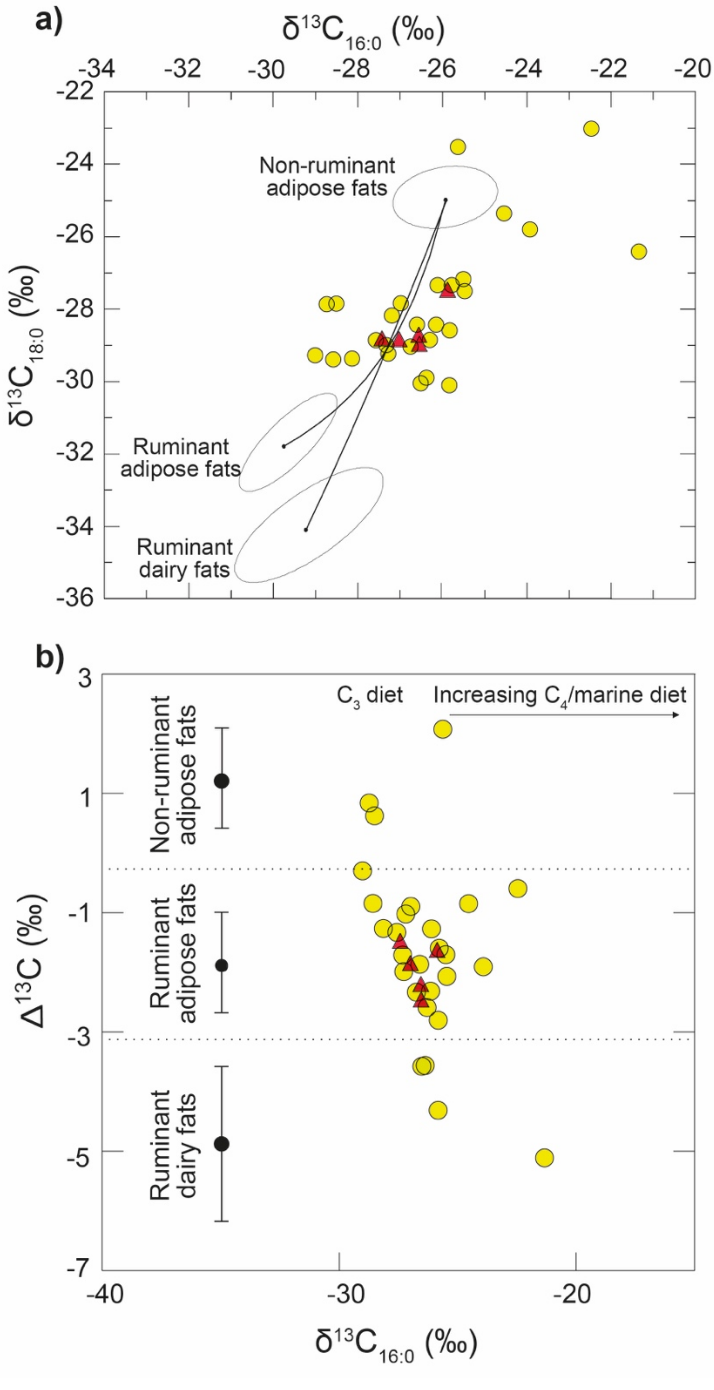


Figure 4. 19. (a) δ^{13}C values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Shengavit. (b) The difference in the δ^{13}C values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Red triangle symbols represent TLEs with evidence of plant processing with CPI values >2. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.6 Sotk-2

The lipid residue recovery rate from the analysis of KA pottery from Sotk-2 was 100% of 4 sherds. As the sample size is low and sherds are preselected, the lipid recovery rate cannot be properly reported for the overall site. The average concentration of lipids in the extracts was 116.9 µg g^{-1} with the highest concentration being 158.2 µg g^{-1}. GC analysis of the extracts from Sotk-2 with significant concentrations of lipid (n = 4) demonstrates that the free fatty acids, palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$), LCFAs (n-$C_{14:0}$ to n-$C_{24:0}$), odd- and even-chained *n*-alkanes and *n*-alcohols (Figures 4.20 and 4.21). In particular, extracts SK6 and SK23 most likely correspond to plant processing evidence, where the stearic acid (n-$C_{18:0}$) is lower in abundance and *n*-alkanes are present, maximising at C_{29}. Extract SK51 suggests petroleum contamination, where *n*-alkanes of carbon chain length C_{18} to C_{33} have been calculated for the CPI (Figure 4.20).

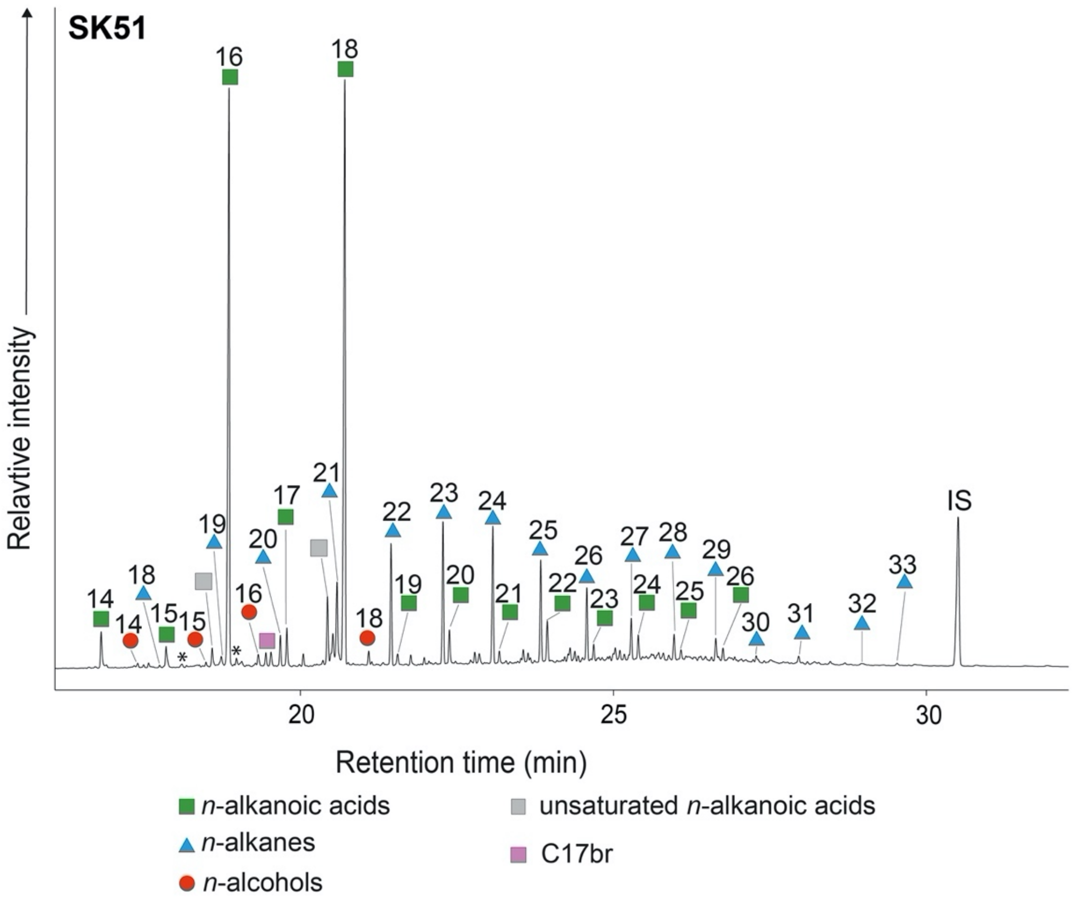


Figure 4. 20. Partial GC profile of the acid extracted FAME from Sotk-2 (SK51), illustrating the distribution of *n*-alkanes characteristic of contamination (CPI = 0.8). IS is the internal standard, C_{34} *n*-alkane; * denotes contamination.

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(o-alkylphenyl) alkanoic acids (APAAs) and other aquatic biomarkers (IFAs and dihydroxy acids), however, none were detected.

The $\delta^{13}C_{16:0}$ values range between -22.2 ‰ and -27.6 ‰ (Figure 4.22). Similar to Mokhra-Blur and Shengavit, there is enrichment in the $\delta^{13}C_{16:0}$ values, suggesting a C_4 influence or environmental factors. Based on the $\Delta^{13}C$ values, 50% of the potsherds correspond to ruminant adipose and 50% to ruminant dairy products. While this is expected, of these sherds, SK6 and SK23 correspond to possible plant processing as well (50%).

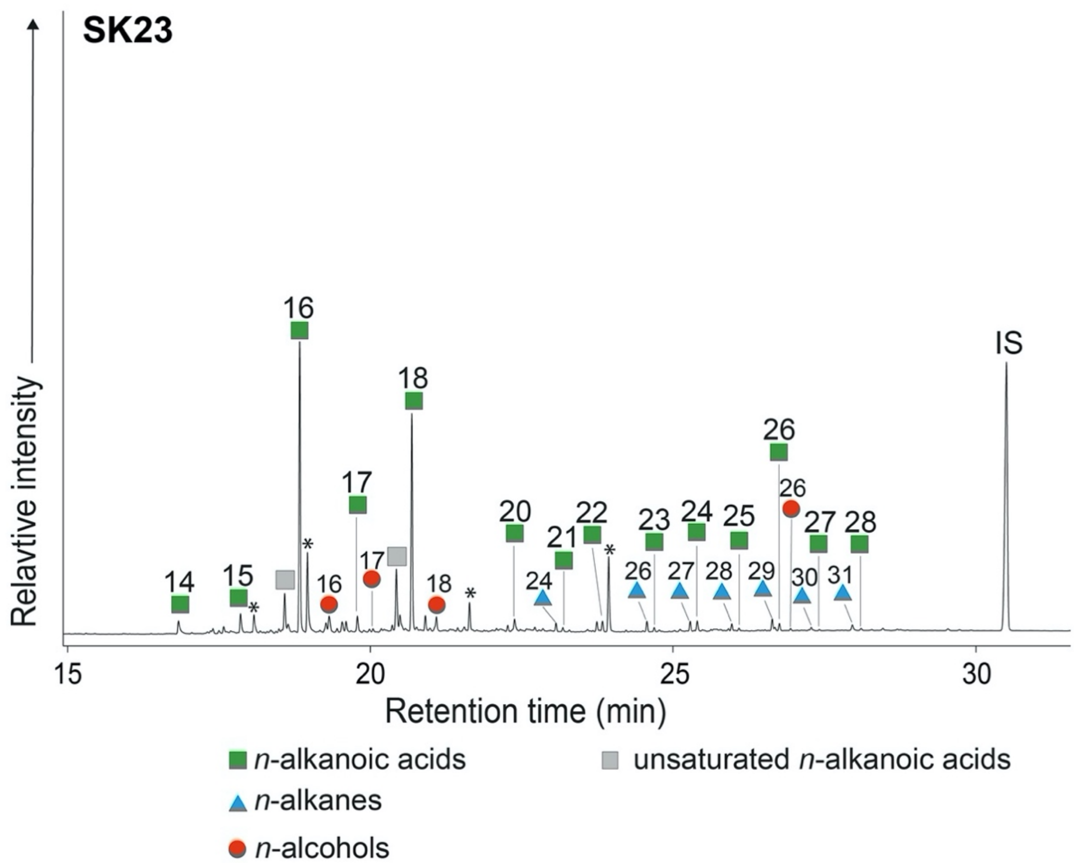


Figure 4. 21. Partial GC profile of the acid extracted FAME from Sotk-2 (SK23), illustrating a mixture of both animal fats (dairy residue) and possible plant lipids (CPI = 1.05). IS is the internal standard, C_{34} *n*-alkane; * denotes contamination.

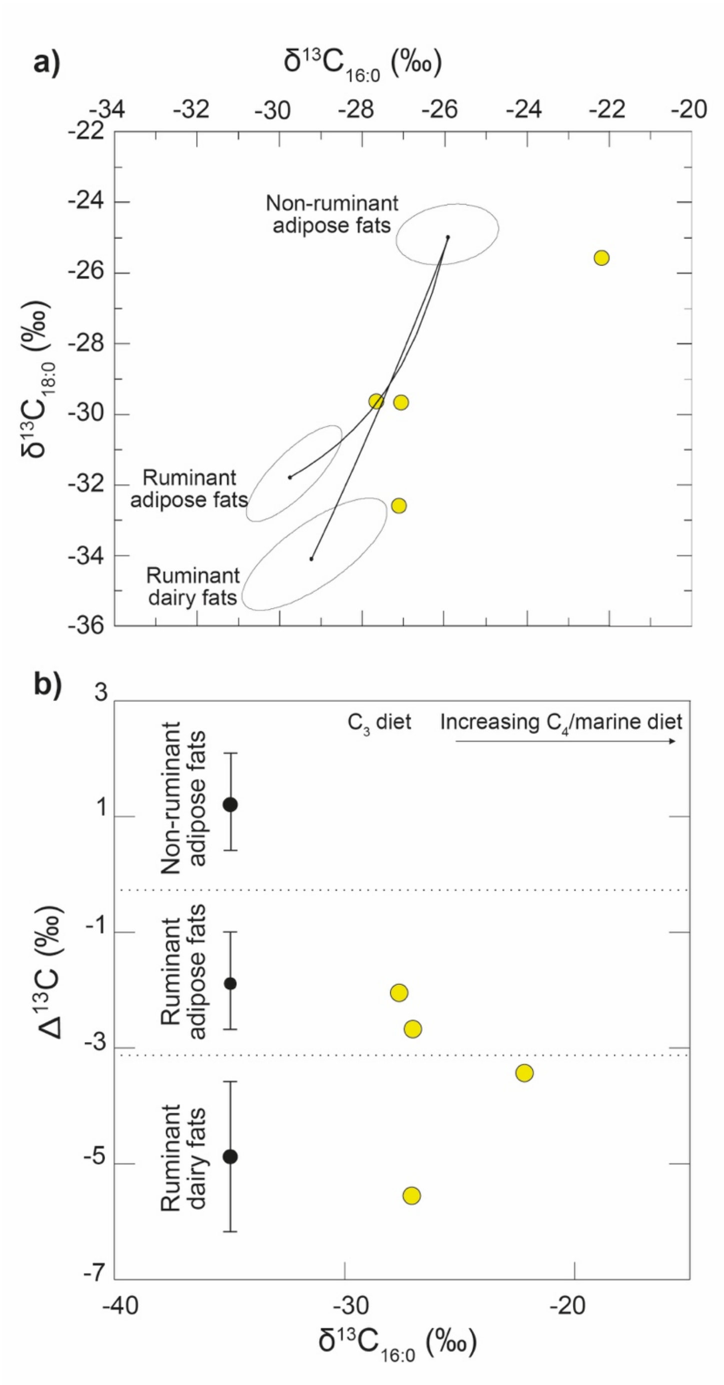


Figure 4. 22. (a) δ^{13}C values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Sotk-2. (b) The difference in the δ^{13}C values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.4.7 Talin Tombs

The lipid residue recovery rate from the analysis of KA pottery from Talin Tombs was 100% of 4 sherds. As the sample size is low and sherds are preselected, the lipid recovery rate cannot be properly reported for the overall site. The average concentration of lipids in the extracts was 262.1 μg g^{-1} with the highest concentration being 408.2 μg g^{-1}. GC analysis of the extracts from Talin Tombs with significant concentrations of lipid (n= 4) demonstrates that the free fatty acids, palmitic (n-$C_{16:0}$) and stearic (n-$C_{18:0}$), are the most abundant components (Figure 4.23), alongside odd- and even-chained n-alkanes (C_{19} to C_{26}), hydroxy fatty acids (C_{24}), and even-chained n-alcohols (C_{12} to C_{20}). In particular, potsherd T5 contains LCFAs of n-$C_{14:0}$ to n-$C_{30:0}$ (Figure 4.23). Unsaturated ($C_{16:1}$ and $C_{18:1}$,) and branched (C_{17}) chain fatty acids are also common, but in low abundance.

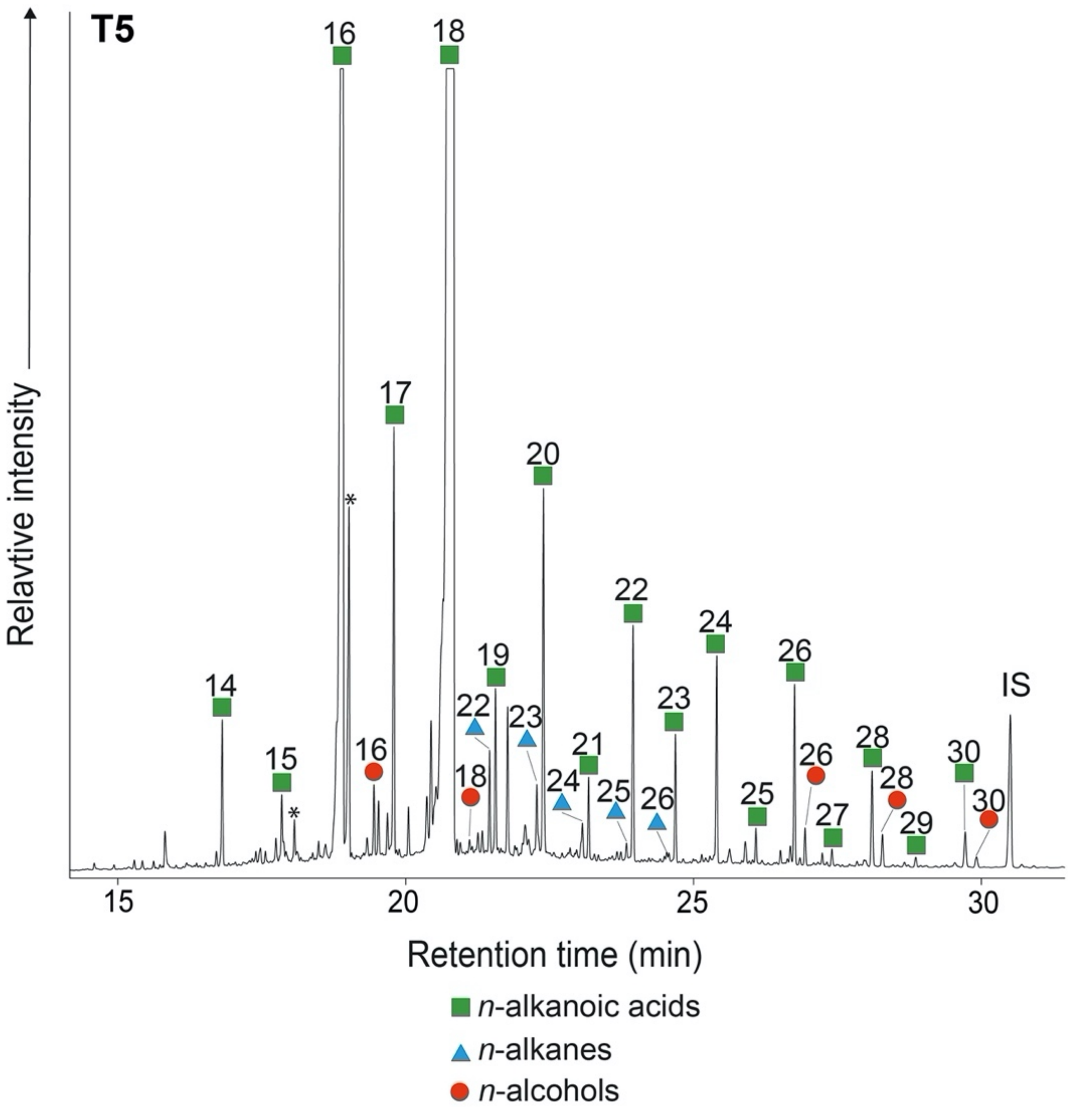


Figure 4. 23. Partial GC profile of the acid extracted FAME from Talin Tombs (T5), classified as ruminant adipose fats. IS is the internal standard, C_{34} n-alkane; * denotes contamination.

All residues containing an appreciable lipid concentration were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(*o*-alkylphenyl)alkanoic acids (APAAs) and other aquatic biomarkers (IFAs and dihydroxy acids), however, none were detected. The $\delta^{13}C_{16:0}$ values range between -26.1 ‰ and -27.0 ‰ (Figure 4.24). Based on the $\Delta^{13}C$ values, 25% of the potsherds correspond to ruminant adipose and 75% to ruminant dairy products. While the sample size is low, dairy products are more common at Talin Tombs.

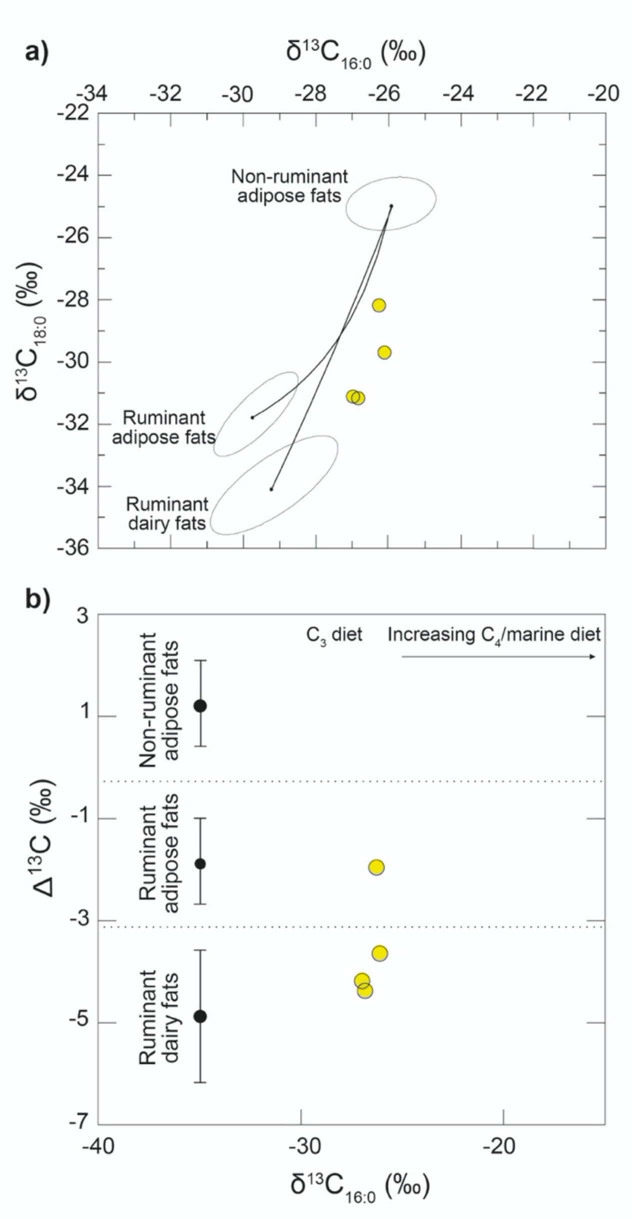


Figure 4. 24. (a) $\delta^{13}C$ values for the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Talin Tombs. (b) The difference in the $\delta^{13}C$ values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids. Each data point corresponds to an individual vessel. Analytical precision is ± 0.3 ‰.

4.5 Discussion

The results reported here provide the first direct evidence of the processing of various commodities, including plants, leafy vegetables, and/or fruit, birch bark tar, and a new outlook on the overall economic and subsistence strategies of Bronze Age people in the core area of the KA culture (Table 4.3 and Appendix D, Table 1). The synthesis of the data reported here is discussed in Chapter 5. In the next few sections, results are consolidated and divided into sections discussing the research questions and aims set out in the beginning of the Chapter (Section 4.2).

4.5.1 Terrestrial resources: primary and secondary products

The abundance of animal fats recorded reflects the importance of animals to Kura-Araxes inhabitants, as primary and secondary products predominate the findings. Characterisation of degraded fats was achieved through stable carbon isotopic values ($\delta^{13}C$) of the major fatty acids (n-$C_{16:0}$ and n-$C_{18:0}$). Degraded ruminant adipose products were the most common class of lipid detected in Kura-Araxes potsherds, at 56% (Table 4.3). The $\delta^{13}C$ values obtained indicate that animals were raised primarily on a C_3 diet (Copley *et al.*, 2003; marked by the confidence ellipses). However, the $\delta^{13}C$ values of the fatty acids in the TLEs from the sites of Shengavit, Sotk-2, and Mokhra-Blur exhibit an isotopic shift (Figures 4.15, 4.19 and 4.22). The isotopic shift is generally indicative of environmental factors, such as aridity (Evershed *et al.*, 2008b), warm climate (Whelton *et al.*, 2018; Dunne *et al.*, 2012; Nieuwenhuyse *et al.*, 2015), and animals grazing on salt marshes (Drake, 1989; Couto *et al.*, 2013), which can broaden the $\delta^{13}C$ values. As a result, lipids from these sites have been classified using their $\Delta^{13}C$ (= $\delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) values. In general, the $\delta^{13}C$ values vary over a wide range within each settlement, suggesting a variety of vegetation types and microenvironments (Fayvush *et al.*, 2017; Fayvush and Aleksanyan, 2020). At the archaeological settlement of Shengavit, $\delta^{13}C_{16:0}$ values of herbivore fatty acids range between -21.3 and -29.0‰. Similarly, Mokhra-Blur's $\delta^{13}C_{16:0}$ values of herbivore fatty acids range between -21.5 and -27.2‰. The enrichment of these values suggests some input of C_4 plants in the diet of ruminants and/or non-ruminants. Domesticated C_4 crops are absent during the EBA, as millet does not appear in the archaeological record until the Middle/Late Bronze Age in South Caucasus (Hovsepyan, 2015; Herrscher *et al.*, 2018; Martin *et al.*, 2021). However, wild C_4 vegetation and salt marshes are common in the region of Armenia, specifically in the Ararat Plain, where Shengavit and Mokhra-Blur settlements are located (see Figure 4.25; Akopian *et al.*, 2018; Fayvush and Aleksanyan, 2020). Lipid extracts with less depleted $\delta^{13}C_{16:0}$ and $\delta^{13}C_{18:0}$ values (potsherds from Gegharot and Karnut-1) appear to have originated from an animal fat source. Due to the significantly low amount (8%) of aquatic resources detected, it is not enough to suggest the cause of enrichment; thus, animals grazing and foddering on salt marshes in this region, is likely the cause of enriched $\delta^{13}C$ values causing offset from the confidence ellipses (Drake, 1989; Couto *et al.*, 2013; Akopian *et al.*, 2018).

Dairy products, in comparison to ruminant carcass fats, were lower than expected (31%), as various archaeozoological studies report the importance of secondary products (Summers, 2014). However, dairying seems to dominate more at Gegharot (55%), Talin Tombs (75%), and Sotk-2 (50%) (Sections 4.4.1, 4.4.6 and 4.4.7), than at other settlements (Table 4.1). Based on the sample size of Sotk-2 and Talin Tombs, data should be treated as supporting evidence. Pigs are represented in EBA KA sites across South Caucasus, but in very low numbers (Decaix *et al.*, 2019; Simonyan and Rothman, 2015). Non-ruminant sources, most likely pig or wild boar (Appendix D, Table 1) are evident at Shengavit (9%) and Karnut-1 (55%) (Section 4.4.2).

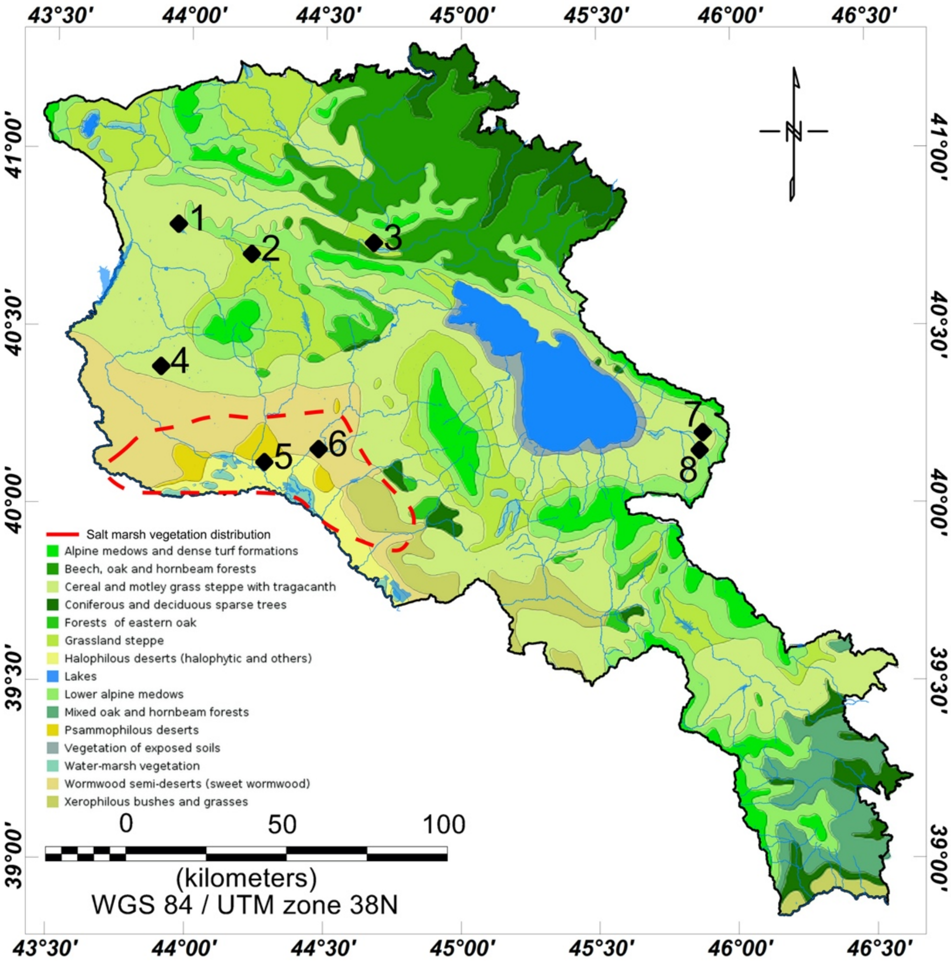


Figure 4. 25. Vegetation map of Armenia, including rivers and one of the major freshwater lakes in the region, Lake Sevan. Salt marsh vegetation distribution approximated in dashed red lines (Akopian *et al*., 2018; Fayvush and Aleksanyan, 2020). Sites: (1) Karnut-1, (2) Gegharot, (3) Margahovit (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1. These settlements are distanced between 17 and 176 km, where Shengavit and Mokhra-Blur are 17 km apart. Settlements are roughly 50-80 km apart. Maps modified using Adobe Illustrator. Maps produced by L. Manoukian using Oasis Montaj Software (www.seequent.com); Vegetation layer GIS base map source: https://sustainable-caucasus.unepgrid.ch (Suren Arakelyan; GEORISK Scientific Research Company).

4.5.2 Investigating plant exploitation and processing

4.5.2.1 Aliphatic lipids

Evidence for the exploitation of plants is found at all sites, except Talin Tombs (Table 4.4). In particular, plant aliphatic lipids are recorded at Sotk-2 (50%), Shengavit (45%), Margahovit (41%), Mokhra-Blur (38%), and in small amounts at Gegharot (9%) and Karnut-1

(33%) (Table 4.4 and Appendix D, Tables 1 and 2). Abundant *n*-alkanes with an odd-over-even dominance were observed in extracts lacking high abundance of animal fats, implying the processing of plants in some vessels (Figure 4.16). Diagnostic long-chain fatty acids from $C_{20:0}$ to $C_{28:0}$, high abundances of $C_{18:1}$ unsaturated fatty acids, odd-numbered *n*-alkanes ranging from $C_{19:0}$ to $C_{33:0}$, even-numbered *n*-alcohols ranging from $C_{14:0}$ to $C_{30:0}$, *n*-hydroxy alkanoic acids, and short-, medium- and long-chain α,ω-dicarboxylic acids were detected (Figures 4.9 and 4.16). Such distributions are possibly characteristic of plant wax and/or seed oils (Dunne *et al*., 2016; Dunne, 2021; Kolattukudy *et al*., 1976; Diefendorf *et al*., 2011). Overall, 29% of potsherds contained lipid profiles that can be characterised as plant. *N*-alkane distributions have been calculated for the carbon preference index CPI (Diefendorf *et al*., 2011) and P_{aq} proxy ratio (Table 4.4). The CPI was calculated to determine whether the *n*-alkanes derived from epicuticular plant waxes or from post-depositional contamination (Bray and Evans, 1961; Rommerskirchen *et al*., 2006; Freeman and Pancost, 2014). The $\delta^{13}C$ values for the series of *n*-alkanes derived from terrestrial plant waxes range from -35.6 to -24.3‰. These reflect the carbon isotope values of C_3 leaf wax lipids, which range between -39‰ and -29‰, and some C_4 input due to salt marsh and water-stressed vegetation (Collister *et al*., 1994).

Table 4. 4. P/S ratios, CPI, P_{aq} , and classification of trimethylsilylated TLEs. P/S ratio = relative abundance ratio of $C_{16:0}/C_{18:0}$ fatty acids, where values greater than 4 indicate a plant origin. CPI = measures the relative abundance of odd-over-even carbon chain lengths; CPI values for all plant species have strong odd-chain preferences, ranging between 1.6 and 82.1 (Diefendorf *et al.,* 2011; Bush and McInerney, 2013; Herrera-Herrera *et al.*, 2020). P_{aq} = emergent and non-emergent aquatic macrophyte input; P_{aq} <0.1 corresponds to a terrestrial plant input; P_{aq} 0.1-0.4 to emergent macrophytes, and P_{aq} 0.4-1.0 to submerged or floating macrophytes (Ficken *et al*., 2000). N/D – not determined, signal intensity too low.

Laboratory Code	Site	P_{aq}	CPI	P/S	Classification
SH21	Shengavit	0.48	2.7	11.3	Plant
SH32	Shengavit	0.23	18.8	0.5	Plant
SH45	Shengavit	N/D	N/D	5.6	Plant?
SH79	Shengavit	0.57	2.9	9.7	Plant
SH82	Shengavit	0.85	0.9	1.2	Plant?
SH97	Shengavit	0.19	3.3	2.4	Plant
SH105	Shengavit	0.52	1.6	11.2	Plant
SH108	Shengavit	0.55	N/D	0.2	Plant?
SH111	Shengavit	0.31	2.3	0.3	Plant
SH132	Shengavit	N/D	N/D	0.1	Plant wax
MB001	Mokhra-Blur	1.00	2.0	3.8	Plant?
MB1	Mokhra-Blur	N/D	N/D	1.2	Plant resin?
MB6	Mokhra-Blur	0.22	5.0	1.0	Plant
MB9	Mokhra-Blur	0.84	1.1	0.7	Plant resin
MB11	Mokhra-Blur	0.78	N/D	N/D	Plant resin
MG2	Margahovit	0.00	69.0	1.1	Plant wax
MG3	Margahovit	N/D	N/D	1.6	Plant?
MG19	Margahovit	0.14	16.5	0.6	Plant
MG20	Margahovit	N/D	N/D	2.1	Plant?
MG26	Margahovit	N/D	N/D	1.7	Plant?
MG30	Margahovit	N/D	N/D	2.5	Plant?
MG31	Margahovit	N/D	N/D	3.6	Plant?
MG43	Margahovit	0.14	1.5	0.4	Plant?
MG46	Margahovit	N/D	N/D	3.5	Plant?
SK6	Sotk-2	0.39	0.8	3.2	Plant?
SK23	Sotk-2	0.00	1.05	1.2	Plant?
KRT2	Karnut-1	N/D	N/D	7.8	Plant?
KRT12	Karnut-1	N/D	N/D	4.9	Plant?
KRT34	Karnut-1	N/D	N/D	7.2	Plant?
KRT35	Karnut-1	N/D	N/D	N/D	Plant wax
KRT56	Karnut-1	N/D	N/D	1.0	Plant?
KRT64	Karnut-1	0.81	N/D	1.1	Plant
G28	Gegharot	N/D	N/D	0.9	Plant wax
G31	Gegharot	N/D	N/D	0.8	Plant wax

4.5.2.2 Terpenoids

The presence of terpenoids in KA vessels suggests the exploitation of higher plants (Hayek *et al*., 1990; Charters *et al*., 1993). Triterpenoids were also identified in five extracts from Margahovit (MG2; Figure 4.9), Karnut-1 (KRT35), Gegharot (G28 and G31; Figure 4.4) and Shengavit (SH132). Identification of triterpenoids was conducted using GC-MS, as the components displayed base peaks at *m/z* 189 and molecular ions ($M^{+\bullet}$) at *m/z* 426, 498 and 468; comparisons with reference mass spectra identified the characteristic components of birch bark tar; lupeol, lupeol and betulin in conjunction with their degradation markers produced via oxidation and heating e.g., allobetul-2-ene, 3-oxoallobetulane, and 28-oxoallobetul-2-ene (Aveling and Heron, 1998; Colombini and Modugno, 2009; Rageot *et al*., 2019; 2021; Perthuison *et al*., 2020).

As an adhesive, birch bark tar has been discussed in archaeological contexts dating to the Mesolithic and Neolithic (Aveling and Heron, 1998; Rageot *et al*., 2019; 2021; Regert *et al*., 1998; 2003; 2006), as well as the European Middle Palaeolithic (Blessing and Schmidt, 2021). These terpenoid compounds were mostly likely used as resinous substances (i.e., waterproofing agent, adhesives, glue or medicinal purposes) (Aveling and Heron, 1998) and processed into tars and pitches obtained from the pyrolysis of resinous wood (Mills and White, 1994; Rageot *et al*., 2019; 2021). Based on the compounds present, it is possible to suggest the form and function of these KA vessels (potsherds G28, MG2 and SH132). The triterpenoid molecular compositions of various potsherds (Table 4.5) are likely associated with strong heating markers (Rageot *et al*., 2019: 296). For these specific potsherds, fatty acids were identified in conjunction with birch bark tar. The biomarkers associated with these potsherds (Table 4.5) indicate the double-pot *per descensum* method in producing birch bark tar (Rageot *et al*., 2019: 298). This is indicative of a system where two pots were used for the production of birch bark tar (double-pot system) (Figure 4.26).

Table 4. 5. Potsherd samples containing biomarkers illustrating terpenoids characteristic of birch bark tar and strong heating markers (Rageot *et al*., 2019; 2021).

Sample code	**Terpenoids**	**Comments**
G28	Lup-2,20(29)-dien-28-ol (TMS);Allobetul-2-ene; 28-oxoallobetul-2-ene; Betulone (TMS); Betulin (TMS)	Strong heating markers
G31	Lup-2,20(29)-dien-28-ol (TMS)	-
KRT35	Betulin (TMS); Unidentified terpenoids	-
MG2	Lup-2,20(29)-diene; Lup-2,20(29)-dien-28-ol (TMS); Allobetul-2-ene; Lupenone; Lupeol (TMS); Unknown terpenoid; 28-oxoallobetul-2-ene; Betulone (TMS); 3-oxoallobetulane; Betulin (TMS); Allobetulinol (TMS)	Strong heating markers
SH132	Lup-2,20(29)-diene; Lup-2,20(29)-dien-28-ol (TMS); Allobetul-2-ene; Betulin (TMS); Betulone (TMS); Betulin (TMS); Allobetulinol (TMS)	Strong heating markers

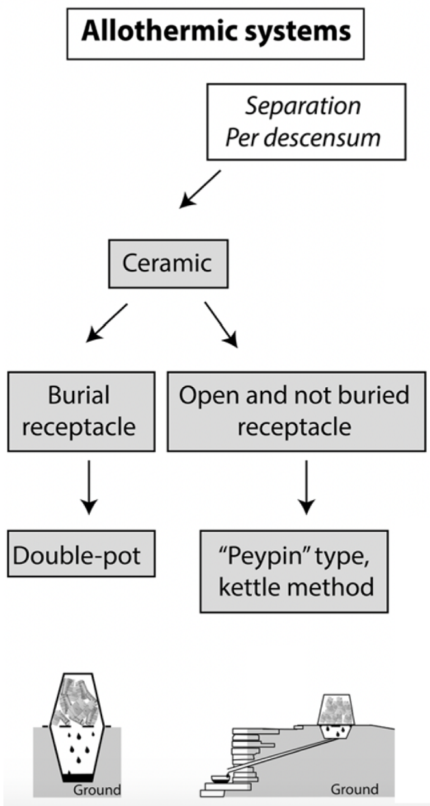


Figure 4. 26. Double-pot system (per descensum) method for the production of birch bark tar (adapted and reproduced from Rageot *et al*., 2019: 279).

Diterpenoids deriving from the oxygenated pyrolysis of *Pinus spp.,* dehydroabietic acid and 7-oxodehydroabietic acid, were detected in TLEs from Mokhra-Blur (77%) and Karnut-1 (30%) and these are likely to have derived during firing of the pottery (Hansel *et al*., 2004) as forests comprising hazel, fir, and pine species were abundant in the area during the EBA (Connor and Kvavadze, 2014; Messager *et al*., 2020; Joannin *et al*., 2014; Leroyer *et al*., 2016; Jude *et al*., 2016).

The direct evidence of plant consumption and processing sheds a new light on subsistence strategies of Kura-Araxes mountainous zones and illustrates the first evidence of processing of leaf plants identified in lipid residues from Armenia and the general region of the Caucasus. The $\delta^{13}C_{16:0}$ values (-21.3 ‰ to -29.0 ‰) for plant wax-derived *n*-alkanes and *n*-alkanoic acids unequivocally confirm the processing of C_3 grasses, C_4 salt marshes, and aquatic/water-stressed plants largely available near rivers and Lake Sevan, confirming the archaeobotanical sources commonly cultivated (Irvine *et al*., 2019; Herrscher *et al*., 2018; Decaix *et al*., 2019; Messager *et al*., 2015). More specifically, P_{aq} values illustrate that aquatic macrophytes are common near Mokhra-Blur and Shengavit settlements in the Ararat Plain, indicating the processing of aquatic plant species from freshwater rivers and lakes (Dunne *et al*., 2016; Ficken *et al*., 2000). Five extracts from Shengavit, Gegharot, Margahovit, and Karnut-1 confirmed the processing of plant wax, as the distribution of odd-over-even preference for the $C_{25:0}$ to $C_{31:0}$ *n*-alkanes is characteristic of an origin from plant lipids and epicuticular waxes (Figures 4.9 and 4.16) (Dunne *et al*., 2016; Dunne, 2021; Kolattukudy, 1976).

In addition to the main cereal crops such as wheat and barley, carbonized fruit and nut remains have been recovered and likely represent the plant-based dietary intake consumed and processed in these vessels. Plant lipid distributions are common at Shengavit, Margahovit, and Mokhra-Blur, but underrepresented at Karnut-1, Talin Tombs, Sotk-2 and Gegharot. Plant lipids are poorly mobilised resulting in limited transfer to the potsherd matrix (Dunne *et al*., 2016; Hammann and Cramp, 2018), and absorbed lipids are replaced over time, representing a mixture of foodstuffs cooked during the vessel's use-life (Miller *et al*., 2020). As such, low lipid recovery from Margahovit, Karnut-1, and Gegharot is likely due to plant-based food, which is tenfold lower than that of meat (Miller *et al*., 2020) (Appendix D, Table 2).

4.5.3 Aquatic commodities

All potsherds containing an appreciable amount of lipids were screened using GC-MS in selected ion monitoring (SIM) mode for the presence of ω-(*o*-alkylphenyl)alkanoic acids (APAAs) by scanning for the molecular ions ($M^{+\cdot}$) for APAAs of carbon chain lengths $C_{16:0}$ to $C_{22:0}$ at *m/z* 262, 290, 318 and 346 and the fragment ion of the base peak *m/z* 105. Aquatic biomarkers (APAAs $C_{18:0}$ to $C_{20:0}$ and traces of $C_{22:0}$, and isoprenoid fatty acids) were detected in 9 extracts (8%) (Figures 4.4 and 4.17; Tables 4.3 and 4.6; Appendix D, Table 2). Six of the extracts (G31, SH9, MB3, MG9, MG29, and MG33), contained all three isoprenoid fatty acids (IFAs), and an absence of APAAs. IFAs derive from phytol in marine algae (Cramp and Evershed, 2014; Cramp *et al*., 2019); 4,8,12-trimethyltridecanoic acid (TMTD), 2,6,10,14-tetramethylpentadecanoic acid (pristanic acid), and 3,7,11,15-tetramethylhexadecanoic acid (phytanic acid). The presence of APAAs in four lipid extracts (MB3, MG17, SH48 and SH68) suggests that the aquatic commodities were heated to high temperatures of >200°C in the pottery vessels (Hansel *et al*., 2004; Bondetti *et al*., 2020). Some extracts contained C_{18} APAA, but without C_{20} and C_{22} APAAs and isoprenoid fatty acids, these extracts were not labelled as sherds containing aquatic products (Evershed *et al*., 2008a; Cramp and Evershed, 2014; Appendix D, Figure 2).

Due to the low recovery and taphonomic bias of fish remains across Kura-Araxes archaeological sites, evidence for the consumption of marine and/or freshwater resources is lacking, and preservation can be problematic (Cramp and Evershed, 2014). A plethora of fish species are available across the region including *Cyprinidae* and *Salmonidae* (Decaix *et al*., 2019). The presence of partial suites of aquatic biomarkers (APAAs and IFAs) in potsherds confirms the processing of freshwater fish resources by KA inhabitants at Gegharot, Shengavit, Mokhra-Blur, and Margahovit, establishing diversity in food sources exploited. This is unsurprising due to the vicinity of river systems and freshwater lakes (Figure 4.25), including confirmed fish consumption through stable isotopic analysis on bone collagen at Chobareti, a neighbouring site in Georgia (Messager *et al*., 2015). The low amount of aquatic processing in potsherds complements the low abundance of fish bones found in faunal assemblages. Since APAAs form at >200°C temperatures, it is possible to suggest that not all pots were cooked at boiling temperatures (Hansel *et al*., 2004; Bondetti *et al*., 2020).

Table 4. 6. Summary of aquatic biomarkers detected in KA vessels from the studied sites. Key: tr (traces). No Dihydroxy fatty acids were detected and therefore a column has not been included for this category.

Site	Location	Lab code (potsherd)	APAAs	IFAs
Gegharot	Mountainous; Near Aragats Massif	G31	-	TMTD, pristanic, phytanic
		G32	-	Phytanic
		G35	-	Phytanic
Karnut-1	Mountainous; Near Kasakh River	KRT34	C_{18}	-
		KRT56	C_{18}	-
		KRT59	C_{18}	Phytanic
Margahovit	Mountainous; Near Lake Sevan	MG2	-	Phytanic
		MG9	-	TMTD (tr), pristanic, phytanic
		MG16	-	Pristanic
		MG17	C_{18}, C_{20}(tr), C_{22}(tr)	Phytanic(tr)
		MG23	-	TMTD, pristanic
		MB26	-	TMTD, pristanic
		MG28	-	Phytanic
		MG29	-	TMTD, pristanic, phytanic
		MG33	-	TMTD, pristanic, phytanic
		MG43	-	Pristanic, phytanic
Mokhra-Blur	Ararat Plain; Low-land	MB3	C_{18}, C_{20}(tr), C_{22}(tr)	TMTD, pristanic, phytanic
		MB4	C_{18}	-
		MB7	C_{18}	-
		MB8	C_{18}	-
		MB10	C_{18}	-
Shengavit	Ararat Plain; Low-land	SHK6	C_{18}	-
		SH9	-	TMTD, pristanic, phytanic
		SH21	-	TMTD
		SH48	C_{18}(tr), C_{20}(tr), C_{22}(tr)	TMTD, phytanic
		SH63	-	Phytanic
		SH68	C_{18}, C_{20}, C_{22}(tr)	Pristanic, phytanic
		SH72	-	Pristanic, phytanic
Sotk-2	Mountainous; Near Lake Sevan	SK6	-	TMTD, pristanic
		SK23	-	TMTD, pristanic
		SK46	-	Phytanic
		SK51	-	Phytanic
Talin Tombs	Mountainous	T2	-	Phytanic

4.4 Conclusion

This chapter presents results of animal fats, plants, aquatic resources, as well as non-dietary natural products such as tars and resins processed in Kura-Araxes archaeological pottery. The results reported here provide the first lipid residue analysis of potsherds from the South Caucasus region, an outlook of dietary practices from multiple sites. Further discussion of the commodities processed, the diversity of culinary and dietary practices, and the overall interpretation of the KA social structure is provided in Chapter 5. Overall, results presented in this chapter are discussed site-by-site and by commodities: terrestrial resources, plant (including waxes and resins) exploitation, and aquatic products.

This section presented and discussed novel data in understanding Kura-Araxes foodways, as well as the use of KA vessels. The following conclusions can be made:

- The $\delta^{13}C$ values of lipid residues reflect a consistently C_3 terrestrial diet throughout the EBA Armenia, as attested by archaeobotanical evidence; Hovsepyan, 2015; Herrscher *et al*., 2018; Martin *et al*., 2021. However, a slight enrichment in $\delta^{13}C$ values exhibited at Shengavit, Mokhra-Blur and Sotk-2, indicates the grazing of C_4 vegetation which broaden the $\delta^{13}C$ values (salt marshes) (Drake, 1989; Couto *et al*., 2013).
- Dairying was not the main commodity detected in residues, and commodities include a wide range of resources (plant, non-ruminant and ruminant animal carcass fats) across all sites.
- Aquatic resources were detected in 9 extracts (8%), suggesting a low input of freshwater resources widely available across all settlements.
- Similar subsistence practices were not observed across KA sites. Diversity of diet and culinary practices suggest local adaptation to environments and natural products.
- Terpenoids and diterpenoids were detected at various settlements, revealing both birch bark tar and resin through the exploitation of *Pinus* species.

CHAPTER 5

Kura-Araxes Pottery Use and Production in the EBA:

Synthesis Discussion

5.1 Introduction

This chapter synthesises and discusses results presented in Chapters 3 and 4 and reflects on the overarching research questions and aims presented in Chapter 1, emphasising insights that can be established from the analysis of the Kura-Araxes (KA) pottery tradition through a multi-analytical approach, as well as comparing the findings with previously published studies. Reiterating the research questions set out in Chapter 1, this chapter synthesises results through the following research questions: (1) pottery production and technological analysis, (2) culinary practices, inferences on the direct use of pottery and diet, and (3) the reconstruction of KA socio-economy and societies. In short, Chapter 1 – Section 1.6.1, how was KA pottery produced and what was it subsequently used for? Research questions comprised two significant dimensions (transformation and transmission) repeated under each heading and discussed in Sections 5.2, 5.3 and 5.4. Lastly, the overall question is discussed and synthesised in Section 5.5 (*how do culinary traditions and craft production reflect the socio-economic organisation of Kura-Araxes communities*)?

Chapter 3 investigated a detailed analysis of KA pottery in terms of production technology through the identification of inclusions, temper, and any manufacturing processes visible *via* microscopy methods. Chapter 4 provided new information on the organics produced and consumed in KA vessels, as well as a reconstruction of the overall diet site-by-site. ORA (organic residue analysis) results yielded a high concentration of lipids (average concentration of extracted lipids, 244.3 mg g^{-1}; highest, 3384.9 mg g^{-1}), which allowed this study to infer on plant processing, since plant lipids are poorly mobilised in the ceramic matrix and are generally low in concentration in ORA studies, as exemplified in experimental work (see Hammann and Cramp, 2018; Miller *et al.*, 2020). The high lipid preservation achieved through ORA work in this project allowed this project to investigate plant processing lipids, providing direct evidence of plant processing in the EBA (Early Bronze Age) by KA communities settled in Armenia. Chapter 4 also discussed vessel usage and commodities processed in KA vessels.

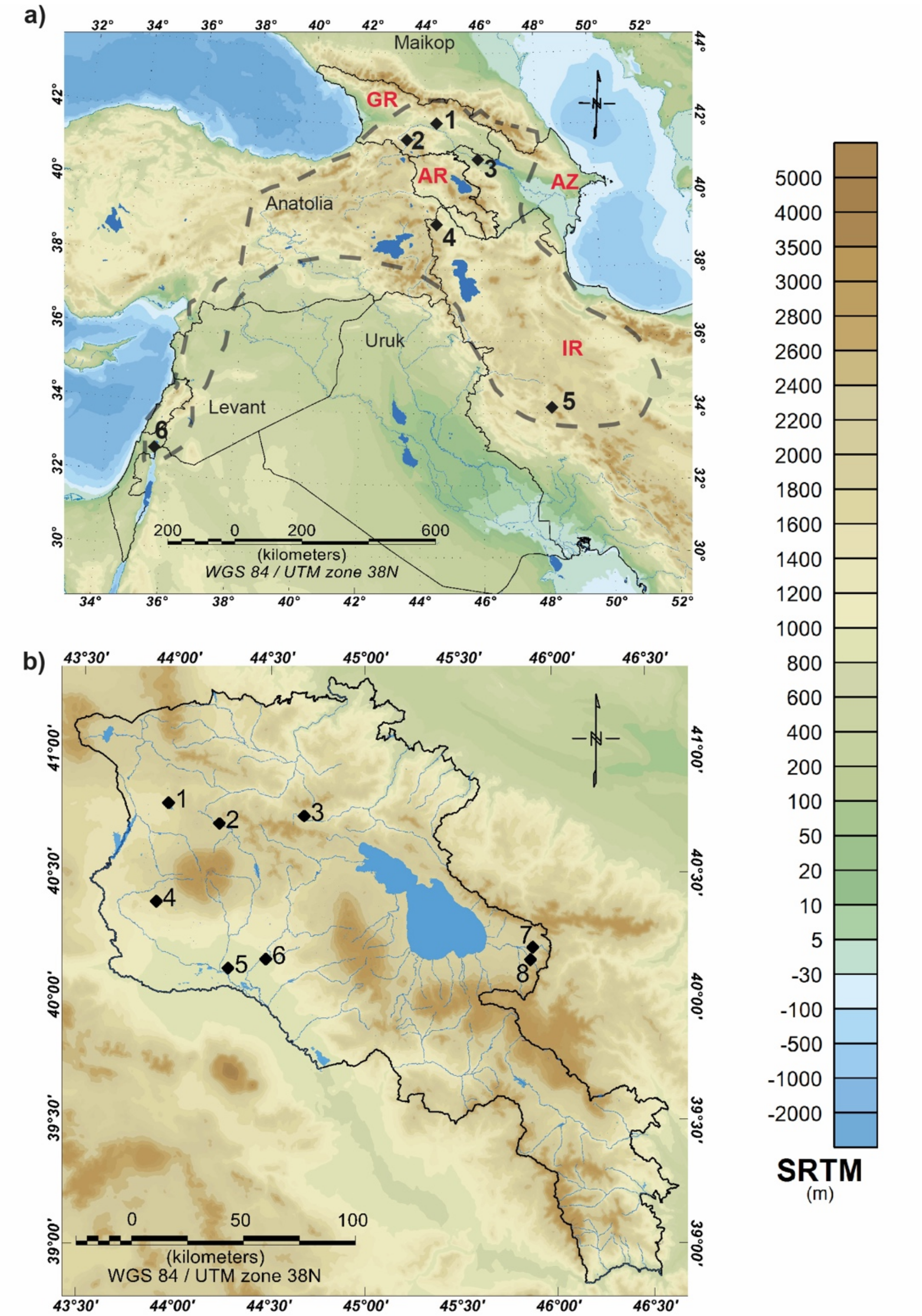


Figure 5. 1. (a) Topographic map of the Caucasus and Ancient Near East displaying the extent of the Kura-Araxes cultural phenomenon in dashed lines, approximated (AR is Armenia, GR is Georgia, AZ is Azerbaijan and IR is Iran), representing sites mentioned in text (1) Natsargora and (2) Chobareti in Georgia, (3) Mentesh Tepe in Azerbaijan, (4) Köhneh Shahar and (5) Godin Tepe in Iran and (6) Beth Shean in Israel. (b) Topographic map of Armenia, including rivers and one of the major freshwater lakes in the region, Lake Sevan. Sites: (1) Karnut-1, (2) Gegharot, (3) Margahovit (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1. These settlements are distanced between 17 and 176 km, where Shengavit and Mokhra-Blur are 17 km apart. Settlements are roughly 50-80 km apart. Maps modified using Adobe Illustrator by N. Manoukian. Maps produced by L. Manoukian using Oasis Montaj Software (www.seequent.com); SRTM 1, Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global.

5.2 Revisiting the *chaîne opératoire* processes

Research themes and questions:

- *Transformation: an assessment of the overall chaîne opératoire – how was KA pottery made and is there evidence of technological change and/or continuity among coeval KA settlement sites in the homeland 'core' region, South Caucasus? Is there evidence of technological uniformity/standardisation (i.e., methods of paste preparation, raw materials, production techniques, etc.)?*
- *Transmission: What were the main raw materials that formed KA pottery traditions across settlements in Armenia and is there a technological signature (i.e., volcanic ash and/or obsidian) that can be traced throughout archaeological sites in the South Caucasus?*

Chapter 1 covered what is known about the Kura-Araxes culture, as well as its pottery production. This section addresses the research framework and questions whether other KA settlements (published data regarding petrographic analyses) suggest similar patterns to the findings reported in this thesis. The comparison of pottery traditions across various Kura-Araxes settlements provides archaeologists with a tentative model for the *chaîne opératoire* traditions in varying physical and economic environments (Iserlis *et al*., 2010). Recent studies applied to Kura-Araxes ceramics incorporate the archaeometric characterisation of ceramics providing a broader view of the production systems, organisation of production and *chaîne opératoire* (Iserlis *et al*., 2010; 2015; Hovsepyan and Mnatsakanyan 2011; Heydarian *et al.*, 2020). Kura-Araxes pottery assemblages from the sites examined in this thesis represent the 4th and 3rd millennium BC and development of pottery traditions during the EBA period. As mentioned in Chapter 1.5, archaeometry studies on ancient ceramics from the Caucasus region have focused mainly on the study of morphological and decorative attributes of the vessels to shape our understanding of technological development, in terms of inter-regional connections between sites and regional areas (i.e., Georgia, Armenia, Azerbaijan, the Levant, Anatolia and northwestern Iran; Figure 5.1). Petrographic data from this thesis will be discussed and compared with published petrographic data from the region in Sections 5.2 and 5.3.

Fundamental questions in ceramic analysis include aspects of production, specialisation, connectivity, innovation and technological transfer (Quinn, 2013; Roux and Courty, 2019; Spataro *et al*., 2019). The production of pottery and the subsequent use of this predominant prehistoric craft provides clues into the economic and social choices of past potters. Ceramic style and technology are not static. While ceramic styles represent the basis of typological analysis, technological analysis represents another avenue in understanding changes in potters' choices of pottery production. The analysis of new ceramic styles and/or new technological features can help archaeologists identify specific relationships in societies (Latour, 2005). *Chaîne opératoire* analysis allows archaeologists to describe the actions of ancient potters in a series of operational steps grounded by the social and cultural setting (Iserlis *et al*., 2010: 246; Dobres, 2000; 2010; Edmonds, 1990; Eramo, 2020; Nelson, 1991; Giacomo, 2020; Livingstone Smith, 2007; Pelegrin *et al*., 1988). This social archaeological investigation is possible through petrographic analyses, where the raw materials and choices of potters are visible on a microscopic scale. These choices can serve either functional needs for pottery production, social purposes and/or symbolic (Arnold, 1985; 2005; Gosselain, 1998; 1999; Livingstone Smith, 2007; Miller, 1985).

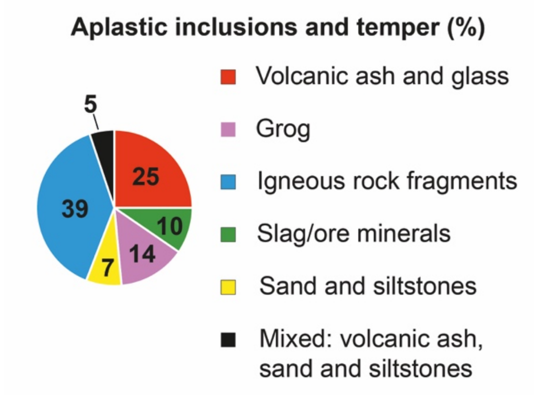


Figure 5. 2. Aplastic inclusions and temper recorded at all KA sites examined in this thesis through thin-section petrography (Gegharot, Karnut-1, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs). Results presented in percentage (%).

In Chapter 3, potsherds from several KA sites (Gegharot, Karnut-1, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs) were examined using microscopy techniques. The microscopy and chemical results were discussed in Chapter 3.4, regarding the dataset of 420 potsherds analysed through stereomicroscopy, 140 thin-sections, and 17 fine-ware potsherds for SEM-EDS. Results suggest that KA potters used a wide range of raw materials at each settlement to produce pottery vessels (see Chapter 3.5 and Figure 5.2). However, at some settlements, the use of various types of aplastic inclusions indicates a preference of diverse raw materials, as opposed to a standard technological signature. This is implied by the multiple fabric pastes recorded at a few sites. For example, at Shengavit and Mokhra-Blur, grain-sizes varied, and potters preferred raw materials ranging from volcanic ash as well as sandstone coarse-wares. In contrast, at Margahovit, Sotk-2 and Norabak-1, fine- to medium-grained vessels were more common and pastes were less diverse. Standardisation in the manufacture of KA vessels appears to be more common at some settlements than at others. Furthermore, the fabric pastes differ widely, ranging in the use of raw materials such as sandstones, siliceous clay, grog, volcanic ash and igneous rock fragments (Figure 5.2).

A diverse set of resources were used locally at each settlement, hypothesised as local pottery production. Based on the findings, it is possible to suggest that volcanic ash and medium-grained igneous rock fragments as natural inclusions (quite possibly temper) were the common raw material across all KA settlements examined. A household production and industry focused on community specialisation (Costin and Hagstrum, 1995) most likely exemplify the socio-economic structure of KA potters and inhabitants at these settlements. Community specialisation in pottery production describes "autonomous individual or household-based production units, aggregated within a single community, producing for unrestricted regional consumption" (Costin and Hagstrum, 1995: 621).

Furthermore, based on comparative petrographic studies from other KA settlements in Armenia, local readily-available clay has been suggested by Iserlis *et al*., (2010; 2015). Tempering the clay does not appear to be a major technological marker of KA pottery reported here. However, it is important to note that differentiating between temper and aplastic inclusions naturally present in the procured clay is a challenging task. Without appropriate clay samples from the region and near sites, these interpretations require further research and analyses (Rice, 2015). As such, additional clay samples are required to strengthen the study. Moreover, rock fragments of various grain sizes can occur naturally within the clay. Due to the vast heterogeneity displayed in the geological characterisation of Armenia, clay samples can aid in future petrographic interpretations (see Chapter 3.1 – Section 3.1.3; Figure 3.3 for geological map).

Grog (crushed recycled pottery) is a technological marker reported at KA sites in northwestern Iran (Heydarian *et al*., 2020; Mason and Cooper, 2009) and in Georgia (at Khashuri Natsargora; Babetto *et al*., 2021). In this thesis, four out of eight KA sites examined yielded some evidence of grog inclusions, low in quantification (14%; Gegharot, Fabric 2; Shengavit, Fabric 3; Karnut-1, Fabric 2; Talin Tombs, Fabric 1). Moreover, it has been suggested by Babetto *et al*., (2021) that fine-wares illustrate crushed fragments of obsidian added to the paste at the KA settlement in Natsargora Georgia; however, the fine-wares examined in this thesis *via* SEM-EDS establish volcanic glass morphologies as rhyolitic tuff and other fragments of volcanic ash typically > 60 wt% of SiO_2 (Chapter 3.4). Various scholars have suggested obsidian as temper and aplastic inclusions in KA pottery (Hayrapetyan, 2008; Hovsepyan and Mnatsakanyan, 2011; Iserlis *et al*., 2010; 2015). However, it is important to note that these interpretations have implications, as obsidian can often be misidentified. Obsidian lava flows in the South Caucasus and eastern Anatolia are localised (Palumbi *et al*., 2014; Frahm *et al*., 2016) and identifying such inclusions would allow archaeologists to geo-reference the raw materials directly, as obsidian is geochemically unique. Essentially, distinguishing between these volcanic ash and glass morphologies is significant in establishing provenance, as well as reconstructing pottery technology. Careful work is required in future pottery analysis studies in the South Caucasus, as the geological characterisation of the region comprises complex geological signatures of various pyroclastic and igneous rocks. The extent of volcanic ash (rhyolitic tuff, pumice and scoria) used in KA pottery implies the importance of clay exhibiting natural inclusions of volcanic ash and other volcanic sources of temper. The direct identification of rhyolite, dacite and trachyte inclusions was possible through SEM-EDS and some thin-sections (Chapters 3.3 and 3.4).

One of the technological steps (forming methods) interpreted as part of the *chaîne opératoire*, is similar across various settlements. Chapter 3.5 reported a few identifiable hand-built forming methods, particularly hand-built slab production, coiling (the formation of relic coils to shape pottery), and the drawing of clay upwards during the production process to achieve the desired shape. Coiling is a technique where the potters form thin worm-rings and pinch the clay to form a pot (Rice, 1987: 124-125). This technique is visible in thin-section, based on the circular alignment of inclusions (Quinn, 2013: 177). These interpretations are drawn based on the alignment of inclusions (i.e., circular motion for coils), as well as some striations visible on the whole vessel, macro-scale. While whole vessels were not consulted for this study, an area that might be explored by future researchers, whole vessels should be conducted to assess the common forming methods observed across KA sites during the EBA.

Based on the diversity of fabric pastes, specifically the use of various raw materials, across sites examined, potters at these KA settlements did not follow a specific technological regimen to prepare the pottery paste. In this step of pottery production, regional variation across KA settlements is quite common (Smith, 2015: 109; see Palumbi and Chataigner, 2014 for a similar interpretation). It is important to note that further work requires in refining the chronological resolution of these KA settlements, as well as the associated limited contextual information (outlined in Chapters 1 and 2). Potsherds from these settlements represent the EBA (KA I 3600/3500-2900 BCE and KA II 2900-2600/2500 BCE), which spans a thousand years (Badalyan, 2014). In general, the assemblage examined in this thesis covers the end of the EBA (KA II). Further work must be conducted on refining the chronological resolution of KA contexts, as well as the overall EBA period in this region.

Raw material procurement is most likely a local adaptation to the access of available resources, as well as the procurement of a standard clay that can be constantly used for technical success within settlements. At Gegharot, pottery production is quite uniform; potters preferred igneous clasts and inclusions as a tempering method. In contrast to this, potters at Shengavit and Mokhra-Blur preferred multiple raw material sources (sandstones, grog—crushed pottery, volcanic ash, igneous clasts, basalt, etc.). The use of various raw materials implies that standardisation was quite limited at these sites. However, at Gegharot and Margahovit, potters were most likely using the same outcrop of clay, which might indicate a more standardised approach to pottery production, as well as craft specialisation. Furthermore, the medium-grain sized fabrics and less fine-pastes recorded at Mokhra-Blur and Karnut-1 suggest that potters did not heavily refine and/or levigate the clay prior to forming the vessels. This is contrasted at settlements where fine-paste sherds are evident (Gegharot, Margahovit, Norabak-1, Shengavit, Sotk-2 and Talin Tombs).

Based on the geology of Armenia, local clay most likely included a variety of igneous clasts and volcanic ash. For instance, at Gegharot, sources of andesite, trachyandesite, andesite-dacite, dolerite-basalt lava flows, tuffs, tuffaceous conglomerates, and tuffaceous sandstones are available locally. Based on the analyses presented in Chapter 3.3 (Section 3.3.1), tuff does not appear to be a common component of the fabric recorded at Gegharot, despite its availability as a raw material source near the site of occupation (see geological map, Figure 3.3). Compared to neighbouring sites, such as Karnut-1, tuff (and other volcanic ash morphologies) is quite common as one of the main components found in the clay matrix, as well as at further sites such as Shengavit, Mokhra-Blur and Talin Tombs. Potters most likely preferred specific clay for their pottery production (*chaîne opératoire*). This point agrees with Iserlis *et al*., (2015: 21) and their observation that Kura-Araxes potters employed 'technological conservatism' and that at each KA settlement examined, potters practiced their unique technological *chaîne opératoire*.

Once clay sources were collected, potters followed various steps to form the KA vessels. For instance, 'clay mixing' is a term used to describe the use of more than one clay type (Rice, 1987; 2015). It is possible to suggest, based on data presented in Chapter 3.5, clay mixing was common at Shengavit, Mokhra-Blur and Talin Tombs. Clay typically rich in volcanic igneous clasts was mixed with sedimentary-based clay rich in sandstones (see Chapters 3.4.2 and 3.4.3; Mokhra-Blur Fabrics 2 and 3, and Shengavit Fabric 4). Significantly, Gegharot, Margahovit, Karnut-1, Shengavit and Talin Tombs potters preferred igneous-rich raw materials, which were further refined and levigated for finer pastes. Coiling was also a common method of forming reported at KA settlements discussed in Chapter 3.5.

In terms of the overall surface treatment and design of KA pottery, it is possible to suggest that the burnishing technique was achieved through the use of a tool (most likely a pebble), which was applied when the pot was leather-hard (Lepère, 2014). Most of the inclusions are aligned parallel to the surface, which indicates careful hand-burnishing (Quinn, 2013: 182; Santacreu, 2014: 79). Based on the analysed thin-sections and SEM-EDS potsherd samples, slipping has been observed at six out of eight sites (Karnut-1, Margahovit, Mokhra-Blur, Shengavit, Sotk-2, and Talin Tombs). Slips were observed at Shengavit through SEM-EDS and all other site observations were reported through thin-section optical microscopy. While slips were observed at six sites examined in this thesis, potsherds displaying clear slips are generally quite rare in the petrographic findings. It is significant to note that studies suggest slips were common for KA potters and that this technology further spread southwest to the Levant region (Khirbet Kerak, Chazan and McGovern, 1984: 34; Greenberg, 2007). Slips most likely aided the burnishing step for KA potters, adding a thin layer to work with finished vessels.

Perhaps burnishing vessels was merely a stylistic expression, as well as a functional one (Rueff *et al*., 2021). Burnishing reduces the permeability to liquids through the vessel walls (Ionescu *et al*., 2015). Ionescu *et al*., (2015: 23) also claim that upon firing, burnished vessels show a better resistance against thermal shock cracking, because of the water-saturated walls and hence a smaller thermal gradient. Essentially, burnishing may have improved the heating efficiency of cooking pots (Schiffer *et al*., 1994). In Chapter 3.4, a high quality burnishing procedure was suggested for KA pottery. The nature of this technique requires practical skill and an essential labour-intensive and time-consuming component of the production process of pottery (Ionescu and Hoeck, 2020).

Based on the visual estimation through thin-section petrography and SEM-EDS, it is likely that firing temperatures ranged between 650-800 ºC, in order to achieve a reduction environment (Babetto *et al*., 2021). It has been argued that high firing temperatures are required for reducing conditions (Maggetti, 1982; Maggetti *et al*., 2011), but without the evidence of furnaces and kilns, it is difficult to interpret the firing temperature and regimen directly. For instance, the reduced black Greek Attic wares underwent a great degree of vitrification and sintering, which resulted in the closure of the fine pores (Tite *et al*., 1982: 124). Rice (2015: 175-177) mentions that the sintering and closing of fine pores produces a highly technical form of pottery. It is possible that bonfire or pit-firing was the main firing technology employed by Kura-Araxes inhabitants at various settlements, as various sites yielded multiple small pits (i.e., at Shengavit; Rothman, 2017). Incomplete oxidation and the variable firing temperatures recorded across the KA assemblage examined here suggest the variation of fuel sources. Chazan and McGovern (1984: 23) state that, "the assumption of an open pit firing also helps to explain a peculiarity of most of the red and black lustrous examples. While the interior of the vessel and the exterior rim were exposed to air throughout firing, the remainder of the exterior was in a reducing atmosphere until just near the end of the firing." Furthermore, they claim that this effect could have been achieved in an open pit firing by packing organic material as fuel around the vessels, thus smoking and cutting off oxygen to its exterior (Chazan and McGovern, 1984: 23). According to VanValkenburgh *et al*., (2017), kilns do not necessarily reach higher temperatures than open firings. This is based on Gosselain's (1992) survey of open firings, noting the highest temperatures ranging 800-945 ºC. As such, Rice (2015) also suggests that fresh fuel must be added regularly, due to the fact that smoke is produced, as gases are released from the fuel and the pottery itself. The KA pottery assemblage was most likely produced in a reduction environment, showing a wide range of oxidation, as the surface and pottery cores can vary between black, buff, orange, red, and even grey (Chapter 3).

Iserlis *et al*., (2010: 250) studied clay from Aparan III, which is a contemporary settlement near Gegharot. They concluded that the soils might appear in various places within the Aragats massif, the provenance of vessels cannot be determined on the basis of its clay and temper alone (Iserlis *et al*., 2010: 250). Reference clay material from other sites will aid in this investigation; however, it is possible that one or some of the sources surrounded Mount Aragats were obtained by potters. Kura-Araxes pottery was most likely produced locally, using selective raw materials to achieve optimum success in pottery production. At Gegharot and Karnut-1, potters procured raw materials from Mount Aragats and/or near the Kasakh River, due to the high frequency and amount of coarse inclusions of igneous rock fragments and volcanic-based inclusions (Smith *et al.*, 2009). Many minerals undergo alteration (MacKenzie *et al*., 2017: 30); the most common rock-forming minerals crystallize at relatively high temperatures and when they cool, they may be partly replaced by other minerals which are stable at lower temperatures. This alteration is visible in most fabrics associated with Gegharot, due to the nature of raw materials. Weathered feldspars are also very common at Gegharot (see Fabric 5, Chapter 3.4). Shengavit potters obtained clay nearby, rich in sandstones and volcanic ash, most likely near river-beds. The type of ash that appears to be distinguishable in thin-section petrography resembles glassy welded rhyolite tuff and glassy welded crystal tuff (Figure 5.3a and 5.3c; the *eutaxitic texture* as the main morphological characterisation of Shengavit ash inclusions (Figure 5.3b and 5.3d; Shengavit and Karnut-1 volcanic ash texture in fine clay matrices). These textural features have also been recorded as fabric components at other sites examined in this thesis, such as Mokhra-Blur (Figure 5.3e to 5.3h) and Talin Tombs (see Chapter 3.3 for fabric photomicrographs).

Essentially, based on the raw materials, forming methods, various firing temperatures and homogeneous surface treatment examined, the KA settlements analysed in this thesis suggest that there is no specific technological signature that can be traced across KA settlements. However, the *chaîne opératoire* is comparable across sites, where hand-built production and specific surface treatments most likely formed a specialised production process.

Grog, suggested by some scholars (Mason and Cooper, 1999), is not common across all settlements. While various raw materials were used, this step did not influence the final achieved product. The main technological marker appears to be common use of volcanic ash/glass and medium-grained igneous clasts as temper.

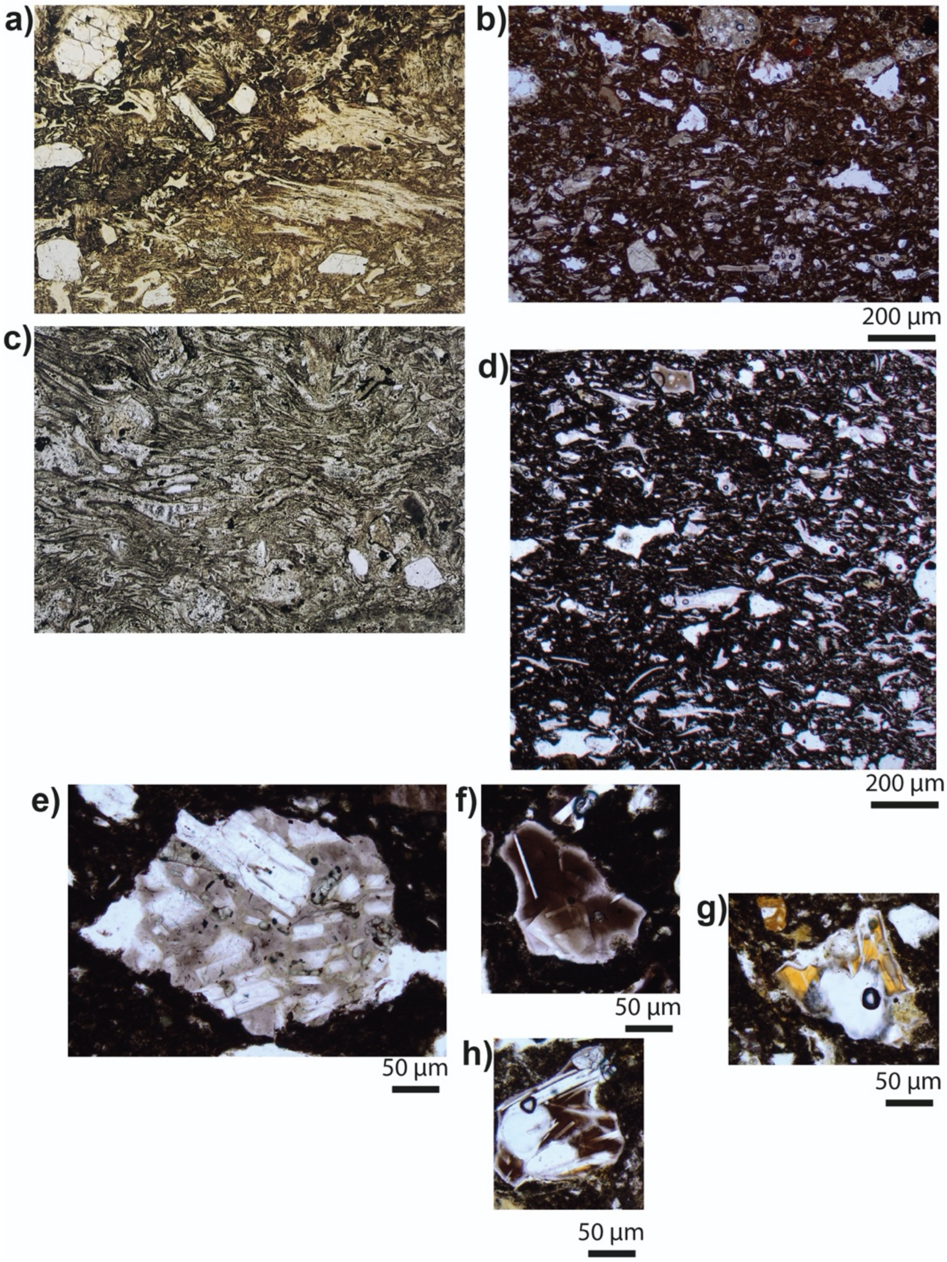


Figure 5. 3. (a) Glassy unwelded rhyolite tuff, with crystals of quartz and feldspar embedded in fine glassy particles known as ash. (b) Sample potsherd SH132 from Shengavit in PPL and x4 magnification. (c) The glassy matrix in this rock has an apparent discontinuous lamination caused by extreme compaction and welding of original pumice fragments. The regular alignment of the flattened fragments is known as eutaxitic texture. (d) Sample potsherd KRT59 from Karnut-1 in PPL, x2 magnification. (e) Sample potsherd MB7 from Mokhra-Blur in PPL and x10 magnification. (f, g, h) Sample potsherd MB10 from Mokhra-Blur in PPL, x10 magnification. Figures (a) and (c) reproduced from MacKenzie *et al*. (1982: 8); Figures (b), (d), (e), (f), (g) and (h) exemplify volcanic ash morphologies in potsherds analysed in this thesis.

5.3 Vessel use and function

Following the *chaîne opératoire*, post-firing and preparation of vessels, aspects of its use and function are related to decisions made by potters during the manufacturing process. Vessel use and function serve the purpose of these vessels. An emphasis is placed on the function of pottery (Sillar and Tite, 2000), by determining how potters constructed the vessels (i.e., fabric pastes and manufacturing technology) and what these pots were used for (Skibo, 2013; 2015). Oftentimes, pottery use, and function are included in the *chaîne opératoire* sequence as part of the life-history of the pot (Skibo, 2013; Sillar and Tite, 2000), but studies rarely combine these methods to infer archaeological questions, with few published to date (Spataro *et al*., 2019). Hommel *et al.*, (2017: 151) have suggested that craft production is intertwined with various environmental and economic restraints. As the potsherds examined in this thesis are fragments, the full typology and vessel design are unavailable. The organics embedded in pottery can shed light on what vessels were used for. Based on the KA pottery analysis from Chapter 3 (pottery technology) and Chapter 4 (dietary inferences and pottery use), there is no correlation between the fabric texture (fine- and coarse-wares) and organic residues embedded in the matrix. Both fine- and coarse-wares yielded residues, comprising various commodities, such as animal products and plant processing.

Findings reported in Chapter 4.5, *indirect* craft and technological production are interpreted by examining the products produced (i.e., birch bark tar production). This is an indication that KA pottery was used for non-culinary goods, as well as part of the KA economy. Birch bark tar was identified at Gegharot, Karnut-1, Margahovit and Shengavit (Chapter 4.5). Rageot *et al*., (2019) have conducted experimental studies, indicating multi-use vessels in the process of producing birch bark tar at archaeological sites in France. This study is compared with findings exemplified at the archaeological site of Margahovit in Armenia. This indicates the multi-functional tools KA pottery served for the EBA economy. Based on the strong heating markers identified in the potsherd extracts, KA pots were used for the production of birch bark tar following the 'double-pot' system proposed by Rageot *et al*., (2019; 2021). These pots are burnished and suggest the multi-function they served. Other plant sources include possible production of pine resin at Karnut-1 and Mokhra-Blur.

Furthermore, burnishing KA pottery most likely reduced the permeability of vessel walls (Ionescu *et al*., 2015). Most cooking and utility vessels observed at KA settlements are frequently burnished on their outer surfaces. Burnishing prevents liquid permeating to the outer surface, and this reduces heating effectively; as such, burnished vessels might be difficult for boiling foodstuffs. As a functional feature, burnishing vessels can be used for cooking stews or porridges, as suggested by Simonyan and Rothman (2015). Previous studies have noted that burnished pots were used as specialised cooking wares (i.e., at Tell Sabi Abyad in northern Syria; Nieuwenhuyse *et al*., 2015). The thermal resistance of burnished KA vessels makes them ideal tools for cooking, based on the high lipid recovery of burnished wares in experimental studies (Drieu *et al*., 2019). While some scholars have suggested that wine production is most likely a KA characteristic (Batiuk, 2013), further scientific investigations are required in defining biomarkers for such investigations (Drieu *et al*., 2020b).

5.4 Culinary and dietary inferences

This thesis provided results on the first application of organic residue analyses (ORA) of pottery from the South Caucasus, which is part of the missing step of the *chaîne opératoire* serving what these burnished vessels were used for, and subsequently, what was cooked in KA vessels? By answering the research questions posed in Chapter 1, Chapter 5 addresses questions about foodways, cuisine, dietary practices and the use of KA pottery in the EBA.

While studies have investigated crop and plant choices in the EBA (Hovsepyan, 2015; Herrscher *et al*., 2018; Martin *et al*., 2021), including animal and subsistence strategies (Summers, 2014; Wilkinson, 2014b; Davoudi *et al*., 2018), very few studies have considered a consolidated view of the subsistence and dietary practices of EBA inhabitants of the South Caucasus. Furthermore, the combined approach, alongside ORA studies, provides a significant outlook on the socio-economy in general.

An integration of archaeological findings alongside biomolecular evidence provides direct evidence on how both plants and animals were used economically in these societies, as well as what was cooked in the KA vessels. The biomolecular analysis of lipids from potsherds from Kura-Araxes settlements across Armenia provides strong evidence for a diversified diet, challenging the uniform socio-economic nature of these cultural communities defined by homogeneous pottery style and 'material culture package'.

As mentioned in Chapter 1, the current view suggests that KA communities are linked by a highly distinctive 'cultural package' despite vast geographic distances, comprising similar architecture, material culture, such as tools, metallurgy, and pottery styles across a wide territorial region (Sagona, 2018; Smith, 2005; Rothman, 2015). Material culture and pottery style display a profound level of uniformity across settlements in the core region, South Caucasus, and further expanding to territories in Anatolia, north-western Iran, Near East and the Levant (Sagona, 2018; Iserlis *et al*., 2015; Summers, 2014). Contrary to this, findings reported in this thesis demonstrate diverse subsistence practices occur across all settlements within Armenia, South Caucasus, and there are slight differences between highly contrasting environments, including mountains (Gegharot, Margahovit, Karnut-1, Talin Tombs and Sotk-2) and lowland river-based settlements (Mokhra-Blur and Shengavit). These findings from lipid residue analysis of Kura-Araxes pottery suggest differentiation in economic practices across settlements, environmentally-, and locally-driven. Thus, diversification in culinary and food practices was quite common in the EBA period (KA I-II; Chapter 2; Chapter 4), in contrast to neighbouring regions exhibiting a homogeneous diet, such as coeval Kura-Araxes settlements in Azerbaijan (Herrscher *et al*., 2018) and EBA settlements in Anatolia (Irvine *et al*., 2019). Lipid residue analysis provides compelling data that there is no strict uniform diet across Kura-Araxes settlements; dietary practices and food traditions are diverse and transformed KA communities to form local identities.

Results presented in Chapter 4 provide strong evidence for the exploitation of meat and secondary products (i.e., milk, cheese, yoghurt, butter, 'ghee', etc.), evident at various KA sites examined (see Chapter 4; reproduced overall diet, Figure 5.4). Dairy products are common in mountainous environments, as they provide necessary carbohydrates, fats, and nutrients to survive in harsh environments (Carrer *et al*., 2016), including the ability to store products such as cheese, yoghurt, butter (ghee), etc. (Sherratt, 1983; Evershed *et al*., 2008b). Moreover, fermented dairy products retain nutritional value (Buttriss, 1997) and fermented milk is still widely consumed in Armenia and South Caucasus today (Thevenin, 2021). The identification of dairy products through lipid residue analyses supports the domestic nature of fauna found at the Kura-Araxes settlements examined and across mountainous zones of the South Caucasus; however, while dairying is prevalent in Anatolia (7^{th}-3^{rd} millennium BCE), Southwest Asia (Warinner *et al*., 2014; Irvine *et al*., 2019; Evershed *et al*., 2008b; Nieuwenhuyse *et al*., 2015; Chahoud *et al*., 2016) and Eurasia (Wilkin *et al*., 2020; 2021), a high predominance of dairying is not recorded at EBA KA settlements examined here, as biomolecular analysis of dairy residues constituted 31% (n = 36) of the potsherds overall, even though an intensification of secondary products was suggested based on the faunal evidence and kill-off patterns of domestic species (Appendix D, Table 1; Piro and Crabtree, 2017; Sherratt, 1983).

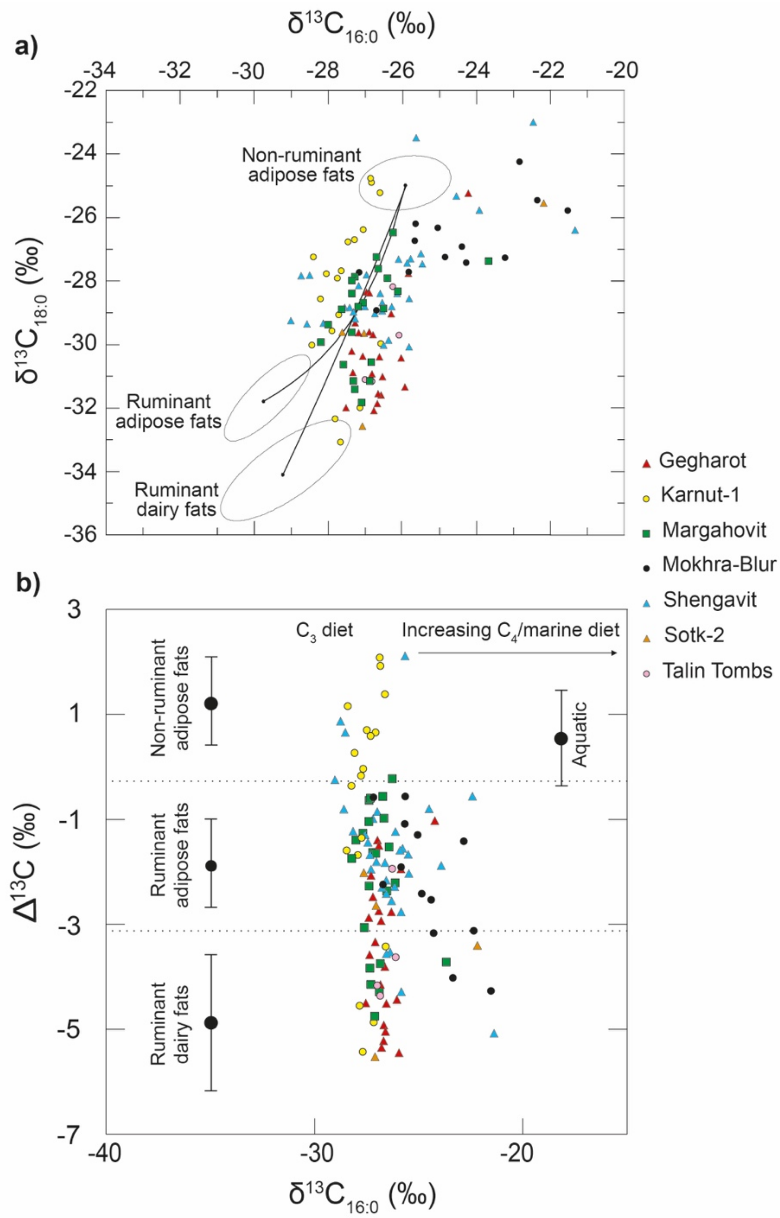


Figure 5. 4. Combined scatter plot showing (a) $\delta^{13}C$ values of the major fatty acid components (n-$C_{16:0}$ and n-$C_{18:0}$) prepared from lipid extracts from Gegharot, Karnut-1, Margahovit, Mokhra-Blur, Shengavit, Sotk-2 and Talin Tombs. The values of reference fats are represented by confidence ellipses ($\pm 1\sigma$) for animals raised on a strict C_3 diet (Copley *et al.*, 2003). The three annotated fields correspond to P = 0.684 confidence ellipses relating to modern fats of animals raised on a purely C_3 diet in Britain (Copley *et al.*, 2003). (b) The difference in the $\delta^{13}C$ values of the n-$C_{18:0}$ and n-$C_{16:0}$ fatty acids ($\Delta^{13}C = \delta^{13}C_{18:0} - \delta^{13}C_{16:0}$) obtained for the n-$C_{16:0}$ and n-$C_{18:0}$ fatty acids prepared from lipid extracts from all sites. Ranges depicted represent the mean ± 1 s.d. of $\Delta^{13}C$ values for a global database published elsewhere comprising modern reference animal fats from various geographical settings that include: Africa (Dunne *et al.*, 2012), United Kingdom (Dudd and Evershed, 1998), Kazakhstan (Outram *et al.*, 2009), Switzerland (Spangenberg *et al.*, 2006) and the Middle East (Gregg *et al.*, 2009). Each data point corresponds to an individual vessel. Refer to Chapter 4 for individual plotted sites and residues with evidence of plant processing. Analytical precision is ±0.3‰.

Scholars have suggested that animal husbandry was the foundation of KA's economic structure (Kushnareva, 1997; Kohl, 2009; Samei and Alizadeh, 2020; Samei *et al*., 2019; Simonyan and Rothman, 2015). As such, faunal patterns associated with the Kura-Araxes 'package' primarily suggest domestic species (Sagona, 2018), where over 50% of the domestic ungulates (in NISP) comprise of sheep, goat, and cattle (Decaix *et al*., 2019); i.e., at Köhne Shahar in Iran (Alizadeh *et al*., 2018; Samei *et al*., 2019), Chobareti (Messager *et al*., 2015) and Natsargora in Georgia (Rova *et al*., 2010) (see Figure 5.1 for a map of archaeological sites mentioned). Moreover, the earliest evidence of dairying reported in the Eurasian steppe (c. 3500-2500 BC; Wilkin *et al*., 2020; 2021) is contemporary to the KA cultural phenomenon. As such, Sherratt (1983) claimed that the secondary products revolution and the Uruk expansion coincided.

Perhaps the KA economy was not primarily reliant on secondary products and that other commodities were equally favoured (e.g., Karnut-1, Margahovir, Mokhra-Blur and Shengavit). However, at Gegharot, Talin Tombs, and Sotk-2, dairy products comprise over 50% of the potsherds analysed, exhibiting the importance of dairy products over other foodstuffs specific to these settlements, most likely due to the high cattle and caprines ratio (Badalyan *et al*., 2008). While these pots were most likely used for a variety of purposes, dairying was favoured at settlements in higher mountainous regions of >1000 m asl (Margahovit, Karnut-1, Talin Tombs, Sotk-2 and Gegharot) than lowland zones (Mokhra-Blur and Shengavit) (Chapter 4; Figure 5.4). Overall, 56% of potsherds contained ruminant adipose sources (Figure 5.4). The high percentage of carcass residues detected within the pottery vessels suggests that a meat-based diet was preferred over secondary products (Wilkinson, 2014b; Summers, 2014). The identification of ruminant carcass products, primarily at Gegharot, Shengavit, Mokhra-Blur, Margahovit, Sotk-2 and Talin Tombs, confirms that various domestic species and wild game formed an important element of the KA subsistence base, and played a large role in the diet of

EBA inhabitants. The main wild species hunted during the EBA was red deer (*Cervus elaphus*) at Shengavit and gazelle (*Gazella subgutturosa*) at Gegharot (Chahoud *et al*., 2016).

Previously published coeval human and faunal stable isotope analyses across the neighbouring region of Anatolia indicate a degree of homogeneity in dietary habits comprising terrestrial C_3 based domestic crops and animal proteins, primarily *Ovis* and *Capra* (Irvine *et al*., 2019). In terms of the KA, a homogeneous dietary pattern persists at various settlements, including Chobareti in Georgia (Messager *et al*., 2015) and Mentesh Tepe in Azerbaijan (Herrscher *et al*., 2018). While the EBA human diet focuses on sheep, goat, and cattle husbandry (milk and meat), various scholars have suggested that the KA economy is mobile, semi-nomadic and/or pastoralism, largely based on indirect proxies including archaeobotanical and zooarchaeological data (Kushnareva, 1997; Piro and Crabtree, 2017; Siracusano and Bartosiewicz, 2012; Badalyan *et al*., 2014; Samei *et al*., 2019; Decaix *et al*., 2019; Monahan, 2007). Due to the nature of transhumance pastoralism suggested by scholars, there is limited pig (*Sus* scrofa) faunal evidence implying commodities based on pig products. However, this is remarkably contrasted at Karnut-1, where the $\Delta^{13}C$ values are characteristic of non-ruminant adipose sources (i.e., pig) and/or mixed non-ruminant/ruminant adipose sources processed in vessels, comprising 55% of potsherds analysed (see Figure 5.4 and Chapter 4, Figure 4.8). Additionally, mixing curves display input of some non-ruminant sources at Margahovit, Mokhra-Blur, and Shengavit. These results do not correlate with observed faunal assemblages in the region, where pig remains are rare (Piro and Crabtree, 2017; Badalyan *et al*., 2008), questioning the food choices and overall economic structure of these communities. Moreover, it is possible that wild boar and other non-ruminant sources (i.e., bird) also contributed to the diet. Faunal remains classified as bird are fragmentary in the archaeological record (Reitz and Wing, 2008; Ledogar and Watson, 2019: 5618). Further investigation is required into the osteological data associated with these sites. A pastoral economy requires movement from mountainous to lowland zones (Hammer and Arbuckle, 2017); in contrast, a more sedentary lifestyle is required to maintain pigs. Possibly, due to environmental conditions, pigs were primarily kept in forested areas (Messager *et al*., 2017) of the north-eastern part of the Armenian Highland, i.e., at Margahovit and nearby settlements.

Significantly, the $\delta^{13}C$ values observed for the major fatty acids (n-$C_{16:0}$ and n-$C_{18:0}$), indicate the grazing and fodder of local environments. Clear differences are seen where Mokhra-Blur and Shengavit display local values in C_3/C_4 vegetation, in comparison to mountainous settlements comprising strictly C_3 vegetation such as Gegharot, Margahovit and Karnut-1 (Figure 5.4; see Chapter 4 for individual plots). These findings suggest that settlements were most likely agropastoral and/or sedentary (Sagona, 2018; Smith, 2005; Wilkinson, 2014b; Badalyan *et al*., 2014; Samei *et al*., 2019; Rova *et al*., 2010). Agropastoral communities are more robust (Honeychurch and Makarewicz, 2016), as the use of carts and ploughs provided opportunities, access to rivers, lake basins, and areas suitable for farming and dairy production to survive harsh winters in mountainous areas.

5.5 Towards an integrated biomolecular and archaeometric approach

The overarching aim of this thesis is to investigate the transmission and transformation of KA pottery and reconstruct aspects of the socio-economic organisation of KA settlements, through the lens of cuisine and crafts. As the KA is defined as an archaeological culture in the EBA, it is significant to assess the diverse patterns observed in the results. Archaeological cultures, in definition, are largely based on shared characteristics across timescales, landscapes, and regional extensions (Hofmann and Bickle, 2011). From a reconstructive point of view, it is evident that Kura-Araxes populations facilitated a diverse subsistence economy, exploiting local sources for pottery production, use, and cuisine. Distinct culinary practices across the examined KA settlements, highlight the heterogenous and complex nature of the socio-economic structure within the region. The high percentage of ruminant carcass fats alongside non-ruminant, aquatic and plant lipids, is likely due to the mixing of commodities, primarily focused on a high caloric intake of meat consumption, occasional vegetable, and plant-based sources concurrent with secondary products. Evidence of mixing of commodities suggests boiling, stewing, and steaming foodstuffs, confirming interpretations made through archaeological (Wilkinson, 2014b; Simonyan and Rothman, 2015) and ethnoarchaeological contexts of the region (Hovsepyan *et al*., 2016); however, it is imperative to note that lipids can be preserved and mixed over time through multiple cooking events (Miller *et al*., 2020). Much like pottery production, food preparation entails similar tasks of ingredient gathering, processing, and mixing (Hastorf, 2017); such tasks embody the human behavioural component of cultural transmission (Lévi-Strauss, 1966). Human-environment interactions with animals and plants encouraged the construction of cultural human behaviour in the past (Gosden, 1999), where commensality and food practices are intrinsically tied to social human behaviour, as well as shared identities (Kerner *et al*., 2015; Hastorf, 2017; Harris and Cipolla, 2017). Shared identities most likely correspond to the imitation of the KA pottery forming methods, style and surface treatment. However, the specific acquirement of temper and aplastic inclusions, as well as the organisation of the potting communities, slightly differed across settlements suggesting environmentally-driven choices based on local resources (Chapter 3.5).

These findings postulate the characterisation of archaeological cultures and/or *Kura-Araxes cultural phenomenon* based on the socio-economic structure of food traditions (Hastorf, 2017). Archaeological cultures are assigned due to a particular way of doing things, identity, and relatedness (Hofmann and Bickle, 2011); for instance, the Linearbandkeramik in Central Europe, a well-known 'pottery' culture, based on a shared identity (Harris and Cipolla, 2017). Thus, the shared 'material culture package' of KA represents a shared social signature, when occurred together, scholars termed these societies as homogeneous. However, through this investigation, it is clear that culinary practices and food traditions of the KA vary site-by-site in the 'core' area of this cultural phenomenon. Through biomolecular lipid analysis of potsherds, the proposed nature of Kura-Araxes cultural societies is challenged. Thus, the characterisations of the KA archaeological phenomenon, and/or the common definitions prescribed to pastoral societies in this region, require fresh new outlooks.

The socio-economic organisation of KA communities across these settlements suggests independent household industries and units (Canuto and Yaeger, 2000; Meskell, 2002; Costin, 1991: 621). It is also possible to suggest that the possible non-ruminant signature ($\Delta^{13}C$ values) displayed at various settlements (Karnut-1, Shengavit and Mokhra-Blur) suggests an urban household autonomy (Zeder, 1996: 298). Thus, the analysis of pottery production, pottery use and dietary inferences, most likely indicate independent household units following a network of knowledge transmission (Gosselain, 1998).

Based on the shared material characteristics of the KA culture, it is clear that there are slight technological differences across KA settlements through the analysis of pottery and in comparison to published data. The act of producing pottery is a socially-embedded task (Roux *et al*., 2018), where the *chaîne opératoire* or the sequence of manufacturing pottery is often referred to communities of practice (Lave and Wenger, 1991: 98; Gosselain, 2008). Production requires specialised labour (Costin and Hagstrum, 1995) and the 'know-how' of raw materials, especially to emulate the homogeneous burnished wares. The imitation of these styles suggests that potters and EBA inhabitants most likely networked and transferred ideas (transmission and transformation) but maintained region-specific and site-specific choices in raw material procurement. The Kura-Araxes 'cultural phenomenon' acts as a model system for other cultures, such as the LBK and Yamnaya, as mentioned. Understanding variability in pottery production and the subsequent use of pottery, alongside culinary traditions, evokes a significant contribution to archaeological research. Craft production is socially embedded and foodways are culturally intrinsic (Villing and Spataro, 2015: 13). In defining regional variation, these findings suggest that EBA settlements in Armenia and the South Caucasus resembled local hybridised household communities. Similar interpretations have been suggested by various scholars who interpreted regional differentiation based on architecture, size of settlements, and other macro-characteristics of material culture (Sagona, 2018; Palumbi and Chataigner, 2014).

The EBA spans a thousand years (c. 3500-2500 BCE) and the archaeological timescale is an important factor to consider when interpreting human behaviour spatially and temporally. Thus, findings reported in this thesis provide an overall trend, and the vast time-range should be considered when reconstructing the KA through different dietary practices and the characterisation of pottery groups. Various terms have been used in the current literature: *hybridization*, *cultural package*, *regionalism*, etc. Much of the literature has focused on the KA's diversification within its region of interest (South Caucasus), where homogeneous artifacts display some stylistic heterogeneity as well (Badalyan, 2014), which has sparked long-lasting debates on characterising this culture as a whole (Wilkinson, 2014a). Cuisine and food consumption are related to the economic organisation of groups (Wilkinson, 2014b: 210). As such, the analysis of archaeological pottery is a snapshot of past habitual lifeways contingent on human actions related to style, culture, technology, consumption, direct use of pottery, and subsistence.

5.6 Conclusion

The reconstruction of KA pottery technology (*chaîne opératoire*) and the analysis of absorbed residues in KA pottery provide new data and interpretations on the EBA cultural phenomenon of the South Caucasus, focused on Armenia. This thesis explores a combined interdisciplinary approach in defining ceramic complexes within archaeological cultures, where (1) cuisine and food traditions remain a cultural identity, and (2) the technological basis of pottery making is transferred via potters and close communities. This thesis presents data relevant to the broader discussion of EBA pottery traditions in the South Caucasus region. A microscopy investigation on 420 potsherd samples from selected Kura-Araxes settlements in Armenia provides data to define the fabric pastes, as well as the choices that potters adopted during the manufacturing process, such as, refining the clay, forming the vessel, firing, etc. (Rice, 1987; Peterson, 2009; Roux *et al*., 2018). This thesis also provides the first set of organic residue analyses of the region and period in question, culminating data for 164 potsherds spanning various KA settlements in Armenia.

The results reported here provide the first lipid residue analysis of potsherds from the South Caucasus region, an outlook on the dietary practices from multiple sites. These findings report the diversity of culinary and dietary practices across an archaeological culture and place the earliest evidence of dairying in Armenia and the South Caucasus region (c. 3500-2500 BCE), which is integral to our understanding of cultural evolution of prehistoric people residing in mountainous zones, including the interplay and relationships with neighbouring regions. While the $\delta^{13}C$ values of the major fatty acids (n-$C_{16:0}$ and n-$C_{18:0}$) in relation to faunal and archaeobotanical data support evidence for the exploitation of secondary products, meat and plant processing, the diversified sources consumed across settlements demonstrates a major dietary and culinary regimen unrelated to the overall Kura-Araxes cultural and EBA package reported previously. Rather than a pastoral communities of shared identities (Sagona, 2018), each settlement is structured based on a myriad of local socio-economic practices which formed the make-up and identity of cultural diversity (Palumbi and Chataigner, 2014; Messager *et al*., 2015; Herrscher *et al*., 2018). The diversity of diet and resource utilisation suggest social complexity in the EBA (Irvine *et al*., 2019) and that individually these societies were heterarchical (non-hierarchical) and community-based (Alizadeh *et al*., 2018; Samei and Alizadeh, 2020; Wilkinson, 2014b). This is a paradigm shifting notion, as culinary traditions may or may not be the main aspect of the KA cultural characterisation, but specific to each local community and/or environment. While Kura-Araxes settlements (Gegharot, Shengavit, Karnut-1, Mokhra-Blur, Sotk-2, Talin Tombs, and Margahovit), are linked with similar artefacts and other characteristics, the dietary regimen are not consistent, questioning the alleged social unity of these communities.

Considering the high preservation of lipids at archaeological sites in Armenia, the ongoing investigations into organic materials will likely shed light on many theoretical debates discussed by archaeologists over the past decades. Lipid residue analysis as a methodological focus has wider implications for prehistoric research, principally in how we define past cultures and lifeways, and is paramount to the holistic approach in synthesising material assemblages to reconstruct past human behavioural systems (Hastorf, 2017; Harris and Cipolla, 2017). The high abundance of animal foodstuffs detected in pottery, alongside plant and aquatic evidence, reflects the importance of both animals and plants in the diet, indicating an agro-pastoral and sedentary-based community structure. Compared with faunal, archaeobotanical and environmental data within and from neighbouring regions, results from this thesis may indicate that the dietary and culinary practices do not corroborate with the unified 'material culture package' under the umbrella of the 'Kura-Araxes cultural phenomenon'. Perhaps variability in cuisine and interregional diverse socio-economic practices marked by intensified farming, rather than uniform materiality, caused its daunting territorial expansion. This is imperative to note as KA was a 'global' phenomenon in the Near Eastern world (Wilkinson, 2014a), and its socio-economic structure places an importance to our understanding of wider prehistoric cultures and populations (Hofmann and Bickle, 2011).

These results can be compared with contemporary archaeological sites across the Ancient Near East, Caucasus, as well as neighbouring cultures in Eurasia, in order to understand technological and cultural processes imbued in pottery production and the extent of material cultures, as well as foodways. Thér *et al*., (2017) state that "the possible trajectories of the innovative process are approximated specifically through the polarities between product and process innovation and transmission of cultural traits in open and closed learning networks." The KA people occupied various areas of southern Caucasus marked by geological, environmental and ecological differences, as well as neighbouring regions across the Fertile Crescent. It is most likely that technological traditions moved around the landscape, forming cultural hybridity and interplay among potters and communities across the ancient Near East (Sagona, 2018). Evidence suggesting regional variation is visible through the various diverse choices of the *chaîne opératoires* (specific raw materials and temper choices), and less so with other technological choices (forming methods, surface treatment, firing, and occasional temper choices). The combination of biomolecular lipid residue analysis and microscopy (material analyses) provide a novel lens to investigate the socio-economic factors pertaining to prehistoric choices in the production of pottery, as well as the choice of products consumed in them.

CHAPTER 6

Conclusion and future directions

This thesis investigates and discusses the *chaîne opératoire* of Kura-Araxes pottery production, as well as characterising use of pottery as inferred from the survival of organic residues. Alongside this task, this thesis discusses the first analysis of lipid residues, diet and subsistence practices in Early Bronze Age (EBA) South Caucasus through the analysis of absorbed residues embedded in Kura-Araxes (KA) pottery at several sites in Armenia. The primary aim of this thesis was to investigate technological similarities and differences in pottery production, use of pottery as inferred from the survival of organic residues, and dietary inferences through organic residue analysis (ORA). As pottery is the main identifier of the KA cultural phenomenon, an integrated multi-analytical approach was applied to this material in order to investigate the archaeological questions outlined in Chapter 1 and discussed in Chapter 5.

The research questions are addressed through the application of a combined archaeological, microscopic, molecular, and isotopic approach. On the macro-level, variability in surface technique, firing and overall paste was suggested. On the micro-level, the results provided new insight for understanding the technological differences and similarities in pottery production across several KA settlements in Armenia and compared with published petrographic data. Followed by the assessment of the KA pottery *chaîne opératoire*, the assemblage was studied using the lipid biomarker approach and stable isotopic proxies, in order to reconstruct the direct use of pottery, food processing, cooking practices, and aspects of the socio-economic structure of the KA settlements examined (Gegharot, Karnut-1, Margahovit, Mokhra-Blur, Norabak-1, Shengavit, Sotk-2 and Talin Tombs). While the sample size lacked in a few regions (Norabak-1, Sotk-2 and Talin Tombs), this study is the first ORA analysis of the region and period in question, and future studies can expand on this sample set.

Findings in this thesis reveal the following: (1) There is some technological similarity in pottery production across coeval KA settlements in Armenia, with subtle differences in the *chaîne opératoire* aspect, such as temper, aplastic inclusions and raw material choices. (2) Standardisation appears to be more common at some settlements (Gegharot, Karnut-1, Talin Tombs), as opposed to others (Mokhra-Blur, Shengavit, Margahovit, Sotk-2 and Norabak-1). However, it is imperative to note that potsherds should be direct dated in order to conclusively compare and contrast techniques in pottery production, as the EBA covers a vast timescale. (3) Igneous rock fragments and volcanic ash were the main technological signatures and raw materials employed by potters in the overall region, following similar *chaîne opératoire* choices in forming and surface treatment design. (4) Organic residue analyses (ORA) suggest a diverse dietary inferences and food choices at each KA settlement examined. More specifically, findings suggest that the KA were agro-pastoral communities. As mentioned, scholars suggested that regional differentiation was quite common in the EBA, towards the end of KA II (2900-2600/2500 BCE, Badalyan, 2014; Sagona, 2018; Palumbi and Chataigner, 2014). Direct evidence from the production technology, use of pottery, and foodways, confirms these hypotheses. It is possible that the Kura-Araxes EBA inhabitants at these settlements maintained networks that may have facilitated technological transmission and practiced local economic strategies to foodways, implying communities structured on specialisation and household production (Costin and Hagstrum, 1995).

6.1 Clay provenance and chemistry of volcanic ash

For this thesis project, geological maps were consulted (Kharzyan, 2005), which aided the overall petrographic interpretations. However, a disadvantage of this study is that geological and clay sources were not obtained as comparative references for the general chemistry and geological characterisation of each site. This area of research is lacking and very few studies have published such comparable data (Iserlis *et al*., 2015). In order to strengthen interpretations on provenance pottery, understanding trade, networks, and the identification of temper (intentionally added rock fragments), raw materials and clay chemistry are required for this area of research. The absence of clay sources in this project was a limitation when comparing local fabrics and understanding the differences between naturally occurring aplastic inclusions and temper. A database of such fabrics and clay chemistry can immensely aid in future research on ceramic analyses of the South Caucasus region.

Analysing clay deposits and expanding the sample set to build a more robust understanding of clay availability and use will aid and strengthen petrographic descriptions and interpretations. Geochemical analyses using various established methods, such as Scanning Electron Microscopy-Energy Dispersive Spectrometry (SEM-EDS), Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and X-Ray Diffraction (XRD) can complement pottery studies (Hunt, 2016). Significantly, the abundant volcanic ash recorded in Chapter 3 can be analysed using Electron Probe Microanalysis (EPMA) in order to geo-reference and provenance ash deposits across Armenia and the Caucasus region; Chalcolithic obsidian-tempered pottery has been investigated using this approach (see Palumbi *et al*., 2014). Geochemical analysis allows the differentiation of compositional groups independently of the technological process/intentions of the potter (Thér *et al*., 2017). XRD can provide various avenues of pottery analysis, such as the estimation of firing temperature due to the changes of mineralogy recorded (Reedy, 2008: 184-185; Maggetti, 1982; Maggetti *et al*., 2011). Despite the advantages of thin-section petrography, XRD and SEM-EDS can provide direct evidence of the minerals present as well as bulk compositions compared with clay samples. These methods complement one another, and a standalone method does not address all archaeological questions pertaining to this project and beyond. It is hoped that this can be accomplished in the future.

In terms of pottery technology and petrographic analyses, a spatio-temporal investigation will aid in the understanding of pre-EBA (Neolithic to Chalcolithic) and post-EBA (Middle Bronze Age to Iron Age) pottery technology. Why did KA potters adopt the black-burnished style and why did this technological innovation change post-EBA and over time (i.e., oxidised red-slipped and burnished vessels after the Late Bronze Age and in the Iron Age; see Khatchadourian, 2018: 185)?

6.2 Expansion of dietary and culinary studies in the South Caucasus

In terms of the last step of *chaîne opératoire*, potters produced these vessels for cooking and other activities, as shown in Chapter 4 and discussed in Chapter 5. The analysis of absorbed lipid residues in pottery can provide a plethora of information, such as diet and direct use of pottery investigated in this project. The expansion of dietary inferences of the Kura-Araxes inhabitants across the South Caucasus, as well as neighbouring regions of the Ancient Near East will likely shed light on the overall structure of these societies—what were the major commodities processed across neighbouring regions? Were there other settlements characterised by non-ruminant input, as opposed to ruminant carcass fats? The limited amount of information available on stable isotopic analyses of human skeletal remains, as well as faunal data made this investigation difficult to conclude.

Additional solvent extraction can provide other detailed commodities, such as TAG distributions (Evershed *et al*., 1990; 1994). Data on TAG distribution to investigate animal fat origin would be important for additional interpretations on diet (Dudd and Evershed, 1998; Dudd *et al*., 1999; Copley *et al*., 2003). Additionally, statistical tests on lipid data (Bayesian statistics; mixing models, through the application of FRUITS) would be beneficial in understanding dietary inferences and variation spatially and temporally (Fernandes *et al*., 2018; Suryanarayan *et al*., 2021). Expanding these studies to include samples from whole vessels will provide an immense source of information, as fragmentary potsherds lack typological classification. In order to further investigate KA pottery function, sampling potsherd fragments that have been classified specifically as bowls, jars, pithoi, etc., can provide another avenue of research. Further analyses using High-Temperature GC-MS can shed light on the processing of other commodities, such as beeswax production (Roffet-Salque *et al*., 2015; 2017; Dunne *et al*., 2021). A spatio-temporal and chronological study of dietary inferences across the South Caucasus will shed light on the socio-economic organisation of the inhabitants of this region, as well as their relationship with the natural environment. More importantly, modern reference fats are lacking for the South Caucasus region. The absence of this data can cause interpretation challenges related to stable isotopic analyses. As a limitation of this thesis, reference fats can provide information on the $\delta^{13}C$ isotopic enrichment observed for the sites of Mokhra-Blur and Shengavit located in the Ararat Plain.

6.3 Chronometric resolution: ^{14}C direct dating of fatty acids in archaeological pottery

For future research, ORA research in the South Caucasus would benefit from radiocarbon dating extracted lipids, which is a recent development in the field of archaeological science and ORA studies. Given the high lipid preservation reported in this project (3384.9 mg g^{-1}), it would be useful to directly date the extracted lipids absorbed in pottery to resolve chronological inconsistencies in the archaeological record (Berstan *et al*., 2008; Casanova *et al.*, 2018; 2020a, 2020b). Typically, sherds containing lipid concentrations above 500 µg g^{-1} are selected for ^{14}C determinations (Casanova *et al*., 2020a: 1681). This will aid in the chronometric resolution of occupations, as well as directly dating the onset of dairying and other research questions archaeologists can explore in the South Caucasus region. A refinement of the chronology is required, specifically for the EBA, as well as other periods in the South Caucasus archaeological record. Furthermore, this thesis presented data that KA vessels were used as multi-functional tools, serving societies with cooking and other means of technology production, such as birch bark tar. Directly dating the extracted lipids from potsherds can place these technologies on a contextual baseline.

6.4 Final conclusions

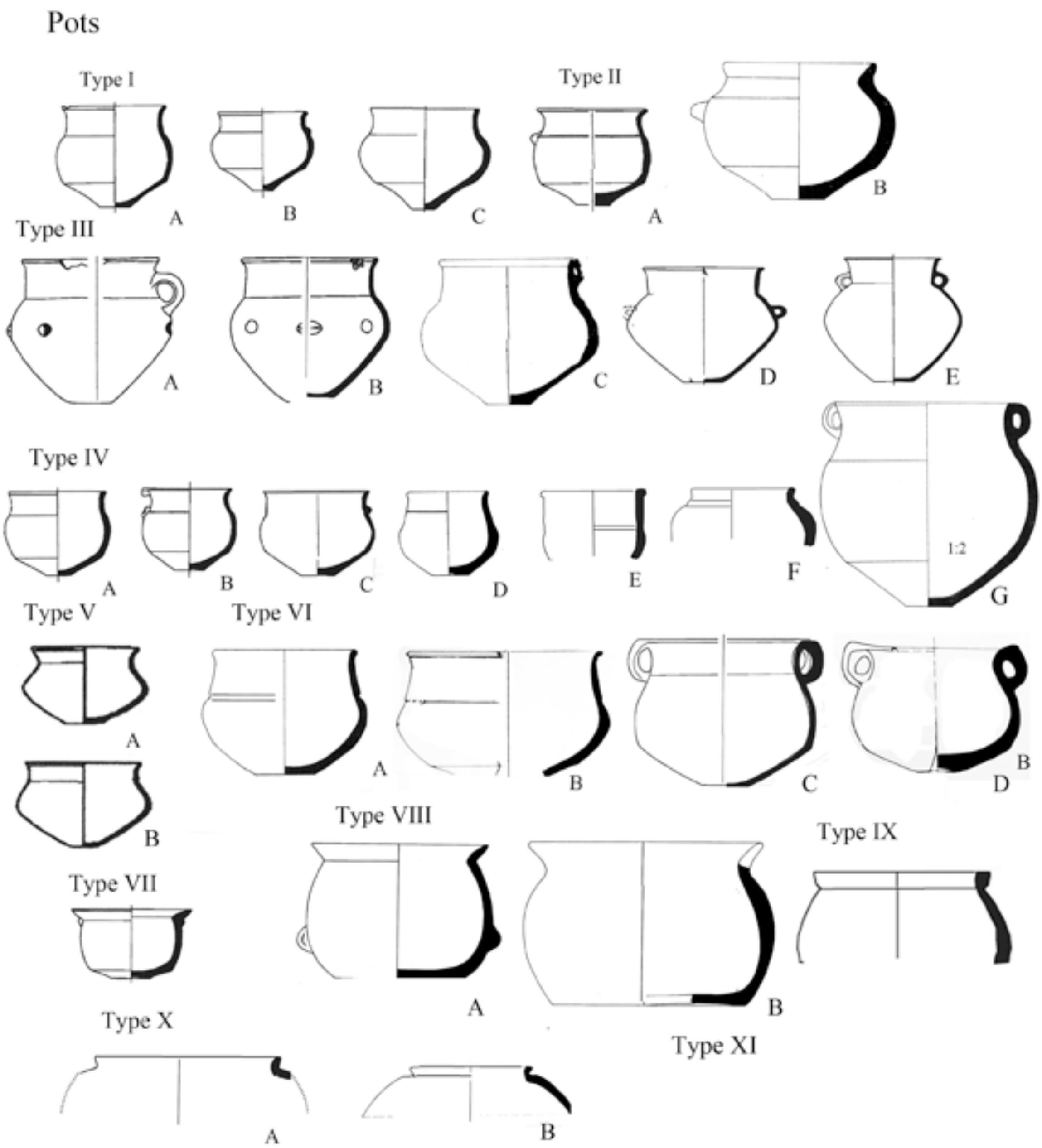
Through these areas, archaeologists can explore new avenues and methodologies in terms of combining compositional information of pottery (biomolecular studies, lipid residue analysis, stable isotopic proxies, archaeometry, etc.), with the aim of improving our understanding of human activity in the past. Gaps in research presented above will provide fruitful data to understanding and contributing ongoing research in the archaeology of South Caucasus. Significantly, coeval neighbouring cultures to the Kura-Araxes cultural phenomena, such as the Uruk and Maikop should be investigated alongside these research areas.

The research questions pursued in this project can be further expanded and investigated through the application of various methods at a larger number of sites. Strict sampling protocols will benefit research in areas where this thesis encountered limitations, i.e., the low number of samples analysed for both Sotk-2 and Talin Tombs (ORA and microscopy). Increasing the sampling size and methodological approach for sites in the South Caucasus will provide a robust basis for comparing other EBA (characterised as Kura-Araxes) settlements across the Ancient Near East. Chronological dating of these sites, including pre- and post-EBA will provide the basis for spatio-temporal analyses and defining differences in pottery use and craft production.

APPENDICES

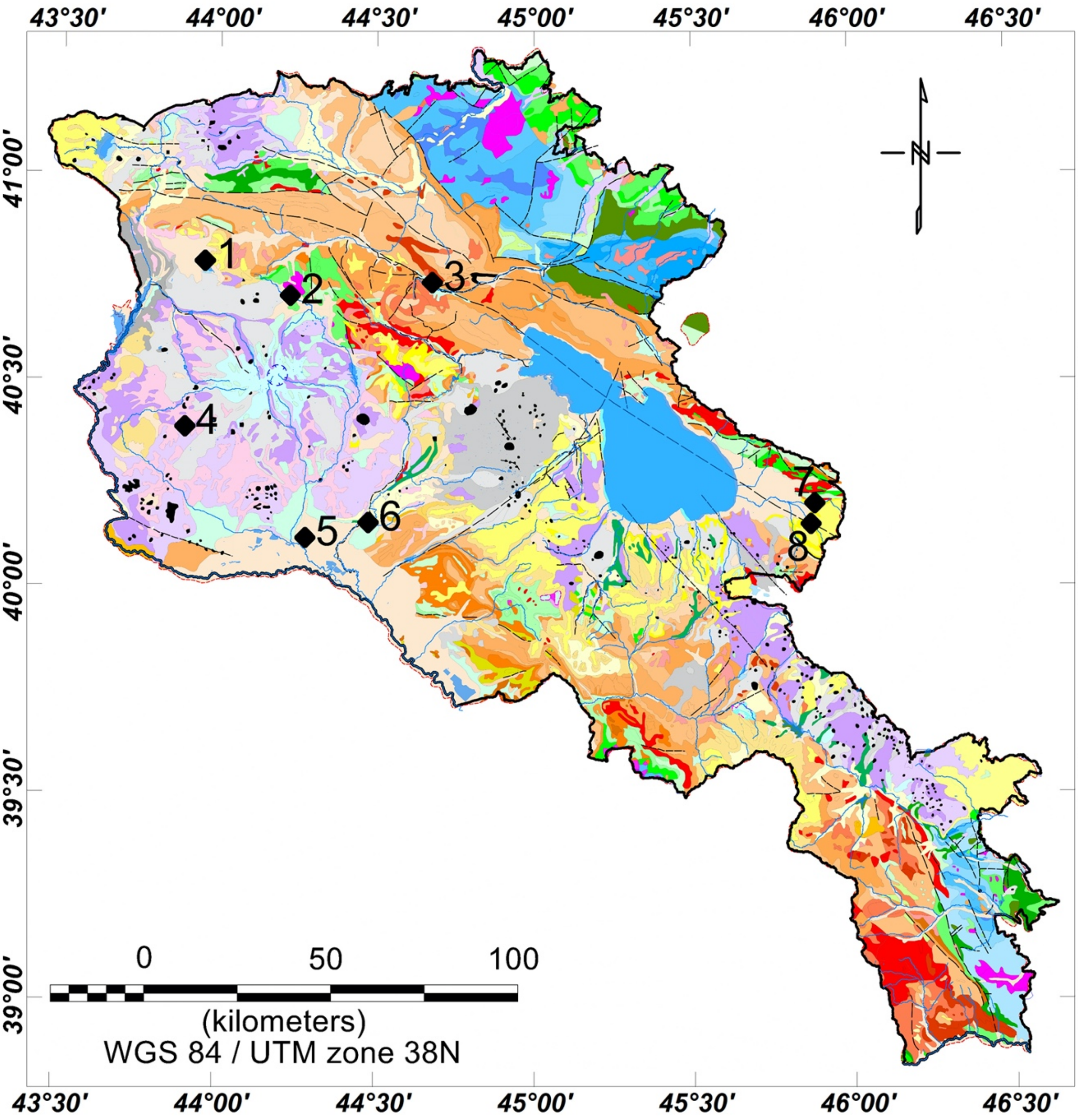
Appendix A

Supplementary Figure: Kura-Araxes pottery typology, exhibiting pots characteristic of fragment potsherds analysed in this thesis; examples from Shengavit (courtesy of Mitchell S. Rothman).



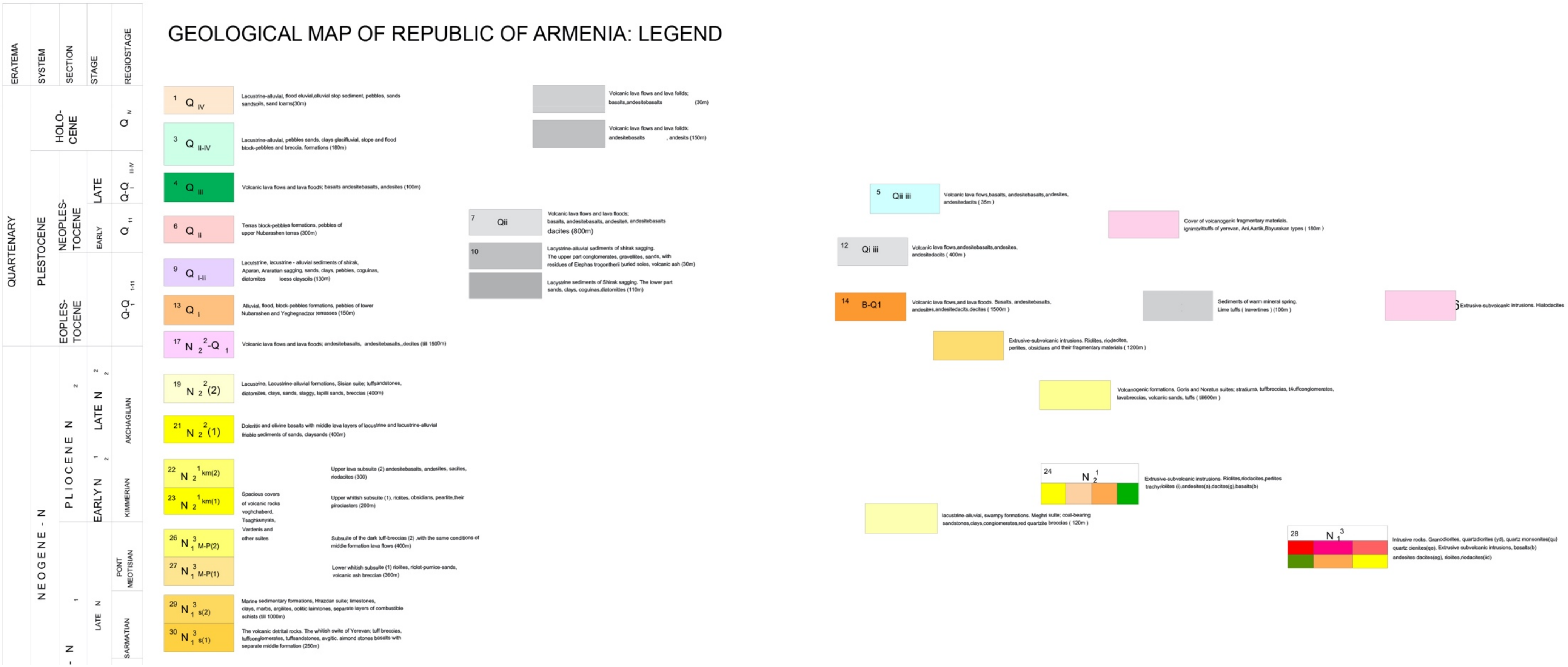
Appendix B

Supplementary Figure: Geology of Armenia and Legend; (1) Karnut-1, (2) Gegharot, (3) Margahovit, (4) Talin Tombs, (5) Mokhra-Blur, (6) Shengavit, (7) Sotk-2 and (8) Norabak-1; (modified from Kharzyan, 2005).



GEOLOGICAL MAP OF REPUBLIC OF ARMENIA: LEGEND

Magnified Geological Map Legend:



CENOZOIC - CZ
MIOCENE
OLIGOCENE
PALEOGENE P
EOCENE P
PALEOCENE P
CRETACEOUS - K
LATE K
CONIAC K
TORTONIAN
HELVETIAN
MIDDLE
EARLY
LATE
SANTONE-MAASTRIKHT
SENOMANE-TURON
ALBI
APTI
Marine sedimentary formations; sandstones, shells, coquinas, limestones (45m)
Marine sediments. Shoraghbyur suite; sandstones, alevrolites, clays, marls, reef lime-stones (1000m)
Marine sediments. Sevan suite; nummulitic limestones, limy sandstones, alevrolites, clays (150m)
Flish sedimentary rocks; limestones, alevrolites, sandstones, conglomerates (580m)
Marine sedimentary rocks; limestones, marls (310m)
Volcanic and volcano-sedimentary formations; andesites, andesitebasalts trachyandesites, their tuffbreccias, lavabreccias, tuffconglomerates, tuff-sandstones, with lens like bodys of limestones.


MEZOZOIC - MZ
JURASSIC - J
TRIASSIC-T
PALEOZOIC - Pz
PERMIAN - P
CARBONI-FEROUS-C
DEVON-IAN-D
PROTEROZOIC PR
PROTEROZOIC
EARLY
LATE
MIDDLE
VALANGHIN-GOTTERIV-BAREMI
TITON-VALANGHIN
OXFORD-TITON
OXFORD
KELOVEIAN
BAT
BAYOUSIAN
Marine sedimentary rocks limestones (300m)
67
Marine volcano-sedimentary rocks. khustup-karmrakar and Artaman suites; basalts, andesitebasalts, their piroclastic tuffs, tuff sandstones
Marine volcano-sedimentary rocks.Tuffconglomerates, tuffbreccias, andesite lavas, limestones, dolomites (1000m)
Marine volcano-sedimentary rocks.Tuffconglomerates, tuffbreccias, tuffsandstones. tuffalevrites. limestones. andesitebasaltic lava flows (340m)
Marine sedimentary rocks. Conglomerates. gravellites. sandstones. caly schists. limestones (1000m)
73
Litoralc marine volcano terrigenous deposites. Argrillites. alevrolites. sandstones. layers of cola. andesitedacitic tuffs. tuffbreccias (1300m)
74
Marine volcanic rocks. Plagioriolites. andesites. andesitedacites. their piroclastics (600m)
Marine volcanic-sedimentary rocks. Andesites. andesitebasalts. diabases. spilites. their piroclastics. argillates. conglomerates (600m)
Marine-sedimentary rocks. sandy clay schists. arkose schists (230)
Litoral marine sedimentary rocks.Sandstones, argillates,clays, layer of coals schists and coals (700m)
Marine-sedimentary rocks. Limestones,marls,dolomites,limestones (550m)
Marine-sedimentary rocks. Limestones,organogenous limestones, bitum inoferous limestones (350m)
82
Marine-sedimentary rocks. Limestones,organogenous limestones,clay schists (400m)
Marine-sedimentary rocks. Limestones,sandstones,quartzites,clayschits (550m)
84
Marine sedimentary rock. sandstones, quartzites, clayschits (1150m)
85
Metamorphosed rocks;Upper gneischists complex. philites, chlonite-actinolitez, quartz-feldspar-sericite and other slates, marbles, metavolcanites (1300m)
87
Metamorphosed rocks; Lower polymetamorphic gneiss-chrystallin slates complex, graphitic and other slates, amphibolites with lens of marbles and dolomites (115m)
Marine sedimentary rocks. Thin exfoliating limestones, marls, alevrolites, sandstones, conglomerates (500m)
Marine sedimentary, volcano-sedimentary rocks. Argiliates, sandy-clay schists, arkose schists, conglomerates, andesites, diabases, their volcano fragmentary formations (800m)
86
Intrusive rocks. trondhjemites, albitites, gneissose granites (y). serpentines. habbros. gabbrodiorites (a)
Marine volcanogenic formations, Miapor suite; basalts, andesitebasalts, their tuffs (2000m)
77
Intrusive rocks, Plagiogranites, Leucokratic granites (py)
Extusive subvolcanic intrusions, Basalts (b)
diorite-porphyrites (dr)
q\U+03b4
\U+03bb\U+03b6
69
Extrusive subvolcanic rocks, quartz andesitedacites (qag), ridacites (ag) plagioriolites (pi)
OTHER SIGNS
Centres of quartenary volcano
The central craters of upper pliocene Aragats ploygenetic volcano
Landslides
Faultes
1. major a-real, b-supposed
2. secondary a-real. b-supposed
SIGNS ONLY IN THE LEGEND
The character of the layers bedding
Concordant bedding
Erosiv discordance
Corner discordance
Azimuth discordance
Unsertain bedding (tectonic or nondiscovered,non studied)

Appendix C

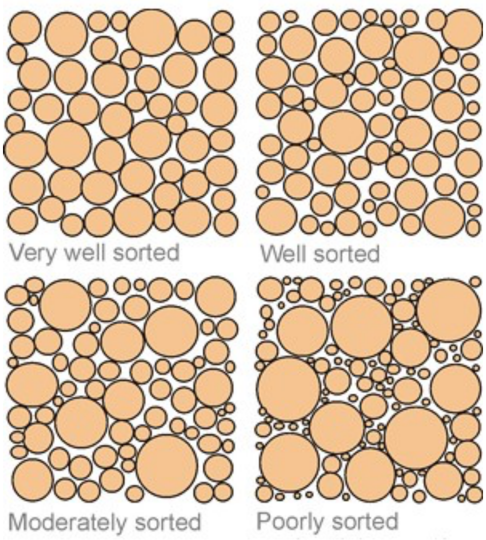
Supplementary Figures: Pottery charts, tables and guides for petrographic characterisation.

Grain size: Sedimentologists have defined parameters for size of inclusions, which should be followed (after Folk, 1980).

Measurement (mm)	Description
>2	Grit
1-2	Very coarse sand
0.5-1	Coarse sand
0.25-0.5	Medium sand
0.125-0.25	Fine sand
0.0625-0.125	Very fine sand
<0.0625	Silt

Sorting classes (after Folk, 1974)	
Sorting class	**Standard deviation σ**
Very well sorted	<0.35
Well sorted	0.35-0.50
Moderately well sorted	0.50-0.71
Moderately sorted	0.71-1.00
Poorly sorted	1.00-2.00
Very poorly sorted	2.00-4.00
Extremely poorly sorted	>4.00

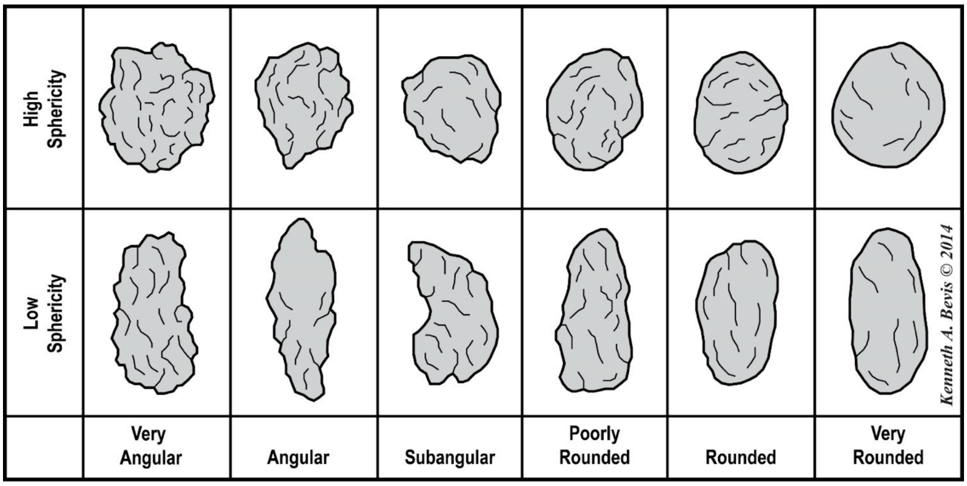
Abundance and Sorting: in some fabric descriptions, inclusions are described as being ‘abundant’, ‘common’, ‘moderate’, or ‘sparse’, but no defined parameters for these values appear to exist.



Comparison chart for sorting and sorting classes (after Pettijohn *et al.*, 1972).

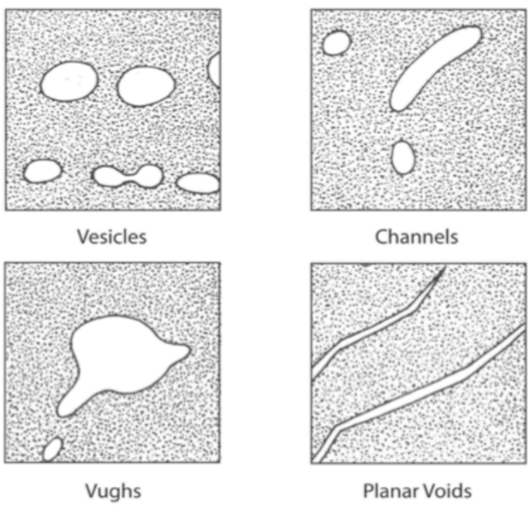
Roundness:
Angular – freshly broken, sharp jagged edges.
Sub-angular – some wear on corners.
Sub-rounded – greater wear of edges, becoming more rounded, but still with angular aspects.
Rounded – almost completely rounded.
Well-rounded – completely rounded.

Shape:
Equant – equal size in all directions.
Sub-equant – rather less than more equal.
Idiomorphic – crystal-shaped.
Tabular – flat but still quite thick.
Platy – flat plate-shaped inclusions.



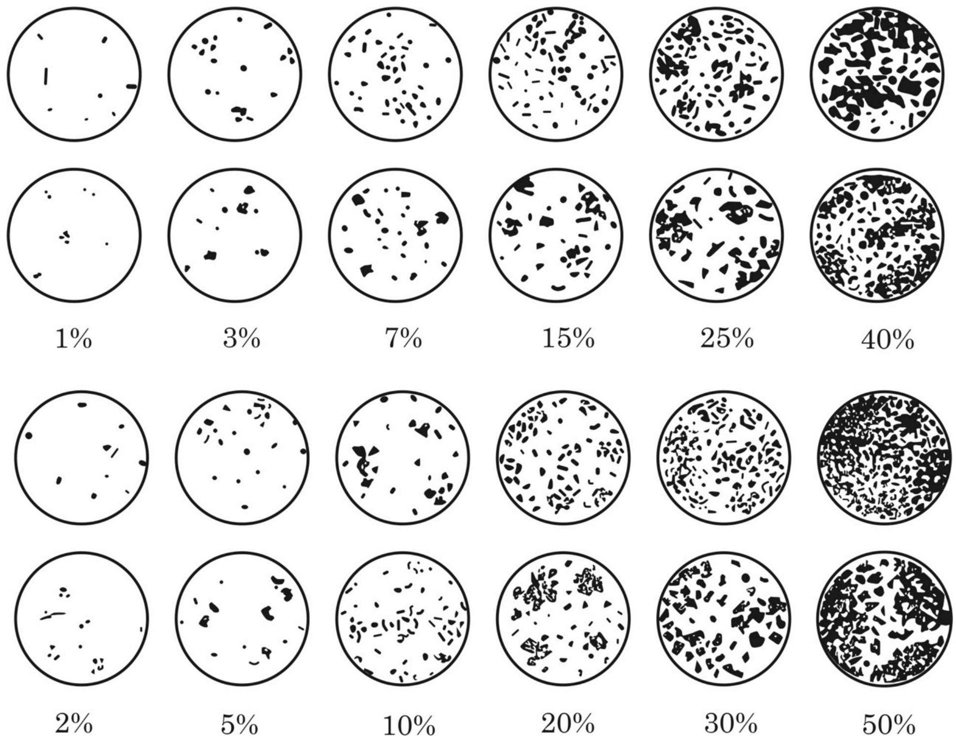
Sphericity and angularity chart. http://intheplaygroundofgiants.com/wp-content/uploads/2014/09/Figure-7-Grain-Shape.jpg

Voids:



Voids are distinct from pores in having held an inclusion (other than gas) prior to firing. Generally, the inclusion was vegetable fibre, which has been burned out, or a calcium carbonate

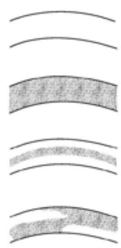
which has similarly been destroyed by the firing. Vegetable fibres often include chaff, chopped straw, or dung, and tend to be thin and elongate, with longitudinal striations. Carbonates may include curvilinear shell, rhomb-shaped sparry calcite, irregular micritic limestone, or rounded micritic limestone or oolites.
Shape of voids (after Stoops 2003: 64). Void characterisation based on Quinn’s (2013: 61) descriptions: small ‘micro’ voids (<0.05 mm); larger (meso: 0.05-0.5 mm, macro: 0.5-2 mm, mega: >2 mm).



Abundance Estimation Chart (after Terry and Chilingar, 1955).

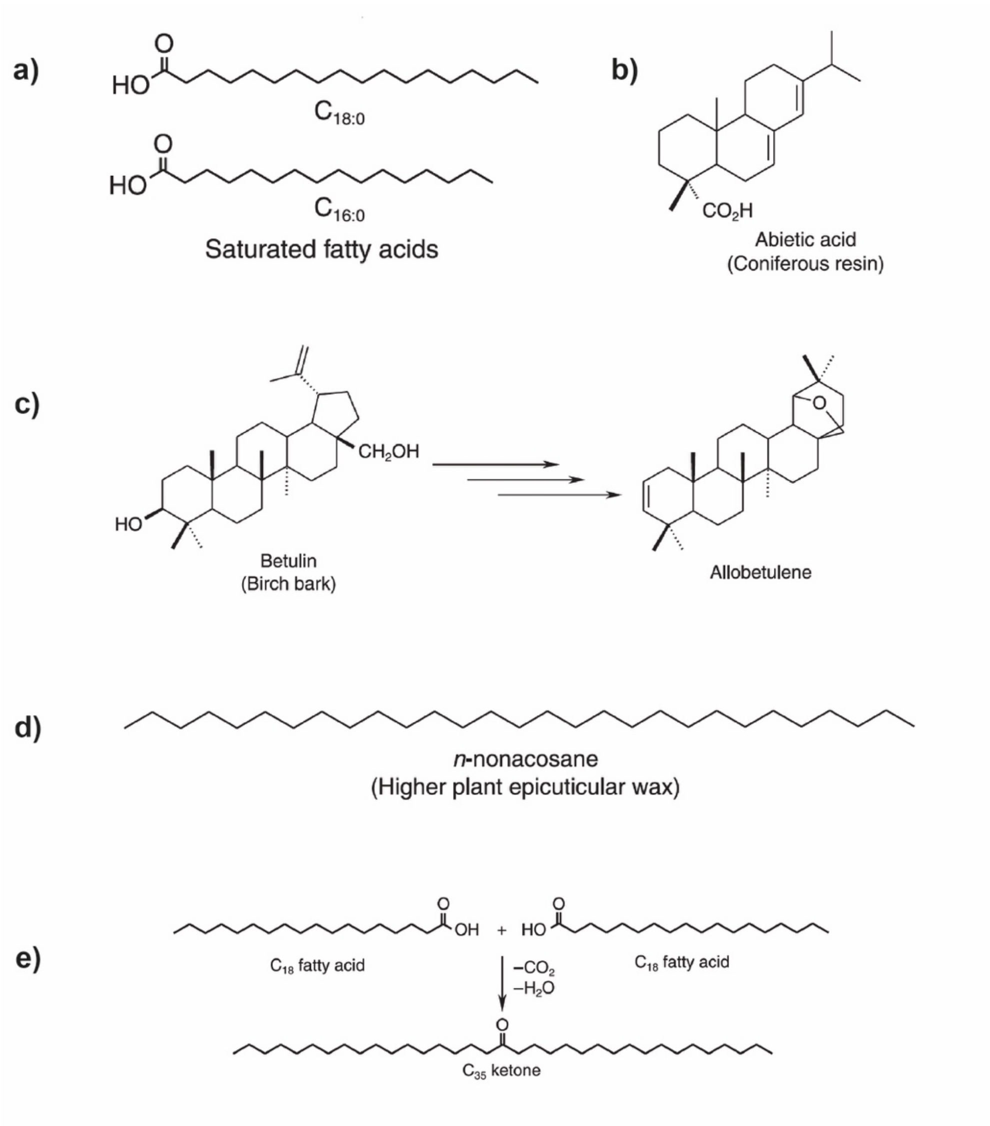
Firing conditions

1. Oxidised (OX)
2. Unoxidised (UNOX)
3. Oxidised exterior, unoxidised core, oxidised interior
4. Irregularly fired (IRF)



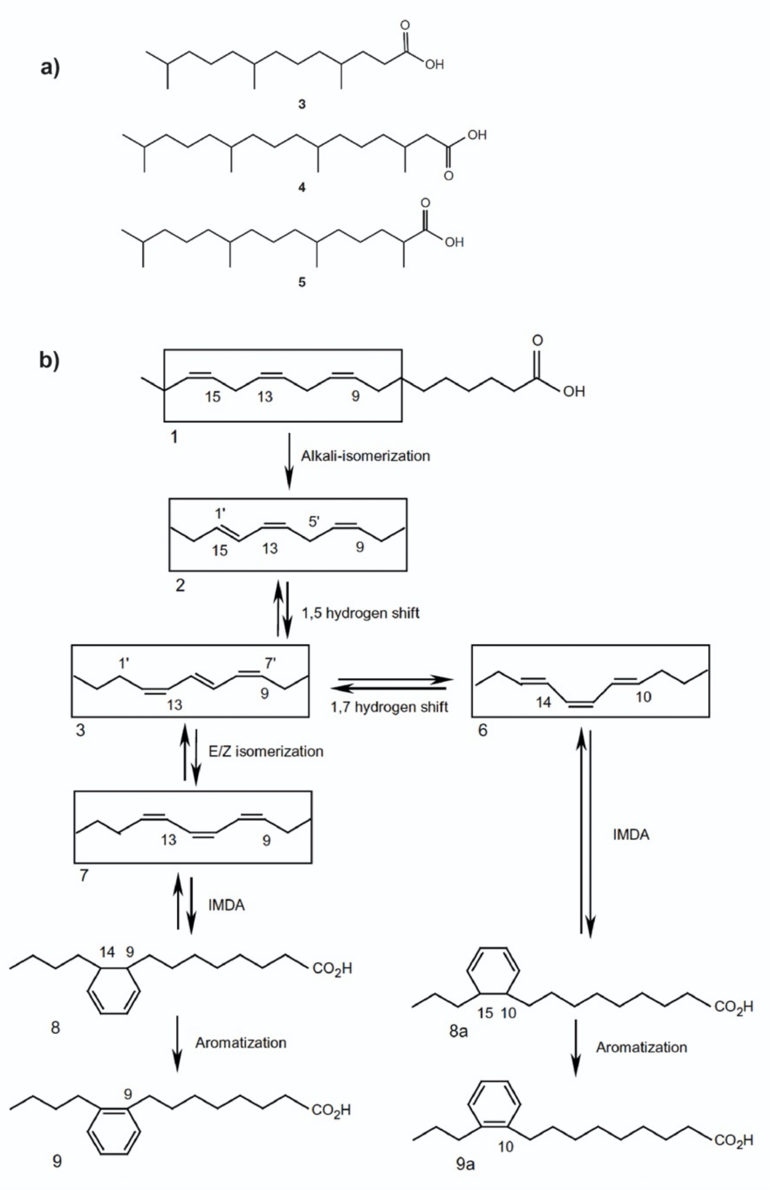
Appendix D

Supplementary Figure 1: Archaeological biomarkers and chemical structures.



Examples of lipid biomarkers detected within archaeological ceramics including, (a) palmitic (n-$C_{16:0}$) acid and stearic (n-$C_{18:0}$) acids characteristic of degraded animal fats; (b) abietic acid, a diterpenoid component of coniferous resin; (c) betulin, a characteristic triterpenoid component of birch bark tar; heating biomarkers markers: allobetulene; (d) nonacosane, a component of epicuticular leaf wax from *Brassica* (cabbage), and (e) C_{35} ketone, biomarker produced by heat treatment of saturated fatty acyl lipids (adapted and reproduced from Evershed, 2008: 898, 900, 901).

Supplementary Figure 2: Archaeological biomarkers and chemical structures.



Examples of lipid biomarkers characteristic of aquatic and marine fats; (a) the isoprenoid fatty acids used as biomarkers for marine fats and oils in archaeological pottery. (3) 4,8,12-trimethyltridecanoic acid (TMTD), (4) 3,7,11,15-tetramethylhexadecanoic acid (phytanic acid) and (5) 2,6,10,14-tetramethylpentadecanoic acid (pristanic); (b) the reaction pathway for the formation of *ω*-(*o*-alkylphenyl)alkanoic acids (APAAs) from *cis, cis, cis*-9,12,15-octadecatrienoic acid following heating at 270 ºC for 17 h (adapted and reproduced from Hansel *et al*., 2004: 3001; Cramp and Evershed, 2014: 323).

Supplementary Table 1: Summary list of Kura-Araxes archaeological site characteristics.

The periodisation of the KA horizon in Armenia includes two temporal phases: KA phase I (*Elar-Aragats*) ranges from 3600/3500 to 2900 BCE while KA phase II (*Karnut-Shengavit*) ranges from 2900 to 2600/2500 BCE (Badalyan, 2014; Badalyan *et al*., 2008).

Site	**Potsherds analysed**	**Longitude**	**Latitude**	**Altitude (m asl)**	**Period**	**Pottery**	**Settlement type**	**Archaeobotany**	**Faunal management strategy**	**References and notes**
Gegharot	35	44.225278	40.705833	2155	KA I-II	Black-burnished	Mountainous - Settlement and fortress	Cereals, barleys (hulled barleys, hulled 2-row barley, 6-row barleys, hulled 6-row barley); wheat (tetra- and/or hexaploid wheats [naked and/or hulled], naked wheats, naked bread wheat, hulled wheats, spelt type wheat, emmer, einkorn type); other cereals (rye), and pulses (lentil, pea, bitter vetch, grass pea, vetches, [wild?]); oil-crops, flax(?); evidence of grape, *Rosa* sp and *Rubus* sp.	Meat-based: diversity of sheep/goat (47.4%), and cattle (49%); occasional wild animals: deer, gazelle, wolf(possibly), toad, snake, and birds. KA I = absence of pigs; KA II = presence of pigs	Monahan, 2007; Badalyan *et al*., 2008 ; Badalyan *et al*., 2010; Badalyan *et al*., 2014; Hovsepyan, 2015; Chahoud *et al*., 2015; Jude *et al*., 2016.
Shengavit	48	44.476667	40.157222	923	KA I-II	Black/buff/red-burnished	Flat, lowland – settlement and necropolis	Cereal-based; large quantities of *Triticum sphaerococcum*; barleys (hulled barleys, hulled 2-row barleys, 2-row barleys, 6-row barleys, hulled 6-row barleys, naked barleys(?); wheat (tetra- and/or hexaploidy wheats [naked and/or hulled], naked wheats, naked bread wheat, macaroni wheat(?), emmer); pulses/vetches (wild?); oil-crops: flax(?); grape; *Rosa* sp and *Rubus* sp.	Meat-based; sheep/goat and cattle husbandry; horse, dog and pig (rare); wild game: red and roe deer	Badalyan *et al*., 2014; Piro and Crabtree, 2017; Hovsepyan, 2015; Chahoud et al., 2015; see Simonyan and Rothman, 2015, for radiocarbon dates.
Mokhra-Blur	13	44.277694	40.120111	844	KA II	Black-burnished	Flat/hill, lowland - settlement	Cereal-based; wheat and barley; Nutlets of *Lithospermum arvense*.	Meat-based; sheep/goat and cattle husbandry; horse, dog and pig (rare).	Badalyan *et al*., 2014; Piro and Crabtree, 2017; Badalyan *et al*., 2008; Hovsepyan, 2015; Badalyan and Avetisyan, 2007; Chahoud *et al*., 2015.
Sotk-2	4	45.886111	40.203333	2100	KA I-II?	Black-burnished	Mountainous – lake – settlement;	Cereal-based; wheat (*Triticum*) and barley (*Hordeum*); (hulled barleys), wheat (tetra- and/or	Meat-based: cattle, sheep/goat, few horses, deer, pig and wolf/dog	Hovsepyan, 2015.

							steppic environment	hexaploidy wheats [naked and/or hulled], naked wheats), vetches (wild?).; evidence of *Rosa* sp and *Rubus* sp.		
Talin Tombs	4	43.895000	40.387361	1600	KA I	Black/buff-burnished	Moutainous – settlement and necropolis	Cereal-based?	Meat-based: cattle, sheep, goat, horse (one tooth), and wild species	Badalyan and Avetisyan, 2007.
Karnut-1	30	43.953942	40.788686	1600	KA II	Black-burnished	Mountainous - settlement	Cereal-based?	Meat-based; Cattle, sheep/goat, horses, and deer.	Badalyan and Avetisyan, 2007; archaeozoological reports, unpublished.
Margahovit	30	44.676667	40.738667	1850	KA II	Black/buff-burnished	Fortified settlement atop hill	Cereal—31%, (Triticeae gen. spp.); Wheat—86%, (*Triticum* spp.); barley and wheat—14% (*Hordeum vulgare*); (hulled barleys, hulled 6-row barley); wheat (tetra- and/or hexaploidy wheats [naked and/or hulled], naked wheats, naked bread wheat, emmer); ryes, and vetches; Weeds—28% (Poaceae, Fabaceae, Rubiaceae, Boraginaceae, Polygonaceae, Cyperaceae, Brassicaceae, Chenopodiaceae, Ranunculaeceae, Violaceae, Lamiaceae).	Meat-based: cattle (38%-74%), sheep/goat (10-17%), pig (4-12%), deer (7-17%), mouflon (2-10%), European roe deer (1-2%), and brown bear (2-5%).	Bobobkyan, A. (personal communication); Gevorgyan *et al*., 2021; Hovsepyan, 2015.

Supplementary Table 2: List of pottery sherds selected for lipid residue analyses and summary of lipid biomarkers detected (GC, GC-MS and GC-C-IRMS).

Sherds were extracted using an established protocol—acidified methanol extraction (Correa-Ascencio and Evershed, 2014).
Key: ($C_{n:x}$) – carboxylic acids with carbon length n and number of saturations x, SFA – saturated fatty acid, UFA – unsaturated fatty acids, Diacid –α,ω-dicarboxylic acids, Alk – alkane, Alc – alkanol/alcohol, Ketones, diHFA – dihydroxy fatty acid, APAA – ω-(o-alkylphenyl) alkanoic acids, br – branched chain acids dominated by *iso* and *anteiso* C_{15} and C_{17}, Isoprenoid fatty acids (IFA): TMTD – 4,8,12-trimethyltridecanoic acid, pris – pristanic acid, phy – phytanic acid; cholesterol, diterpenoids - dehydroabietic acid and other derivatives; terpenoids – indicate the presence of one or several terpenes, including birch bark tar derivatives, and tr – traces. TMS denotes the trimethylsilyl ester and ME denotes methylated. ND is not detected (low concentration).

Sample	Site	Lipid concentration (ug g^{-1})	Total lipid in extract (ug)	$\delta^{13}C_{16:0}$ (‰)	$\delta^{13}C_{18:0}$ (‰)	$\Delta^{13}C$ (‰)	Classification	Compounds (including aquatic biomarkers)
G3	Gegharot	2.83	8.37	-	-	-	-	-
G4	Gegharot	1.10	3.30	-	-	-	-	-
G5	Gegharot	3384.9	7926.0	-27.1	-30.4	-3.4	Dairy	SFA ($C_{14:0-28:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{18, 26}$)
G6	Gegharot	782.7	2130.6	-26.6	-31.6	-5.1	Dairy	SFA ($C_{15:0-28:0, 30:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{16, 18, 20-22, 24, 25, 28, 30}$), Alk ($C_{22, 27, 28, 33}$), ω-Hydroxy FAME (C_{22}), Hydroxy FAME (C_{24})
G7	Gegharot	0.99	2.78	-	-	-	-	-
G8	Gegharot	180.3	510.9	-26.5	-31.1	-4.5	Dairy	SFA ($C_{14:0-28:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{16, 18, 20- 22, 24, 26, 27}$), Alk ($C_{19, 28}$), Hydroxy FAME ($C_{18}$)
G9	Gegharot	971.9	2525.6	-	-	--	-	-
G10	Gegharot	359.9	1065.6	-26.7	-31.6	-4.9	Dairy	SFA ($C_{14:0-28:0, 30:0}$), UFA ($C_{16:1, 18:1}$), Br (C_{17}), Alc ($C_{14, 16-20, 22-24, 26, 28, 30}$)
G11	Gegharot	295.3	611.4	-27.5	-32.0	-4.5	Dairy	SFA ($C_{14:0-26:0, 28:0, 30:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Br ($C_{17}$), Alc ($C_{14, 18, 24, 26, 28, 30}$), Alk ($C_{29, 31}$) Diacid ($C_{14, 16}$)
G12	Gegharot	5.00	13.89	-	-	-	-	-
G13	Gegharot	9.81	25.0	-27.2	-29.7	-2.5	Ruminant adipose fats	SFA ($C_{16:0-26:0, 28:0, 30:0}$), UFA ($C_{16:1, 18:1, 20:1, 22:1}$), Alc ($C_{14, 16-18, 20-22, 24, 26}$), Alk ($C_{29, 31}$)
G14	Gegharot	5.25	15.0	-26.8	-29.7	-3.0	Ruminant adipose fats?	SFA ($C_{16:0-18:0, 20:0, 26:0, 28:0, 30:0}$), UFA ($C_{18:1, 22:1}$), Alc ($C_{16, 18}$), Alk ($C_{29, 31, 33}$)

G15	Gegharot	96.1	244.9	-25.8	-27.8	-2.0	Ruminant adipose fats	SFA ($C_{14:0-26:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{18, 24, 26}$)
G16	Gegharot	646.4	1694.6	-26.9	-28.4	-1.5	Ruminant adipose fats	SFA ($C_{16:0-26:0}$), UFA ($C_{18:1, 22:1}$), Alc ($C_{16-22, 24, 26}$), Hydroxy FAME (C_{24-26}), Chol
G170	Gegharot	4.00	11.8	-	-	-	-	SFA ($C_{16:0-18:0, 20:0-24:0, 26:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{14-18, 20-22, 24, 26}$)
G171	Gegharot	0.87	2.40	-	-	-	-	-
G18	Gegharot	2.23	6.20	-	-	-	-	SFA ($C_{16:0, 18:0, 23:0-26:0}$), UFA ($C_{18:1, 22:1}$), Alc ($C_{16, 18}$), Hydroxy FAME ($C_{24}$)
G19	Gegharot	603.4	1639.8	-26.0	-30.5	-4.4	Dairy	SFA ($C_{14:0-26:0, 28:0, 30:0}$), UFA ($C_{18:1, 22:1}$), Br ($C_{15, 17}$), Hydroxy FAME ($C_{24}$)
G20	Gegharot	812.6	2173.6	-	-	-	-	-
G21	Gegharot	59.1	125.9	-26.9	-29.7	-2.8	Ruminant adipose fats	SFA ($C_{15:0-26:0, 28:0}$), UFA ($C_{16:1, 18:1, 20:1, 22:1}$), Br ($C_{17}$) Alc ($C_{16, 18, 20, 22, 24, 26}$), Alk ($C_{30}$), ω-Hydroxy FAME (C_{24}), Hydroxy FAME (C_{24}), Chol
G22	Gegharot	21.2	59.1	-26.8	-31.0	-4.2	Dairy	SFA ($C_{15:0-30:0}$), UFA ($C_{18:1, 22:1}$), Br (C_{17}) Alk ($C_{31, 33}$), Hydroxy FAME (C_{24})
G23	Gegharot	6.20	15.2	-27.0	-28.4	-1.4	Ruminant adipose fats	SFA ($C_{16:0-24:0, 28:0, 30:0}$), UFA ($C_{18:1, 22:1}$), Alc ($C_{18-20, 22, 24}$), ω-Hydroxy FAME (C_{24}), Hydroxy FAME (C_{22-25}), Acetic acid
G24	Gegharot	652.3	1790.3	-26.7	-31.9	-5.2	Dairy	SFA ($C_{15:0-28:0, 30:0}$), UFA ($C_{18:1, 22:1}$), Alc ($C_{16, 18, 22, 24, 26, 28, 30}$), Hydroxy FAME ($C_{23?, 24}$), Ketones ($C_{29?, 31, 33}$)
G25	Gegharot	1.52	3.73	-	-	-	-	-
G26	Gegharot	42.1	119.2	-25.9	-31.4	-5.5	Dairy	SFA ($C_{15:0-26:0, 28:0, 30:0}$), UFA ($C_{16:1, 18:1, 22:1}$), Alc ($C_{16, 18, 20, 22, 24, 26, 30}$), ω-Hydroxy FAME (C_{24}), Hydroxy FAME (C_{23-26})
G27	Gegharot	19.3	53.5	-	-	-	-	SFA ($C_{15:0, C16:0, 18:0, 24:0, 26:0, 28:0}$), UFA ($C_{16:1, C18:1}$), Br ($C_{17}$)
G28	Gegharot	35.1	104.2	-27.4	-30.3	-2.9	Ruminant adipose fats and plants wax	SFA ($C_{14:0-20:0, 22:0-26:0, 28:0, 30:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{16, 18, 20, 22, 26, 28}$), Diacid ($C_{18, 20, 22, 24}$), ω-Hydroxy FAME ($C_{20, 22, 24}$), Hydroxy FAME ($C_{24, 26}$), terpenoids: Lup-2,20(29)-dien-28-ol (TMS), Allobetul-2-ene, 28-oxoallobetul-2-ene, Betulone (TMS), and Betulin (TMS)
G29	Gegharot	34.1	81.5	-24.2	-25.3	-1.1	Ruminant adipose fats	SFA ($C_{15:0-20:0, 22:0-26:0, 28:0-30:0, 32:0}$), UFA ($C_{16:1, C18:1}$), Br ($C_{15, 17}$), Alc ($C_{16-18, 24, 26, 30}$), ω-Hydroxy FAME ($C_{22, 24}$), Hydroxy FAME ($C_{16, 19, 24}$), Ketone ($C_{31, 33?}$)
G30	Gegharot	53.4	153.9	-	-	-	-	-
G31	Gegharot	1285.8	3313.3	-26.6	-30.4	-3.8	Dairy, plant wax and aquatic(?)	SFA ($C_{14:0-24:0, 26:0}$), UFA ($C_{18:1}$), Br (C_{17}), Diacids ($C_{20, 22}$), ω-Hydroxy FAME (C_{22}), terpenoids: Lup-2,20(29)-dien-28-ol (TMS), IFAs (TMTD, Phy, Pris)
G32	Gegharot	142.5	357.4	-27.3	-30.9	-3.6	Dairy	SFA ($C_{14:0-26:0, 28:0-30:0, 32:0}$), UFA ($C_{18:1}$), Alc ($C_{18, 24, 26, 28, 30}$), Diacid ($C_{22, 24, 26, 28}$), ω-Hydroxy FAME ($C_{22, 24}$), Sulfur, IFA: phy

G33	Gegharot	50.1	125.0	-27.3	-29.4	-2.1	Ruminant adipose fats	SFA ($C_{16:0,\ 18:0\text{-}20:0,\ 24:0,\ 26:0}$)
G34	Gegharot	36.1	106.1	-	-	-	-	SFA ($C_{16:0,\ 18:0,\ 24:0}$), UFA ($C_{16:1,\ 18:1}$)
G35	Gegharot	56.9	168.7	-26.8	-32.1	-5.4	Dairy	SFA ($C_{16:0\text{-}18:0,\ 20:0\text{-}26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18,\ 20,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{21,\ 23,\ 25\text{-}27,\ 29,\ 31,\ 33}$), Hydroxy FAME ($C_{24\text{-}26}$), IFA: phy
G36	Gegharot	21.7	61.3	-26.3	-29.1	-2.8	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0,\ 24:0\text{-}26:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18,\ 26}$)
SHA	Shengavit	174.8	466.8	-28.5	-27.9	0.6	Non-ruminant adipose fats	SFA ($C_{14:0,\ 16:0,\ 18:0,\ 20:0}$), Alk ($C_{20,\ 22,\ 23}$)
SHEN10	Shengavit	268.2	604.8	-26.1	-28.4	-2.3	Ruminant adipose fats	SFA ($C_{15:0\text{-}22:0}$), UFA ($C_{18:1}$), Alc ($C_{14,\ 18}$)
SHEN26	Shengavit	847.6	2492.9	-27.6	-28.9	-1.3	Ruminant adipose fats	SFA ($C_{14:0,\ 16:0\text{-}20:0,\ 22:0,\ 24:0}$), UFA ($C_{18:1}$), Alc ($C_{12,\ 14,\ 16,\ 18,\ 20}$), Alk ($C_{17\text{-}22}$), Hydroxy FAME ($C_{12}$)
SH10	Shengavit	1101.5	2661.5	-25.8	-28.6	-2.8	Ruminant adipose fats	SFA ($C_{14:0\text{-}30:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{14,\ 16,\ 18,\ 20\text{-}24,\ 26,\ 27,\ 30}$), Alk ($C_{23}$), Hydroxy FAME ($C_{10}$), Chol
SH11	Shengavit	80.0	135.7	-24.5	-25.4	-0.8	Ruminant adipose fats	SFA ($C_{14:0\text{-}20:0,\ 22:0,\ 23:0,\ 26:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{16,\ 18,\ 20}$), Alk ($C_{18}$)
SH12	Shengavit	1.73	4.96	-	-	-	-	-
SH13	Shengavit	ND	ND	-	-	-	-	-
SH14	Shengavit	0.1	0.2	-	-	-	-	-
SH15	Shengavit	1.6	2.2	-	-	-	-	-
SH23	Shengavit	774.3	2204.4	-26.7	-29.1	-2.3	Ruminant adipose fats	SFA ($C_{15:0\text{-}26:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{16\text{-}20,\ 26}$), Alk ($C_{20,\ 23,\ 25,\ 26,\ 29}$)
SH27	Shengavit	733.5	1773.9	-27.3	-29.0	-1.7	Ruminant adipose fats	SFA ($C_{14:0\text{-}18:0,\ 24:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{14\text{-}22,\ 24}$), Alk ($C_{20,\ 22\text{-}24,\ 26}$), Cholesterol
SH30	Shengavit	936.9	2576.9	-	-	-	-	-
SH32	Shengavit	17.0	43.3	-25.9	-27.5	-1.6	Ruminant adipose fats and plant	SFA ($C_{16:0\text{-}18:0,\ 20:0\text{-}28:0,\ 30:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{14,\ 16\text{-}18,\ 20,\ 22,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{19\text{-}23,\ 25\text{-}31,\ 33}$), unidentified terpenoids
SH35	Shengavit	710.2	1655.6	-	-	-	-	-
SH37	Shengavit	0.64	1.48	-	-	-	-	-
SH38	Shengavit	109.8	248.9	-25.8	-27.4	-1.6	Ruminant adipose fats	SFA ($C_{16:0\text{-}21:0}$), UFA ($C_{18:1}$), Br (C_{17})
SH43	Shengavit	159.8	450.3	-26.1	-27.4	-1.3	Ruminant adipose fats	SFA ($C_{14:0\text{-}21:0}$), UFA ($C_{18:1}$)
SH58	Shengavit	10.4	26.1	-	-	-	-	SFA ($C_{14:0\text{-}18:0}$), UFA ($C_{16:1,\ 18:1}$), Alc (C_{16}), Alk ($C_{19\text{-}21}$), plasticizers

SH64	Shengavit	20.7	54.1	-23.9	-25.8	-1.9	Ruminant adipose fats	SFA ($C_{16:0-26:0, 28:0, 30:0}$), UFA ($C_{18:1}$), Alc ($C_{16, 18, 20-22, 24, 26, 28, 30}$), Alk ($C_{20, 21, 23-25, 27, 29, 31}$), Hydroxy FAME ($C_{24}$)
SH67	Shengavit	737.0	2125.4	-	-	-	-	-
SH79	Shengavit	849.3	2246.2	-27.0	-28.9	-1.8	Ruminant adipose fats and plant	SFA ($C_{14:0-18:0, 24:0, 26:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{14-22, 24, 26}$), Alk ($C_{19-27, 29}$), Hydroxy FAME ($C_{12, 15}$)
SH105	Shengavit	904.0	2315.8	-27.4	-28.9	-1.5	Ruminant adipose fats and plant(?)	SFA ($C_{15:0-21:0, 23:0-26:0}$), UFA ($C_{18:1}$), Alc ($C_{14-18, 20-22, 24, 26}$), Alk (C_{18-33}), Cholesterol, unidentified terpenoid
SH110	Shengavit	821.6	2134.2	-22.5	-23.0	-0.6	Ruminant adipose fats	SFA ($C_{16:0-26:0}$), UFA ($C_{18:1}$)
SH114	Shengavit	128.2	381.4	-21.3	-26.4	-5.1	Dairy	SFA ($C_{15:0-26:0}$), UFA ($C_{18:1}$), Br (C_{17})
SH115	Shengavit	794.5	1850.9	-	-	-	-	-
SH116	Shengavit	7.49	19.1	-27.0	-27.9	-0.9	Ruminant adipose fats	SFA ($C_{16:0-20:0, 22:0, 24:0, 26:0, 28:0}$), UFA ($C_{18:1}$), Alc ($C_{17, 18, 20, 22, 24, 26}$)
SH117	Shengavit	804.7	1966.3	-	-	-	-	-
SH118	Shengavit	76.2	199.9	-	-	-	-	-
SH132	Shengavit	1078.8	2536.7	-26.6	-28.7	-2.2	Ruminant adipose fats and plant wax	SFA ($C_{16:0-22:0, 24:0, 26:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{14, 16-18, 20, 26}$), Diacid ($C_{20, 22}$), ω-Hydroxy FAME ($C_{18, 20, 22}$)-Aliphatic diol? (Component of waxes and beeswax), Terpenoids: Lup-2,20(29)-diene, Lup-2,20(29)-dien-28-ol (TMS), Allobetul-2-ene, Betulin (TMS), Betulone (TMS), Betulin (TMS), Allobetulinol (TMS)
SH134	Shengavit	5.80	17.2	-	-	-	-	-
SHK6	Shengavit	7.26	16.5	-	-	-	-	SFA ($C_{16:0, 18:0}$), APAA C18?
SHA2	Shengavit	56.3	154.6	-28.1	-29.4	-1.3	Ruminant adipose fats	SFA ($C_{14:0, 16:0, 18:0}$), Alc ($C_{12, 14, 16-18}$), Alk (C_{17-23}), Benzoic acid
SH9	Shengavit	686.0	1226.3	-25.6	-23.5	2.1	Non-ruminant adipose fats & aquatic(?)	SFA ($C_{14:0-30:0}$), UFA ($C_{16:1, 18:1}$), Br ($C_{15, 17}$), Alc (C_{19}), IFAs: TMTD, pris, phy
SH20	Shengavit	7.13	17.8	-28.6	-29.4	-0.8	Ruminant adipose fats	FAs C16, 18
SH21	Shengavit	19.1	50.5	-26.5	-29.0	-2.4	Ruminant adipose fats and plant	SFA ($C_{14:0-21:0, 24:0}$), Alc ($C_{16, 18, 26}$), Alk (C_{18-31}), IFAs: TMTD
SH29	Shengavit	4.31	12.2	-	-	-	-	SFA ($C_{16:0, 18:0}$)
SH45	Shengavit	19.3	53.6	-29.0	-29.3	-0.3	Ruminant adipose fats and plant(?)	SFA ($C_{14:0, 16:0-18:0}$), Alc (C_{18}), Alk ($C_{19, 21, 22}$), Sulfur

SH47	Shengavit	51.6	140.2	-25.5	-27.5	-2.1	Ruminant adipose fats	SFA ($C_{14:0, 16:0-26:0, 30:0}$), UFA ($C_{18:1}$), Alc ($C_{18, 26, 30}$), Sulfur
SH48	Shengavit	951.0	2480.0	-26.4	-29.9	-3.5	Dairy and aquatic(?)	SFA ($C_{14:0-30:0}$), Br (C_{17}), APAA C18?, 20(tr), 22(tr?), IFAs: TMTD, phy
SH50	Shengavit	73.9	101.6	-28.7	-27.9	0.9	Non-ruminant adipose fats	SFA ($C_{14:0, 16:0, 18:0}$), Alc ($C_{14, 18, 20}$), Alk (C_{20}), Hydroxy FAME ($C_{10, 11}$), Sulfur
SH63	Shengavit	76.8	206.1	-25.8	-30.1	-4.3	Dairy	SFA ($C_{14:0-25:0}$), UFA ($C_{18:1}$), Alc (C_{18}), Alk (C_{23}), Hydroxy FAME (C_{24}), IFAs: phy
SH68	Shengavit	548.5	1156.5	-27.3	-29.3	-2.0	Ruminant adipose fats and aquatic	SFA ($C_{14:0-16:0, 18:0-24:0, 26:0}$), UFA ($C_{18:1}$), Br ($C_{15, 17}$), APAA C18, 20, 22?, IFAs: pris?, phy
SH72	Shengavit	277.2	805.8	-26.3	-28.9	-2.6	Ruminant adipose fats	SFA ($C_{14:0-26:0, 28:0, 30:0}$), UFA ($C_{18:1}$), Br ($C_{17}$), Alc ($C_{18}$), Alk ($C_{19, 23}$), IFAs: pris, phy
SH82	Shengavit	110.9	176.4	-26.5	-30.1	-3.6	Dairy and plant(?)	SFA ($C_{14:0-18:0, 20:0, 24:0, 26:0}$), UFA ($C_{18:1}$), Alc ($C_{14, 17, 18, 20, 24, 26}$), Alk ($C_{20, 22-29}$), Hydroxy FAME ($C_{11, 15, 16}$), Sulfur
SH97	Shengavit	29.4	83.1	-25.5	-27.2	-1.7	Ruminant adipose fats and plant(?)	SFA ($C_{16:0-30:0}$), Alc ($C_{16, 18}$), Alk (C_{17-33})
SH108	Shengavit	90.2	187.4	-27.2	-28.2	-1.0	Ruminant adipose fats and plant(?)	SFA ($C_{14:0-21:0, 24:0, 26:0, 28:0, 30:0}$), Alc ($C_{16, 18, 19, 26, 28, 30}$), Alk ($C_{17-25, 27, 29, 31, 33}$)
SH111	Shengavit	36.9	101.2	-26.6	-28.4	-1.9	Ruminant adipose fats and plant	SFA ($C_{16:0-18:0, 23:0, 24:0, 26:0, 28:0, 30:0}$), Alc ($C_{14, 16, 18, 20, 22, 24, 26-28, 30}$), Alk ($C_{19-31, 33}$)
SH112	Shengavit	31.3	79.0	-	-	-	-	SFA ($C_{16:0, 18:0}$), plasticizers
MB001	Mokhra-Blur	102.9	296.5	-24.8	-27.3	-2.4	Ruminant adipose fats and plant(?)	SFA ($C_{14:0, 16:0-30:0, 32:0}$), UFA ($C_{22:1, 18:1}$), Alc ($C_{14, 26,, 28, 30}$), Alk ($C_{17--27, 29}$), Hydroxy FAME ($C_{24-26, 28}$), Sulfur
MB1	Mokhra-Blur	143.4	416.3	-21.5	-25.8	-4.3	Dairy and plant/resin?	SFA ($C_{14:0-24:0, 26:0-30:0, 32:0}$), UFA ($C_{18:1}$), Alc ($C_{18, 26, 28, 30}$), Alk ($C_{21, 22}$), Hydroxy FAME ($C_{24}$), Sulfur, Dehydroabietic acid trimethylsilyl ester
MB2	Mokhra-Blur	127.6	379.6	-24.4	-26.9	-2.5	Ruminant adipose fats	SFA ($C_{14:0, 16:0-18:0, 20:0-26:0, 28:0, 30:0}$), UFA ($C_{18:1}$), Alk ($C_{17-27, 29, 31, 33}$), Hydroxy FAME ($C_{24}$)
MB3	Mokhra-Blur	2510.4	6593.3	-22.4	-25.5	-3.1	Dairy(?) and aquatic	SFA ($C_{14:0- 20:0, 22:0- 31:0}$), UFA ($C_{18:1}$), Br ($C_{15}$), Alc ($C_{26}$), Sulfur, APAA C18, 20(tr), 22(tr), IFAs: TMTD, pris, phy
MB4	Mokhra-Blur	250.8	670.7	-25.7	-26.8	-1.1	Ruminant adipose fats	SFA ($C_{14:0-21:0}$), Dehydroabietic trimethylsilyl ester, APAA C18?
MB5	Mokhra-Blur	135.8	359.2	-27.2	-27.8	-0.6	Ruminant adipose fats	SFA ($C_{16:0, 18:0}$), UFA ($C_{18:1}$), Sulfur, Dehydroabietic acid, trimethylsilyl ester

MB6	Mokhra-Blur	129.4	317.5	-26.7	-29.0	-2.2	Ruminant adipose fats and plant(?)	SFA ($C_{16:0,\ 18:0\text{-}30:0}$), Alc ($C_{18,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{20\text{-}33}$), Sulfur, Dehydroabietic acid, trimethylsilyl ester
MB7	Mokhra-Blur	32.3	94.2	-25.8	-27.8	-1.9	Ruminant adipose fats	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1}$), Alc ($C_{18,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{27,\ 29,\ 31,\ 33}$), Sulfur, Dehydroabietic acid, trimethylsilyl ester, APAA C18?
MB8	Mokhra-Blur	85.9	251.3	-25.6	-26.2	-0.6	Ruminant adipose fats	SFA ($C_{14:0\text{-}18:0,\ 20:0}$), UFA ($C_{18:1}$), Alk ($C_{19\text{--}24}$), Hydroxy FAME ($C_{12,\ 13,\ 15}$), Dehydroabietic acid, trimethylsilyl ester, APAA C18
MB9	Mokhra-Blur	41.3	114.9	-22.8	-24.3	-1.4	Ruminant adipose fats and Plant/resin	SFA ($C_{14:0\text{-}20:0,\ 22:0,\ 24:0\text{-}29:0}$), UFA ($C_{18:1}$), Alk ($C_{21\text{-}32}$), Dehydroabietic acid (TMS), 7-Oxodehydroabietic acid (ME)
MB10	Mokhra-Blur	57.1	164.2	-24.3	-27.4	-3.2	Dairy	SFA ($C_{14:0,\ 16:0\text{-}18:0,\ 20:0,\ 22:0,\ 24:0,\ 28:0,\ 30:0}$), Alc ($C_{18,\ 26,\ 28,\ 30}$), Alk ($C_{19\text{-}22}$), Hydroxy FAME ($C_{24,\ 26}$), Sulfur, Dehydroabietic acid, trimethylsilyl ester, APAA C18
MB11	Mokhra-Blur	56.8	159.6	-25.0	-26.3	-1.3	Ruminant adipose fats and plant/resin	SFA ($C_{14:0,\ 16:0\text{-}18:0,\ 20:0,\ 22:0,\ 24:0,\ 26:0}$), UFA ($C_{18:1,\ 22:1?}$), Alc ($C_{14\text{-}16,\ 18,\ 24}$), Alk ($C_{20\text{-}29}$), Dehydroabietic acid (TMS), 7-Oxodehydroabietic acid (TMS)
MB12	Mokhra-Blur	110.6	308.4	-23.3	-27.3	-4.0	Dairy	SFA ($C_{14:0\text{-}22:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0,\ 32:0}$), UFA ($C_{18:1}$), Alc ($C_{18,\ 24,\ 26,\ 28,\ 30,\ 32}$), Dehydroabietic acid (ME)
KRT1	Karnut-1	100.5	282.4	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1,\ 18:1}$), Hydroxy FAME ($C_{23,\ 24}$)
KRT2	Karnut-1	206.5	534.4	-	-	-	Plant?	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1?,\ 18:1}$), Br ($C_{17}$), Hydroxy FAME ($C_{23,\ 24}$)
KRT5	Karnut-1	202.9	479.5	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 20:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1?,\ 18:1}$), Br ($C_{17}$)
KRT6-6	Karnut-1	99.6	207.8	-	-	-	-	SFA ($C_{14:0\text{-}24:0}$), UFA ($C_{16:1,\ 18:1}$), Br (C_{17})
KRT7	Karnut-1	41.3	115.2	-26.8	-24.9	1.9	Non-ruminant adipose fats	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0,\ 23:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$)
KRT8	Karnut-1	55.0	160.2	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0,\ 23:0,\ 24:0}$), UFA ($C_{16:1,\ 17:1?,\ 18:1}$), Br ($C_{17}$)
KRT12	Karnut-1	132.0	386.1	-26.6	-25.5	1.4	Non-ruminant adipose fats and plant(?)	SFA ($C_{14:0\text{-}18:0,\ 22:0,\ 23:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$), Hydroxy FAME ($C_{23,\ 24}$)
KRT17	Karnut-1	65.8	187.2	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{18}$), Hydroxy FAME ($C_{24}$)
KRT20	Karnut-1	55.7	147.1	-28.1	-27.8	0.3	Non-ruminant adipose fats?	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1,\ 18:1}$), Br ($C_{17}$)
KRT28	Karnut-1	83.9	218.1	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$), Hydroxy FAME ($C_{24}$)
KRT33	Karnut-1	114.5	316.6	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$)

KRT34	Karnut-1	70.8	204.0	-	-	-	Plant?	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0,\ 23:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{18}$), Hydroxy FAME ($C_{24}$), APAA C18
KRT35	Karnut-1	171.8	490.8	-	-	-	Plant wax	SFA ($C_{14:0\text{-}20:0,\ 22:0,\ 23:0}$), UFA ($C_{16:1,\ 17:1,\ 18:1,\ 18:2}$), Br ($C_{17}$), Hydroxy FAME ($C_{23\text{-}25}$), Terpenoids: Betulin (TMS) and unidentified terpenoids.
KRT36	Karnut-1	21.1	59.9	-27.7	-29.1	-1.4	Ruminant adipose fats	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 23:0,\ 24:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Hydroxy FAME ($C_{23,\ 24}$)
KRT41	Karnut-1	66.6	193.1	-28.4	-27.3	1.1	Non-ruminant adipose fats	SFA ($C_{14:0\text{-}20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1,\ 18:1}$), Br ($C_{17}$)
KRT48	Karnut-1	79.0	230.1	-	-	-	-	SFA ($C_{15:0\text{-}20:0,\ 22:0\text{-}24:0}$), UFA ($C_{16:1,\ 17:1?,\ 18:1}$), Br ($C_{17}$)
KRT52	Karnut-1	62.4	166.9	-	-	-	-	SFA ($C_{15:0\text{-}24:0}$), UFA ($C_{16:1,\ 18:1}$), Br (C_{17})
KRT53	Karnut-1	9.04	20.9	-28.2	-28.6	-0.4	Ruminant adipose fats	SFA ($C_{16:0,\ 18:0}$), UFA ($C_{16:1,\ 18:1}$)
KRT55	Karnut-1	97.0	253.8	-27.1	-32.0	-4.9	Dairy	SFA ($C_{14:0\text{-}18:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Dehydroabietic acid (TMS)
KRT56	Karnut-1	297.0	813.3	-27.7	-33.1	-5.4	Dairy and plant(?)	SFA ($C_{14:0\text{-}26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1,\ 18:2?}$), Br ($C_{15,\ 17}$), Alc ($C_{17,\ 18?}$), Alk ($C_{29,\ 31,\ 33}$), Dehydroabietic acid (TMS), APAA C18? IFAs: phy
KRT57	Karnut-1	191.2	537.1	-26.9	-24.8	2.1	Non-ruminant adipose fats	SFA ($C_{14:0\text{-}18:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Dehydroabietic acid (TMS)
KRT58	Karnut-1	35.2	104.6	-27.7	-27.7	0.0	Non-ruminant adipose fats	SFA ($C_{16:0,\ 18:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Dehydroabietic acid (TMS)
KRT59	Karnut-1	55.9	158.6	-26.6	-30.0	-3.4	Dairy	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0,\ 24:0\text{-}26:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Dehydroabietic acid (TMS), APAA C18?
KRT60	Karnut-1	85.3	235.5	-27.8	-32.4	-4.6	Dairy	SFA ($C_{14:0\text{-}16:0,\ 18:0}$), UFA ($C_{18:1}$), Dehydroabietic acid (TMS)
KRT61	Karnut-1	77.4	218.0	-27.9	-29.6	-1.7	Ruminant adipose fats	SFA ($C_{16:0,\ 18:0}$), UFA ($C_{18:1}$)
KRT62	Karnut-1	47.6	130.2	-27.8	-27.9	-0.2	Non-ruminant adipose fats?	SFA ($C_{14:0,\ 16:0\text{-}18:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Dehydroabietic acid (TMS)
KRT63	Karnut-1	78.4	185.3	-27.1	-26.4	0.6	Non-ruminant adipose fats	SFA ($C_{16:0\text{-}18:0}$), UFA ($C_{16:1,\ 18:1}$), Dehydroabietic acid (TMS)
KRT64	Karnut-1	126.4	372.2	-28.4	-30.0	-1.6	Ruminant adipose fats and plant(?)	SFA ($C_{14:0\text{-}16:0,\ 18:0,\ 20:0,\ 21:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1}$), Alk ($C_{17\text{-}25,\ 27,\ 29,\ 31,\ 33}$)
KRT65	Karnut-1	34.3	90.6	-27.5	-26.8	0.7	Non-ruminant adipose fats	SFA ($C_{16:0,\ 18:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18}$), Hydroxy FAME (C_{24}), Dehydroabietic acid (TMS)
KRT66	Karnut-1	89.4	266.3	-27.3	-26.7	0.6	Non-ruminant adipose fats	SFA ($C_{14:0\text{-}18:0}$), UFA ($C_{18:1}$)
MG2	Margahovit	118.5	314.9	-23.7	-27.4	-3.7	Dairy and plant wax	SFA ($C_{14:0\text{-}26:0,\ 28:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$), Alc ($C_{14,\ 16,\ 18,\ 20\text{-}22,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{23,\ 25\text{-}29,\ 31}$), Diacid ($C_{16,\ 18,\ 20,\ 22}$), ω-Hydroxy FAME (C_{22}), Hydroxy FAME ($C_{20,\ 24}$), Terpenoids: Lup-2,20(29)-diene, Lup-2,20(29)-dien-28-ol (TMS), Allobetul-2-ene, Lupeone, Lupeol

								(TMS), unknown terpenoid, 28-oxoallobetul-2-ene?, Betulone (TMS), 3-oxoallobetulane, Betulin (TMS), Allobetulinol (TMS), IFAs: phy
MG3	Margahovit	15.5	42.9	-26.7	-27.6	-1.0	Ruminant adipose fats and plant(?)	SFA ($C_{14:0\text{-}16:0,\ 18:0,\ 20:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{14,\ 16,\ 18,\ 20,\ 22,\ 24,\ 26,\ 28}$)
MG5	Margahovit	8.49	18.0	-27.4	-28.0	-0.6	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0}$), UFA ($C_{16:1,\ 18:1}$), Alc (C_{18})
MG7	Margahovit	9.40	26.1	-	-	-	-	-
MG9	Margahovit	431.5	1156.5	-26.8	-30.6	-3.8	Dairy and aquatic(?)	SFA ($C_{12:0\text{-}26:0,\ 28:0,\ 30:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{15,\ 17}$), Alc ($C_{14,\ 18\text{-}20,\ 22,\ 24,\ 30}$), IFAs: TMTD(tr), pris, phy
MG10	Margahovit	19.5	38.5	-27.4	-28.4	-1.0	Ruminant adipose fats	SFA ($C_{16:0,\ 18:0}$), UFA ($C_{16:1,\ 18:1}$), Alc ($C_{16,\ 18}$)
MG14	Margahovit	15.9	36.0	-	-	-	-	-
MG15	Margahovit	8.82	24.3	-28.2	-30.0	-1.8	Ruminant adipose fats	SFA ($C_{14:0\text{-}18:0}$), UFA ($C_{16:1,\ 18:1}$)
MG16	Margahovit	14.5	30.1	-26.4	-27.9	-1.5	Ruminant adipose fats	SFA ($C_{15:0\text{-}18:0,\ 20:0,\ 24:0,\ 26:0}$), UFA ($C_{16:1,\ 18:1,\ 22:1}$), Alc ($C_{18,\ 20\text{-}22,\ 24}$), Cholesterol, IFAs: pris?
MG17	Margahovit	41.2	9.54	-27.3	-31.2	-3.8	Dairy and aquatic	SFA ($C_{15:0\text{-}18:0,\ 20:0\text{-}26:0}$), APAA C18, 20tr, 22tr, IFAs: phy(tr)
MG19	Margahovit	46.8	138.7	-26.5	-28.9	-2.4	Ruminant adipose fats and plant	SFA ($C_{15:0\text{-}18:0,\ 20:0\text{-}30:0}$), Alc ($C_{20,\ 22,\ 24,\ 26,\ 28}$), Alk ($C_{23\text{-}31,\ 33}$)
MG20	Margahovit	6.61	17.5	-27.6	-28.9	-1.3	Ruminant adipose fats and plant?	SFA ($C_{16:0\text{-}18:0,\ 20:0,\ 24:0,\ 26:0}$), UFA ($C_{16:1,\ 18:1,\ 22:1}$)
MG21	Margahovit	41.7	117.0	-	-	-	-	SFA ($C_{14:0\text{-}18:0,\ 20:0,\ 22:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1,\ 20:1}$), Br ($C_{17}$), Alc ($C_{14,\ 18,\ 20,\ 22,\ 24,\ 26}$), Cholesterol
MG22	Margahovit	2.39	6.85	-	-	-	-	-
MG23	Margahovit	1.97	5.61	-	-	-	-	SFA ($C_{15:0\text{-}18:0}$), UFA ($C_{16:1,\ 18:1}$), IFAs: TMTD?, pris?
MG24	Margahovit	5.81	15.5	-28.0	-29.4	-1.4	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0}$), UFA ($C_{18:1}$)
MG26	Margahovit	15.3	40.4	-27.4	-29.6	-2.3	Ruminant adipose fats and plant(?)	SFA ($C_{16:0\text{-}18:0,\ 20:0,\ 24:0,\ 26:0}$), UFA ($C_{18:1}$), Alc ($C_{18,\ 20\text{-}22,\ 24,\ 26}$), Sulfur, Cholesterol, IFAs: TMTD?, pris?
MG27	Margahovit	19.8	55.5	-27.1	-28.7	-1.7	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0,\ 20:0,\ 22:0,\ 24:0,\ 26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1}$), Alc ($C_{16,\ 18,\ 24,\ 26,\ 28,\ 30}$), Alk ($C_{29,\ 31,\ 33}$)
MG28	Margahovit	49.9	139.4	-27.1	-31.9	-4.8	Dairy	SFA ($C_{14:0\text{-}26:0,\ 28:0,\ 30:0}$), UFA ($C_{16:1,\ 18:1}$), Br ($C_{17}$), Alc ($C_{19}$), Hydroxy FAME ($C_{16,\ 24}$), IFAs: phy
MG29	Margahovit	29.2	84.3	-27.3	-31.4	-4.2	Dairy and aquatic(?)	SFA ($C_{14:0\text{-}26:0,\ 28:0,\ 30:0}$), UFA ($C_{18:1}$), Alc ($C_{18,\ 24,\ 26}$), IFAs: TMTD (tr?), pris (tr?), phy

MG30	Margahovit	22.6	61.3	-27.6	-30.7	-3.1	Dairy and plant(?)	SFA ($C_{16:0, 18:0, 20:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{16\text{-}18, 20}$), Cholesterol?
MG31	Margahovit	18.6	50.0	-	-	-	-	SFA ($C_{16:0\text{-}20:0, 26:0, 28:0, 30:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{14, 16, 18\text{-}20, 26, 28, 30}$)
MG33	Margahovit	57.4	122.4	-26.1	-28.3	-2.2	Ruminant adipose fats and aquatic	SFA ($C_{14:0\text{-}24:0, 26:0, 30:0}$), UFA ($C_{16:1, 18:1}$), Br ($C_{17}$), Alc ($C_{16, 18, 20\text{-}22, 24, 26, 30}$), Diacid ($C_{16}$?), IFAs: TMTD, pris, phy
MG34	Margahovit	31.3	67.0	-27.2	-28.8	-1.6	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0}$), UFA ($C_{16:1, 18:1, 18:2?, 20:1}$), Alc ($C_{16\text{-}18}$)
MG39	Margahovit	7.54	20.0	-27.3	-27.9	-0.6	Ruminant adipose fats	SFA ($C_{16:0, 18:0}$), UFA ($C_{18:1}$)
MG40	Margahovit	4.57	10.0	-	-	-	-	SFA ($C_{16:0, 18:0}$), UFA ($C_{18:1}$)
MG43	Margahovit	276.3	813.3	-26.9	-31.2	-4.3	Dairy and plant(?)	SFA ($C_{13:0\text{-}30:0, 32:0}$), UFA ($C_{18:1}$), Br ($C_{17}$), Alc ($C_{12?, 16, 18, 20, 22, 24, 26, 28, 30, 32}$), Alk ($C_{19, 21, 23\text{-}33}$), Hydroxy FAME ($C_{15}$), Ketones ($C_{31, 33?}$), IFAs: pris, phy
MG44	Margahovit	12.6	33.5	-26.3	-26.5	-0.2	Non-ruminant adipose fats	SFA ($C_{15:0\text{-}20:0, 23:0, 24:0, 28:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{16, 18, 20, 26}$), Hydroxy FAME ($C_{24}$),
MG45	Margahovit	10.0	22.8	-	-	-	-	SFA ($C_{16:0, 18:0}$), UFA ($C_{18:1}$), Alc ($C_{16, 18, 20}$)
MG46	Margahovit	7.53	16.3	-26.7	-27.3	-0.6	Ruminant adipose fats	SFA ($C_{16:0\text{-}18:0}$), UFA ($C_{16:1, 18:1}$), Alc (C_{18})
T1	Talin Tombs	87.1	251.3	-26.1	-29.7	-3.6	Dairy	SFA ($C_{14:0\text{-}18:0, 24:0}$), UFA ($C_{18:1}$), Alc ($C_{12, 14\text{-}18}$), Alk ($C_{19\text{-}24}$), Hydroxy FAME ($C_{24}$)
T2	Talin Tombs	359.7	1001.2	-27.0	-31.1	-4.2	Dairy	SFA ($C_{14:0\text{-}26:0}$), UFA ($C_{18:1}$), Br (C_{17}), Alc ($C_{14, 16, 18\text{-}20}$), Alk (C_{22}), IFAs: phy
T5	Talin Tombs	408.2	1111.8	-26.3	-28.2	-1.9	Ruminant adipose fats	SFA ($C_{14:0\text{-}30:0}$), Alc ($C_{16, 18, 26, 28, 30}$), Alk ($C_{22\text{-}26}$)
T7	Talin Tombs	193.3	141.8	-26.8	-31.2	-4.4	Dairy	SFA ($C_{14:0\text{-}17:0, 18:0, 20:0, 22:0, 24:0}$), UFA ($C_{18:1}$), Alc ($C_{14, 16}$), Alk ($C_{17, 19\text{-}24}$), Hydroxy FAME ($C_{11}$)
SK6	Sotk-2	138.6	389.1	-27.0	-29.7	-2.7	Ruminant adipose fats and plant(?)	SFA ($C_{12:0\text{-}18:0, 20:0}$), UFA ($C_{16:1, 17:1, 18:1, 22:1}$), Alc ($C_{12, 16\text{-}24}$), Alk ($C_{22, 24\text{-}30, 31?, 33?}$), Cholesterol, IFAs: TMTD?, pris?
SK23	Sotk-2	27.4	64.3	-22.2	-25.6	-3.4	Dairy and plant(?)	SFA ($C_{14:0\text{-}18:0, 20:0\text{-}28:0}$), UFA ($C_{16:1, 18:1}$), Alc ($C_{16\text{-}18, 26}$), Alk ($C_{24, 26\text{-}31}$), IFAs: TMTD, pris?
SK46	Sotk-2	158.2	445.1	-27.6	-29.7	-2.0	Ruminant adipose fats	SFA ($C_{14:0\text{-}24:0}$), UFA ($C_{18:1}$), Br (C_{17}), IFAs: phy
SK51	Sotk-2	143.3	350.4	-27.1	-32.6	-5.5	Dairy	SFA ($C_{14:0\text{-}26:0}$), UFA ($C_{16:1, 18:1}$), Br (C_{17}), Alc ($C_{14\text{-}16, 18}$), Alk ($C_{18\text{-}33}$), IFAs: phy

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