CERAMIC TRADITIONS AND CERAMIC LANDSCAPES OF THE INDUS CIVILISATION:

Investigating the technologies and socio-economic complexity of rural pottery production in Bronze Age northwest India.

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Preface declaration

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration except as declared in the Preface and specified in the text. It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text It does not exceed the prescribed word limit for the Archaeology Degree Committee.

Ceramic traditions and ceramic landscapes of the Indus Civilisation: investigating the technologies and socio-economic complexity of rural pottery production in Bronze Age northwest India.

Alessandro Ceccarelli, University of Cambridge

Abstract

This thesis explores the technological choices made by rural communities of the Indus Civilisation (c.2600-1900BC) by analysing ceramic materials from three villages in north-west India. The Indus Civilisation has typically been characterised as a society that underwent a broadly homogeneous development, and continuity and transformations of ceramic industries have previously been studied through the use of relatively simplified models of diffusion. The small number of large-scale settlements that are referred to as cities have typically been used to characterise the technological, social and cultural behaviours across the vast zone occupied by Indus Civilisation populations. Within this region, the processes of urbanisation and deurbanisation are much debated, and it has been suggested that climate change played a role in socio-cultural transformations. However, rural dynamics, including lifestyles, craft production and *knowledge-scapes* are often perceived as being marginal.

The rural settlements that have been studied are located at varying distances from large-scale sites, each showing a range of phases of occupation chronologically spanning from the early phases of Indus urban development, to the late urban and post-urban phases. The diversity of settlements has made it possible to explore the impact of societal and climatic changes on ceramic industries, and to assess how communities interacted with variable environments, as well as their technological transformations over time. Through the use of macroscopic and archaeometric analyses of pottery, integrated with ethno-archaeological observations, Indus ceramic traditions have been identified within the rural context. Here craft traditions are presented as a medium for understanding the functional variability of ceramics, as well as the variability of associated socio-cultural groups characterising each site. This approach has made it possible to reconstruct more diverse industries than previously thought, and offered a glimpse into synchronic Indus social networks among villages, as well as their diachronic transformations. The resulting picture suggests that rural social complexity and interactions facilitated the reproduction of a resilient, adaptable, yet mutating system of ceramic traditions. These traditions partially transformed during the Indus Civilisation's phases of urbanisation and deurbanisation. Rural ceramic landscapes adapted to, and were enriched by broader variable social and physical environments, yet maintained their own characteristics and identities.

Acknowledgements

गुर कुम्हार सिख कुंभ है गढ़ गढ़ काढ़ै खोट
अंतर हात सहार दै बाहर बाहै चोट

Guru Kumhar Sikh Kumbh Hai, Gadh Gadh Kadhe Khot
Antar Hath Sahar De, Bahar Bahe Chot

The mentor is the potter, the student is the (unfired) pot,
the mentor gives shape and cures the flaws with care,
always protecting with the palm from inside,
while beating the pot from outside.

Kabir, 15th century, Varanasi, India.

This thesis is part of a broader story of **promises**, **passion** and **sacrifice**. I lived, worked and travelled in India for many years, almost for a decade, which shaped most of my current life. The first time I visited India, I was a young man and I was seeking a new life, having overcome a series of personal difficulties, and was searching for meaning and discovery. I became a disciple of a Himalayan yogi, who for many years provided me with a quiet place to live, a method for healing my mind, a journey towards a new self, and a large family of volunteers and meditation practitioners. I made a constant effort to construct a happier, stronger and better version of myself, while he provided me with the methods to unpack, sharpen and calm my mind. During those beautiful years, I served others in a forest ashram near Pune, and I travelled across the subcontinent, assisting his charitable work, while working on myself.

India gave me so much, including a new, extended family, a healed mind, self-confidence, and a range of new skills. I wanted to give back, after all that had been given to me. Eventually, I **promised** myself I would reciprocate the countless gifts that India gave to me. I moved to London for my Master's on South Asian Archaeology, started and relinquished a first PhD at UCL, and then finally landed at University of Cambridge, where I started and completed this project. This was my own way of showing gratitude to the Hamsa Yoga Sangh charity, the Himalayan yogi Yogiraj Gurunath Siddhanath and Guruma Shivangini, and my friends in India, to whom this thesis is dedicated.

Second, I would like to thank my mentors, who managed to transform my **passion** for archaeology, material culture and South Asia into a professional asset. Figuratively, in Kabir’s words, they have shaped me from a raw lump of clay into a nicely-formed vessel over the course of this project. In particular, I am very grateful to Dr Cameron A. Petrie, my first supervisor, for two reasons. First of all, he trained and coped with an overly enthusiastic, stubborn and energetic Italian researcher for years, which is a complex task in itself. Secondly, he gave me the unique opportunity to join the ERC *TwoRains* team, which had a major impact on my personal life and career development. Similarly, I am extremely grateful to Prof Charles A. I. French (University of Cambridge) and Dr Patrick S. Quinn (UCL IoA). Charly, my second supervisor, has been my main point of contact for broader conceptual questions and personal advice, but also for the daily work in the McBurney Geoarchaeology Laboratory. The same is true for Dr Tonko Rajkovaca, one of the pillars of the McBurney Laboratory and more broadly of the Department of Archaeology in Cambridge. Patrick, my external advisor, helped me become a specialist of material culture and ceramic studies, since the very early stages at UCL IoA. He provided me with the essential tools to secure a PhD position at Cambridge, but he has also constantly passed on cutting-edge analytical techniques to his students, as well as world-class knowledge that helped complete this journey.

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There would be a long list of people and institutions that have significantly helped me in the past years during this journey. For instance, the support of the Nehru Trust at the Victoria and Albert Museum in London, the Fitch Laboratory at the British School at Athens, Greece, and in particular the support of Dr Evangelia Kiriatzi, was essential. Evangelia showed me a different way of doing research when I got disillusioned with academia. Similarly, the encouragement and support of a number of people helped me reach this point, including Dr Silvia Amicone (Tubingen, Germany), Dr Carlotta Gardner, Dr Natalia Lozada Mendieta, Dr Gabriella Manna (MNAO 'Giuseppe Tucci', Rome, Italy), Dr Robert Harding (UCL and University of Cambridge), Dr Daniela De Simone (British Museum, London), and Dr Julia Shaw (UCL). I am also grateful that the ethnographic research project submitted for assessment was approved by the Humanities and Social Sciences Research Ethics Committee, School of the Humanities and Social Sciences, University of Cambridge, School Research Ethics Committee, and the Department of Archaeology Ethics Committee, Cambridge. Similarly, the team at the Faculty of Earth Sciences and Geography was particularly kind and permitted the use of their kilns and Petro-Thin machine.

In terms of politics and activism for social justice and minorities, which I undertook alongside my PhD, there are few people and charities that I would like to thank in particular. Professor Paul Dupree (Magdalene College, Cambridge) was an essential ally in fighting cases of misogyny, racism and homophobia in Cambridge. Similarly, the University of

Cambridge Graduate Union and CUSU played a pivotal role over the past few years. Eventually, I found even more allies in Cambridge when I started my work as President of the Students' Union, which resulted in an even larger degree of support by a number of passionate students.

Finally, as mentioned above, this was also a story of **sacrifice**. I am grateful to my families in Italy and Spain, to my father's family and to my mother's family, brothers and sisters, for their constant support. I love each of them every day, and I miss each of them every day. They have all played a role in this project at different stages, and their support was essential. In particular, I am grateful to my best friends, who are like my brothers, who have kept walking with me in the past 14 years, and keep supporting my crazy ideas: if I made it to the end of this journey, it is because of the constant help and support of Francesco Mangoni and Alberto Casu.

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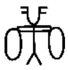
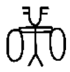
Concepts and contexts.



"Concepts lead us to make investigations;
are the expression of our interest,
and direct our interest".

Wittgenstein 1953, §570

Chapter 1. One hundred years of Indus paradigm: thesis groundwork, aims and structure



1.1 Introduction

Technology and ceramic materials have been an essential part of societies for millennia. As part of daily life, crafts and technologies shape and are shaped by social identities, and are entangled with vital processes of resilience and cultural transformations. The actions of obtaining, reproducing and using crafts go beyond simple utilitarian or economic considerations, and allow humans to explore identities and interactions within and among communities. This is especially important during periods of transformation, when environmental and social changes endanger the sustainability of complex societies. The rediscovery of ancient crafts and technologies allows us to observe how communities organised their systems of production, transmitted their knowledge and skills through generations, organised their lives, and perceived themselves and others.

South Asia's Indus Civilisation (c.3200-1300BC) has been often presented as one of the largest Bronze Age civilisations and a major Old World civilization (Childe 1950; Kenoyer 1998; Possehl 1999a; Wright 2010). Chronologically, it was broadly contemporaneous with the late Early Dynastic, Akkadian, and Ur III periods in Mesopotamia and the Old Kingdom and First Intermediate period in Egypt (Petrie 2019). Geographically, the area covered by Indus Civilisation settlements and material culture includes modern day Pakistan, northern India and Afghanistan, being a vast zone of c. a million square kilometres (Possehl 1997; 1999a). Since the rediscovery of Indus settlements almost one hundred years ago in 1920s (Marshall 1931; Piggott 1950; Wheeler 1950; 1968) and until recent times, the Indus Civilisation has been typically described as a vast, culturally homogeneous complex society dominated by five large-scale settlements. However, this small number of Indus large-scale settlements (c. 80+ ha), typically regarded as urban centres or cities, seem to have been the "exception rather than the norm" within the Indus zone, as the majority of identified settlements were smaller rural communities (Petrie 2019: 109). Within the vast Indus zone, settlements formed in diverse ecological niches, and under a wide variety of environmental conditions, hydrological systems, and rainfall systems (Dixit et al. 2018; Orengo and Petrie 2017a; see Figure 1.1).

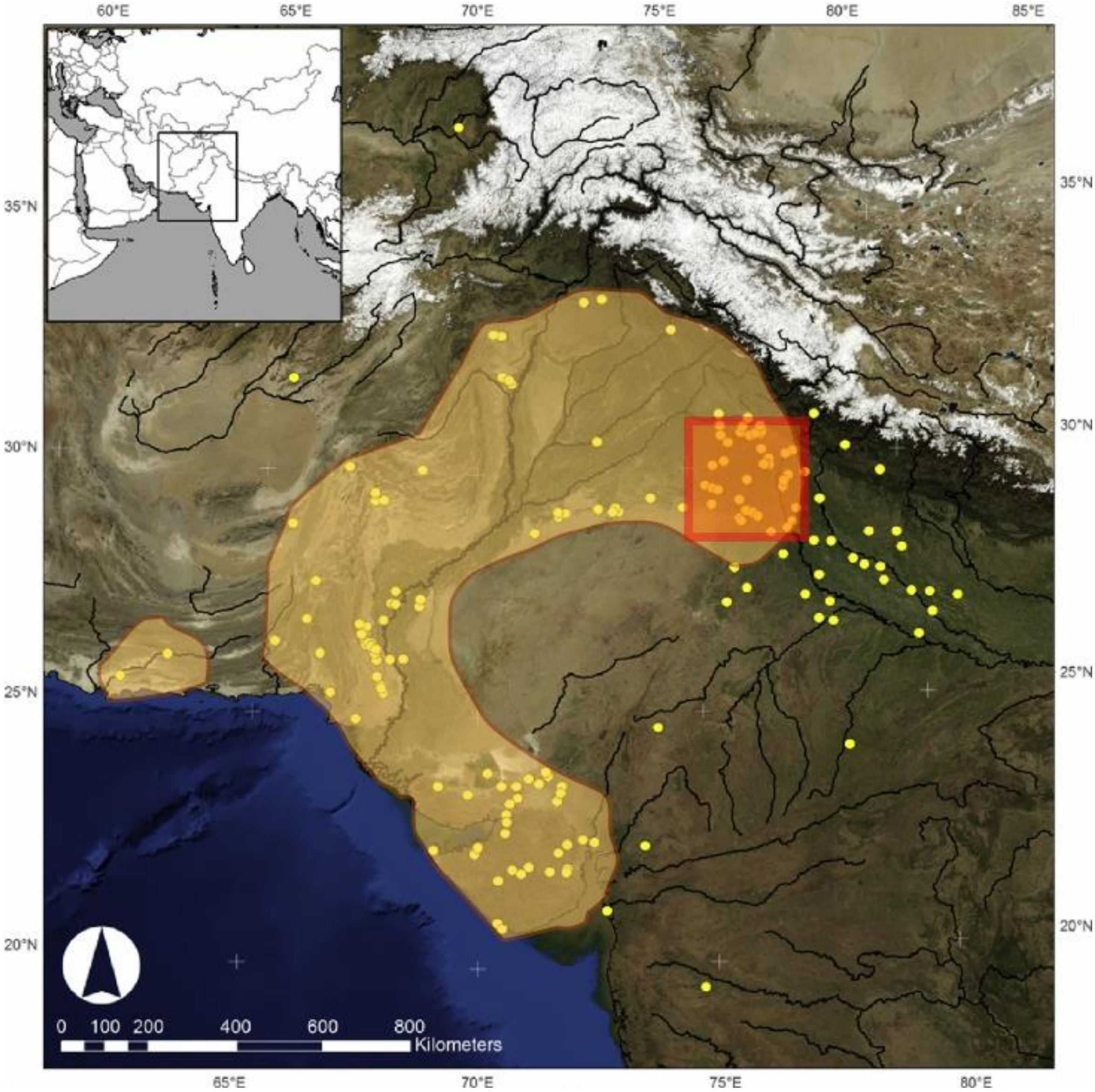
In the past few decades, there has been a gradual shift in the perception of the Indus social, cultural and economic organisation, where more regional variability and the role of rural communities have now taken a more pivotal role (Fairservis 1986; Petrie 2013; Petrie et al. 2017b; Possehl 2002; Weber 2003; Weber et al. 2010). However, little data is currently available to better characterise the rural systems of production in the Indus zone, including ceramic industries, the variability of associated socio-cultural groups, their regional expressions, and how they adapted and reacted to the many environmental and socio-political changes which occurred across the Indus Civilisation development trajectories.

This thesis aims to explore this issue by looking at rural crafts and technologies, and how ceramic traditions, producers and their associated social units transformed, interacted and adapted to local environmental and cultural changes during the expansion, pinnacle, and de-urbanisation processes of the Indus Civilisation (2500-1900BC). By using a multi-site dataset and a holistic approach, this thesis explores the diversity of ceramic traditions, the multi-layered identities of rural communities, and how the rural systems of production were organised and sustained. This project exists in its own, but it is also part of the current *TwoRains* project (see Figure 1.2), and indirectly contributes to the previous *Land, Water, Settlement* project, which investigate the impact of climate and environmental changes at the end of the Indus Civilisation urban period (Singh et al. 2010; 2011; 2018a; 2018b; Singh and Petrie 2009). The predominant focus of this project is devoted to materials from transitional phases identified at northwest Indian archaeological sites, more specifically from periods which took different names at different times of the archaeological research in the region. A consistent nomenclature has been adopted here, which follows (see Table 1.1):

- A Pre-Urban (c.3200-2600BC) to Early Urban transition, characterised by the early development of large-size settlements or Urban settlements;

- The Early-Urban and Late Urban phases (c.2600-1900BC), or Mature Harappan period, marked by the pinnacle of the first South Asian urban centres in modern Pakistan and India (e.g. Mohenjo-Daro, Harappa, Rakhigarhi, Dholavira and Ganweriwala), and associated with the gradual aridification process and the weakening of the ISM in its Late Urban phase (Dixit et al. 2014; 2015; 2018b);

Figure 1.1 Indus and Painted Grey Ware sites. The red square indicates the interested region for the project (Bates et al. 2017a; 2017b; Possehl 1999a).



- The Late-Urban to Post-Urban period of the Indus Civilisation (c. 1900-1400 BCE), frequently associated with ceramic industries produced during the middle stage of the so-called Late Harappan in North-Western India, when urban centres are believed to have 'collapsed' or transformed, the monsoons aligned with modern patterns, and occupational strategies seem to have shifted towards exclusive rural, small-size settlements.

1.2 Research aims and methods

This thesis explores technological choices and ceramic traditions of people living at the study sites and how the urbanisation and deurbanisation processes of the Indus

Civilisation affected them. As part of the broader ERC *TwoRains* project, the present project aims to the understand crafts and technologies at NW Indian sites which fall under the umbrella of the Indus Civilisation using ceramic materials as the main proxy. Pottery is particularly useful for archaeologists, not only due to the durability and abundance of ceramic artefacts in the archaeological record, but also for the vast range of approaches that can be applied to its study. For instance, technological ceramic analysis allows to explore both diachronic and synchronic variability of pottery assemblages taking into account ethno-archaeological and anthropological perspectives (Costin 2001; Dobres and Hoffman 1994, 200; Dobres and Robb 2000, 200; Sofaer 2015; Tite 1999). Such analysis is mainly based on a classification procedure known as the *chaîne opératoire* approach (see Martinón-Torres 2002), which helps to address questions about social choices related to variability of pottery production. On a synchronic level, technological and stylistic variability amongst sites in specific periods can be used for identifying villages' and regional traditions, social relationships, and settlement functions (Roux 2011: 85; 2016); on a diachronic level, besides providing a broad chronological classification of traditions and wares, it can be useful for tracing phenomena of continuity and transformations of the *chaînes opératoires*. Such a vertical perspective may also provide details on how ancient communities transmitted their knowledge and on agencies which contributed to reproducing and innovating ceramic industries over time.

Issues regarding theoretical frameworks and interpretation schemes employed in archaeological ceramic analyses in South Asia will be addressed in detail in Chapters 2 and 3. For instance, observations on regional diversity and variability will be used to counter the widespread idea of homogeneous ceramic production across the Indus zone (see Chapter 2). This thesis aims to move away from the tendency to present narratives based on cultural histories and cultural evolutionary approaches (see Chapter 3.2); and the effects of simplistic evolutionary approches and *demic* diffusionism to rationalise changes and continuity of ceramic industries (see Chapter 3.2.2). Besides archaeological interpretation schemes, ethnographic observations on modern communities of craftspeople in South Asia have also been affected by old-fashioned approaches (see Chapter 3). For instance, the effects of the direct historical approach and of the tendencies to present parallel histories will be summarised, as well as their impact on our current understanding of ancient Indus tools, techniques and technologies (see Chapter 3.4.1).

Figure 1.2. The present PhD project is part of the Work-package 3, ERC TwoRains project.

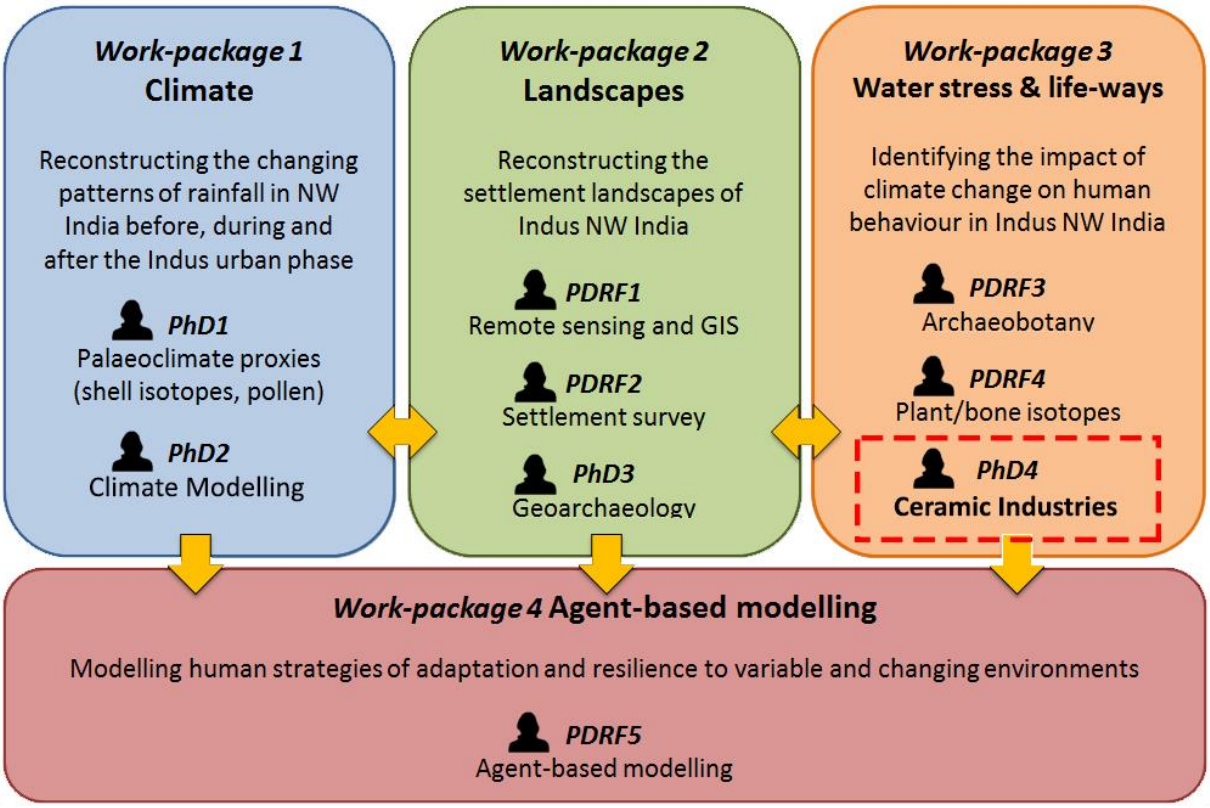


Table 1.1 Chronology of the Indus Civilisation (Kenoyer 1998; Possehl 2002).

Pre-urban period, Early Harappan, Regionalisation Era	Kot Diji, Sothi-Siswal, Damb Sadaat, Tochi-Gomal phase, Amri-Nal	3200-2600BC	Harappa Period 1; Harappa Period 2
Pre -Early Urban transition, Early-Mature Harappan Transition		2600-2500BC	Harappa Phase A (3A) c.2600-2450BC
Early Urban period, Late Urban period, Mature Harappan, Integration Era	Kulli Harappan, Sindhi Harappan, Sorath Harappan, Punjabi Harappan Eastern Harappan Quetta, Late Kot Diji	2500-1900BC	Harappa Phase B (3B) c.2450-2200; Harappa Phase C (3C) c.2200-1900BC
Late-Post Urban transition, Harappan-Late Harappan, Transition		1900-1800BC	Harappa Period 4
Post-Urban period, Late Harappan, Localization Era	Early Pirak (1800-1700BC), Late Sorath Harappan (1900-1600BC), Cemetary H (1900-1500BC), Swat Late Harappan in Haryana and Western Uttar Pradesh (1900-1300BC), Jhukar (1900-1700BC).	1900-1300BC	Harappa Period 5

A systematic study of rural ceramics offer the fresh opportunity to follow a bottom-up approach, and to explore questions of transformation, resilience and transmission beyond the urban sphere. There is much to be learned from the adoption of a comprehensive, integrated and systematic method for the study of rural ceramics that incorporates a range of quantitative and qualitative data. A combined approach is proposed as a feasible and replicable method for studying *chaînes opératoires*, technological choices and ceramic traditions, i.e. a holistic strategy gives the opportunity to understand social dynamics within community dimensions and at a regional level. This requires the integrated use of various techniques, including technological and morphological study of vessels, scientific archaeometric analyses (i.e. thin-section ceramic petrography and geochemistry), data from multiple sites, an understanding of the palaeo-landscape, and comparative experimental and ethno-archaeological studies (see Chapter 4). Such a bottom-up approach will offer an empirically grounded opportunity to explore questions of about the transmission, transformation, and resilience of ceramic traditions. When accompanied by an interpretative shift away from cultural evolutionary paradigms towards nuanced theoretical frameworks, it will be possible to better define the nature of traditions in order to characterise communities of practice, social units, variability of social units and *ceramic landscapes*, which may have 'overlapped' rather than replaced each other in both a synchronic and diachronic perspective.

In order to answer the central research question of this project - **Can a compositional and technological study of rural Indus Civilisation ceramic industries be used to explore communities' identities and relations, and to trace evidence for continuity and changes in Bronze Age northwest Indian societies?** – three sub-questions were developed:

What ceramic technological choices and traditions characterised the Indus rural context? This question aims to explore the variability of technological choices, *chaînes opératoires* and ceramic traditions at each study site. This will consider both synchronic and diachronic variability within each given assemblage.

Did ceramic industries develop or collapse during the Indus early Urban and late Urban periods? This question aims to explore the impact of major socio-political and environmental changes on rural systems of productions and ceramic industries, including the urbanisation and deurbanisation processes and significant climatic changes. The transformations and continuity of systems of production at each major transitional phase will be observed and discussed.

Were ceramic industries in the Urban period sustained by a centralised system of production, or by multi-layered self-sustained horizons of traditional practices? This question aims to understand how systems of productions were organised and expressed in the rural context, exploring the possible scenarios of controlled centralised industries, and the self-sustained landscapes of rural traditional practices. Thus, this will explore how systems of production were organised and sustained within and among rural communities.

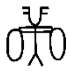
1.3 Structure of the thesis

The thesis is organised in three main parts. Part one will describe the rationale, archaeological issues, methods and materials of the project. Following this introduction, Chapter 2 explores traditionally used theoretical frameworks often used in the study of Indus ceramic materials, such as culture historic interpretations, simplistic evolutionary approaches and *demic* diffusionism (also see Chapter 3.2). This will also propose to adopt a nuanced theoretical framework concerning *making* and *learning* to identify ceramic traditions by means of the *chaînes opératoire* approach, and to explore the variability in social complexity at the studied sites, as well as the related landscapes of craftpeople and traditions. Chapter 3 represents the backbone of this study, presenting the current knowledge of ceramic technologies and industries of the Indus Civilisation, as a result of the past century of archaeological investigation in South Asia. This will highlight the major issues in our understanding of ceramic craft and technologies, as well as certain simplistic interpretations of systems of production in the vast Indus zone. The study site will also be presented there. Chapter 4 will offer a detailed description of the adopted methods as well as the studied assemblages and samples. This will highlight the importance of a nuanced approach for the study of ceramic artefacts for better characterising raw material sources, recipes and manufacturing techniques.

The second part of this thesis will present data and results, and their interpretations. Chapter 5 will present observations sprung from ethnographic work with local communities of potters, especially concerning a better understanding of ceramic manufacturing techniques and raw material sourcing. This will emphases the importance of combining multiple methods to explore the palaeo-landscapes and the variability of clay sources, as well as presenting samples of clay-rich sediments used to characterised the chemical composition of possible sources. Chapters 6, 7 and 8 will present data and results gathered from the study of archaeological assemblages at three settlements, respectively Lohari Ragho (LHR) I and Masudpur (MSD) I in Haryana, and Alamgipur (ALM) in Uttar Pradesh, northwest India. The first part of each chapter will be dedicated to the macroscopic assessment of sherds and vessels. Fabrics, manufacturing techniques and surface treatments will be broken down and assessed in order to identify the technical actions employed in the production of ceramics. In keeping with the *chaîne opératoire* approach, and by using a visual assessment of sherds, the narrative will follow observations on clay pastes and recipes, moving to the description of primary and secondary forming techniques, and eventually culminating with finishing techniques, surface treatments and decorations of vessels. Afterward, within each chapter the above-mentioned technical observations will be combined to reconstruct ceramic traditions. Techno-groups will be presented in a meaningful and comprehensive fashion, describing in detail their characteristics and cross-referencing the technical actions portrayed in the first part of each chapter. Each tradition will resemble an identity card, discussing its manufacturing techniques, decoration and morphologies, and including references to similar synchronic traditions in the region. Petrographic classes identified within each site's assemblage will be presented and discussed, together with the chemical characterisation of ceramic vessels. Petrographic and geochemical analyses will be combined to: (a) reinforce the macroscopic technological observations; (b) better characterise paste preparations and recipes of vessels, resulting in a more detailed understanding of ceramic traditions; and (c) present results concerning possible local or non-local production of vessels.

Part three, i.e. Chapters 9 and 10, will present the discussion and conclusions. This will allow us to provide an answer to the central research question: *How can a compositional and technological study of rural Indus Civilisation ceramic industries be used to explore communities' identities and relations, and to trace evidence for continuity and changes in Bronze Age northwest Indian societies?* The discussions will first revolve around each individual study site, presenting interpretations in a synchronic and a diachronic perspective. These will finally be combined, and will be integrated with interpretations concerning clay-rich sediments and sourcing. The resulting picture will define the nature of traditions and characterise communities of practice, variability of social units and *ceramic landscapes* at rural sites of South Asia's Indus Civilisation.

Chapter 2. A theory of making and learning: traditions, transformations, and landscapes



2.1 Introduction

Ceramic crafts - and artefacts in general - are physical manifestations resulting from the close relationship between makers, materials, and society. The study of ancient crafts has often been undertaken to build chronologies and typologies, characterise identities, and broadly define economic classification ('specialisation') of craft production (Brumfiel et al. 1987; Costin 2001). Little room has, however, been given to study the nature of skills and craft in ceramic production (Hosfield 2009) and the acquisition of knowledge by ancient potters, as an active medium of social change and relations.

In order to understand the development of craft traditions and to observe historical continuity or dis-continuity, it is critical to first explore the relationship between crafters and materials in terms of skills. Craft traditions are linked by common inherited technical gestures (Roux 2016), which are strictly bounded to social, cultural and sensorial perceptions of materials. Society, materials and makers, in this sense, are 'partners in craft', and they can be seen as equally important agents in the production process. The interaction between crafters and materials will be firstly explored, so as to move towards a broader picture and to use archaeological ceramic pottery as a tool to understand variability in functional and social complexity The theoretical approach used in this thesis aims to understand three closely related dimensions, and addresses, directly or indirectly three main levels: (a) the *Individual Dimension*, concerning technological traditions, or the relationship between artisans, technical actions and materials; (b) the *Community Dimension*, concerning mechanisms responsible for transmission of cognitive and embodied knowledge and the development of skills; and (c) the *Regional Dimension,* concerning the broader picture, where relational landscapes and fluid ceramic landscapes are explored and defined.

This chapter proposes moving away from 'old' theoretical frameworks often used in the study of ceramic materials produced and consumed by Indus communities, such as cultural historic interpretations, simplistic evolutionary approaches and *demic* diffusionism (see Chapter 3). This requires moving beyond decorative style and form variability. The presented theoretical framework proposes to identify ceramic traditions by means of the *chaîne opératoire* approach (Coupaye 2015; Dobres 1999; Edmonds 1990; 1990; Lemonnier 1980; 1986; Leroi-Gourhan 1964; 1971; Roux 2016; Sellet 1993), so as to address aspects of technological transformations and innovations. This will make it possible to explore the variability in social complexity at the studied sites, as well as the relational landscapes responsible for the reproduction, changes and resilience of technological traditions and associated social units.

2.2 Current issues

Issues regarding theoretical frameworks and interpretation schemes employed in archaeological ceramic analyses in South Asia will be addressed in detail in Chapter 3. To briefly mention a few of these issues, there are observations on regional diversity and variability which seem to counter the widespread idea of homogeneous ceramic production across the Indus zone (see Chapter 3.2.1.a). Outmoded theoretical frameworks and their implications have been underlined as well. These includes two leading sister thoughts: the tendency to present narratives based on cultural histories and cultural evolutionary approaches (see Chapter 3.2.1.b), and the effects of simplistic evolutionary approaches and *demic* diffusionism to rationalise changes and continuity of ceramic industries (see Chapter 3.5). Besides archaeological interpretation schemes, ethnographic observations on modern communities of craftspeople in South Asia have also been affected by old-fashioned approaches (see Chapter 3). For instance, the effects of the direct historical approach and of the tendencies to present parallel histories have already been summarised, as well as their impact on our current understanding of ancient Indus tools, techniques and technologies (see Chapter 3.4.1).

Mindful of current theoretical issues, a nuanced theoretical framework was deemed necessary in order to gain an understanding of Indus ceramic traditions and producers. The main aim of the following sections is to present the adopted theoretical strategies underling data collection, analyses and interpretation of ceramic materials in the Indus context. Moreover, there is a need to prevent conceptual confusion so as to avoid false analogies between the forms of expression in different 'regions of language' (Wittgenstein 1953: PI 90). Thus, this chapter will also serve to present the 'verbal definitions' of certain concepts adopted throughout the thesis, clarifying the meaning of most recurrent technical terms or signs.

2.3 People and materials

Most of the theoretical framework adopted for this study falls under the umbrella of *materiality* theory. Materiality theory has been largely used to understand ancient crafts and technologies (David and Kramer 2001; Dobres and Hoffman 1994; Martinón-Torres and Killick 2015: 5; Schiffer and Miller 2002; Livingstone Smith 1982; 2001b; DeMarrais et al. 2004), and its high value for archaeometric studies is well established (Jones 2004). Through the examination of the relationship between people, objects and landscapes, this approach aims to rediscover certain social and cultural aspects of ancient communities (Knappett 2012). The *chaîne opératoire* approach is a core component of materiality theory, and it dwells at the core of this study. The definition of the concept of *chaîne opératoire* has changed slightly in the past couple decades, being described as: (a) the life of an object: from procurement and production, to use and discard (Sellet 1993; Sillar and Tite 2000), or as (b) a chain of techniques or operative steps through which a procedural action is accomplished (Dobres 2000: 153–55). The latter definition will be used in this thesis, being possibly the most common in archaeology, and referring to craft production and material activities (Cresswell 1990). In particular, the *chaîne opératoire* of ceramic manufacture focuses on technical actions, on choices made in the production sequence of pottery, and on the reasons behind such choices (Van der Leeuw 1993). In other words, it mostly deals with the *technological choices*, made by potters during the production stage (Gosselain 1998; 1992; 1999; 2000; Lemonnier 1992; Sillar and Tite 2000).

2.3.1 Technologies and traditions

The term *technology* here is intended as a system of actions or *techniques* and the related knowledge of how to transform matter (Cresswell 1990: 46; Ingold 1990: 7; Kline 1985a; 1985b; Lemonnier 1992; Schlanger 2006: 200). The term *technique* here refers to an action or skilled act (Ingold 1993: 433). Broadly, the concept of *technological choice*s refers to the study of the corpus of knowledge and skilled actions possessed by craftspeople, as well as the processes and mechanisms behind it (Lemonnier 1993; Sillar and Tite 2000: 3). This concept/definition is based on the notion that an artisan, or communities of artisans, may have mindfully *chosen* to use one or another set of actions, tools and materials. For instance, in the field of ceramic analyses, these concepts have been largely used in studies concerning the choices and processes behind *chaînes opératoire* of pottery production (Gosselain and Livingstone Smith 2005; Van der Leeuw 1993), including the investigation of technological changes or continuity, social boundaries and identities (Dietler and Herbich 1998; Roux 2003a; Schiffer and Skibo 1987; Stark et al. 2000).

However, the concept of *technological choices* may need further clarification. For instance, in the case of ceramic production, potters may have used a certain set of techniques and materials not due to a direct personal choice. Potters may more simply follow *traditional* manufacturing processes that have been taught to them. In this case, it would be an indirect choice, more or less mindful, of a potter to follow a system of *traditional* knowledge, tools and techniques (Dietler and Herbich 1998; Gosselain and Livingstone Smith 2005). Moreover, in the case of prehistoric or protohistoric communities and landscapes, archaeologists may not be able to identify the many options that a potter might have had. Thus, identifying the mindful *choice* of one or another option could be problematic. To overcome these issues and possible misunderstandings, the concept of technological choices is extended for the purpose of this thesis. It will encompass both the individual agency in a specific context, and the corpus of social actions and practice of a social unit (Lemonnier 1992; 1993). When emphasis needs to be put on the latter aspect, viz. the social practice, then the concepts of *technological traditions* or *traditional practices* shall be used (Dobres and Robb 2000; Roux 2016).

2.3.2 Chaîne opératoire and traditions

This thesis follows the theoretical framework adopted by Roux (2016) for identifying *traditional practices* or *technological traditions* through the reconstruction of *chaînes opératoires*. For understanding the value of this approach in the study of ancient communities, it is appropriate to put emphasis on certain social dynamics tied together with craft producers. Two main concepts should be highlighted here: the first being the learning and transmission processes, the second being ontological boundaries, or the social perimeters within which certain traditional practices are transmitted.

At an individual level, the examination of learning mechanisms and transmission of skills and knowledge through archaeological evidence is well established (Bril et al. 2010;

Dobres 2000; Gandon et al. 2011; Gosselain 2000; Hosfield 2009; Ingold 2001; Kuijpers 2018; Reed and Bril 1996; Stout et al. 2002). This is based on the basic concept that a mentor transmits to the learner not only a corpus of skills and knowledge, but also a specific mental model of how to make things. By means of practice and repetition, the learner progressively acquired the distinctive perceptual-motor and cognitive skills necessary for producing objects. As a result, such skills become essentially "embodied" in the learner. At the individual level, the learner acts as factual "fixing agent" of the cultural model, aiming to reproduce the visual representation of a transmitted mental model (Roux, 2016).

At the community level, the learning and transmission processes happen within a network or group of people kept together by social ties. These social ties are multidimensional functions of social structure, including shared activities and personal attributes, and can be used to determine a social perimeter (Degoy 2008; Gosselain 1998; 2002; Kramer 2008; Livingstone Smith 2000; Roux 2016). The nature and configuration of a given learning community, in this thesis also referred to as a '**social unit**', within which a certain mental and cultural model is transmitted, can be variable. Echoing Roux's words (following Roux 2016; 2019a; 2019b; 2019c; 2019d), **a learning community, or 'social unit', can range from a family to a caste or sub-caste, from a lineage to a guild, from an ethnic-group to a gender, and so forth**. Despite the variable nature of learning networks, a *traditional practice* is always transmitted by a member of a social unit, within which a given technological tradition overlaps with its social boundaries. Therefore, from a social ontology perspective, the documentation of *chaînes opératoires,* combinations of tools, techniques, skills and technical knowledge, and traditional practices, including their processes and transformations, can be used as a medium to identify chronological markers (Gosselain 1992: 559, 572; 2000: 210), as well as to rediscover interactions, identities and cultural practices of social units (Stark 2003: 212). The correlation between **social units** and **technological traditions** seems to be particularly clear when theoretical frameworks show a predilection for a behaviourist approach (Schiffer et al. 2001; Skibo and Schiffer 2001), an evolutionary or neo-Darwinian approach (Boyd and Richerson 2005; Shennan 2002; Shennan and Wilkinson 2001), or a culturalist approach (Latour and Lemonnier 1994; Lemonnier 1992; 1993). Currently, this correlation has now been securely established and broadly accepted, partially thanks the contribution of ethnographic studies (Roux 2011).

Figure 2.1 Diagram showing five simplified stages of pottery production (after Roux 2011; 2016; Miller 1999: Fig 2.1).

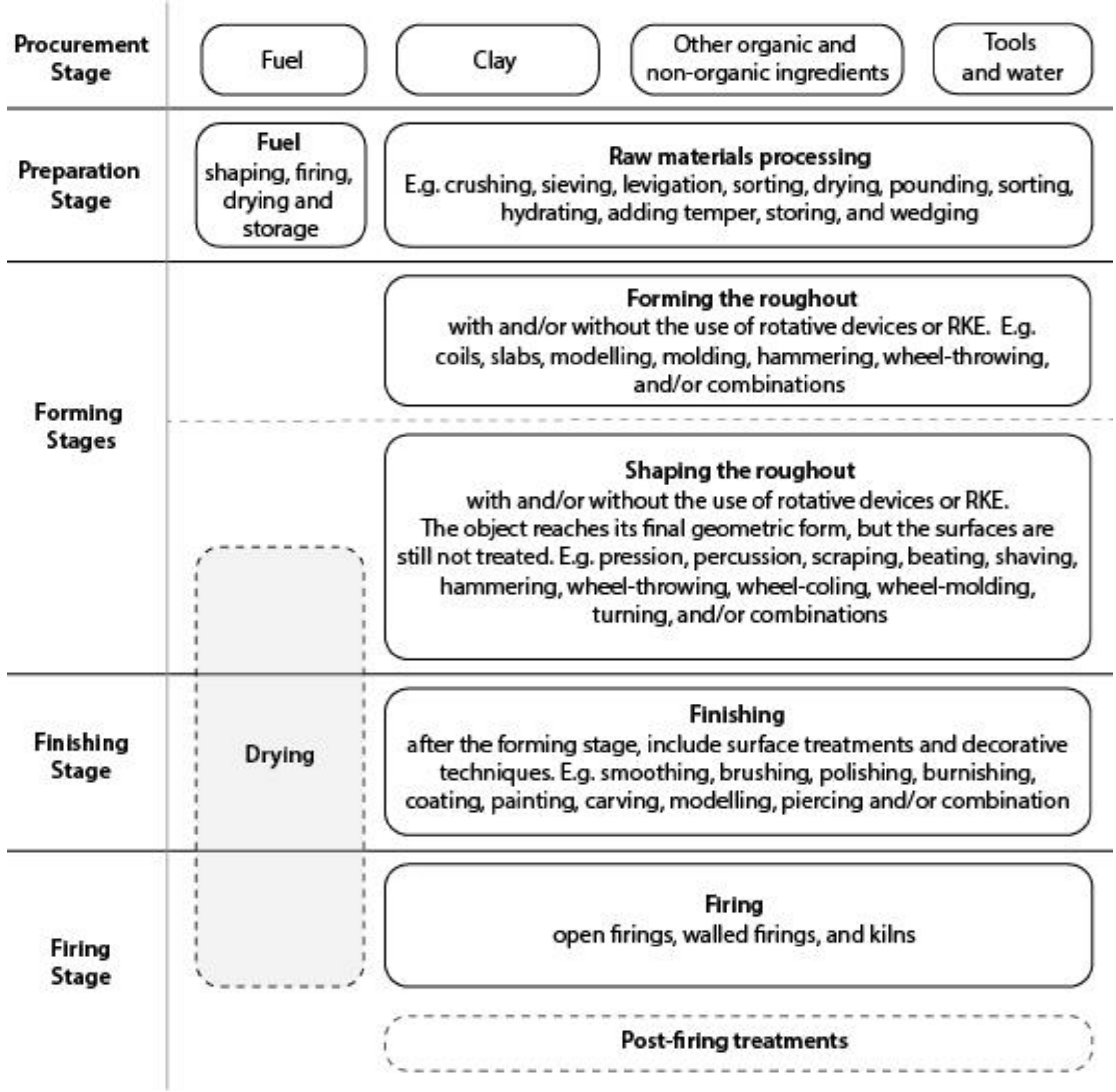
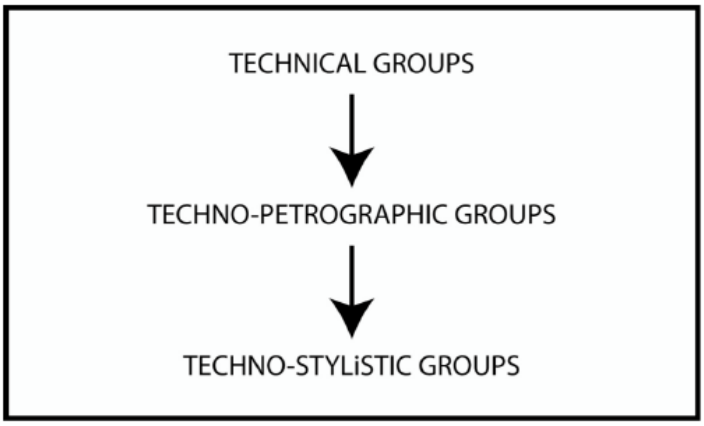


Figure 2.2 The hierarchical technological approach proposed by Roux (2016) for the identification of technical traditions and variability of social units (after Roux 2011).



2.4 Identifying ceramic traditions

When undertaking the study of materials and the sequences of technical actions used by ancient potters in the production of ceramics, universal and particular dimensions should be considered. Generally, it could be said that, in order to produce a successfully finished vessel, most potters would follow a similar line of actions and set of materials. These almost universal actions include: collecting and preparing the clay, forming a vessel, treating and decorating its surface, and finally firing it. However, the concept of *chaînes opératoire* concerns the particular activities involved in each of these stages (see Figure 2.1), and their examination require a detailed level of description.

The identification of recipes and manufacturing processes is not necessarily an easy task and requires a combination of methods. Generally, these methods can be classified into two broad categories: the traditional (visual or macroscopic) assessment, and analytical (or microscopic) techniques (see Chapter 3). In order to gain a detailed understanding of *chaînes opératoire*, the integration of scientific analytical techniques has proved to be remarkably valuable (Martinón-Torres 2002; 2018; Pierret et al. 1996; Reedy 1994; Sillar and Tite 2000). Reverse engineering has been successfully used to reconstruct the whole sequence of technical actions for producing ceramic artefacts (Kingery 1996; Tite 1999: 182). Moving away from simplistic studies of tools, techniques and material properties (Gibson and Woods 1990; Gosselain 1998; Killick 2004), the current predominant trend favors archaeometric methods to address specific archaeological or anthropological questions (Bray and Pollard 2005; Kingery 1996). More broadly, data collected through this type of analyses can be subsequently used to address research questions concerning provenance, distribution, production, use and function of ceramic vessels. More details on the use of scientific analytical techniques in this study are provided in Chapter 6.

The identification and characterization of ceramic traditions requires a precise organisation of collected data, from both macroscopic and microscopic evidence. The organisation of ceramic assemblages according to the *chaîne opératoire* approach follows three hierarchical and sequential sorting stages (Roux 2016; see above Figure 2.2): **(1)** *technical groups*, or the identification of groups according to visual assessment of techniques of forming and fabrics; **(2)** *techno-petrographic,* or the identification of compositional groups via thin-section petrography, and how petrographic fabric groups belong to and characterise the recipe of a single technical group, or where a single petrographic fabric can characterise multiple technical groups; and **(3)** *techno-morpho-stylistic* or techno-stylistic groups, sorting by morphological and stylistic types related to each techno-petrographic group. Each resulting techno-petrographic group represents a distinctive *chaîne opératoire* in the assemblage, which is characterised by ceramic forms and styles when the *techno-stylistic* variables are integrated. In other words, **a techno-petrographic group represents a technical tradition**, which is manifested in its distinctive forms and styles, viz. the techno-stylistic groups.

2.4.1 Functional variability and social complexity

The approach portrayed above serves to explore the (a) functional variability and (b) underlying social variability of ceramic traditions (Roux 2016; Roux and Courty 2007, 2013). There are a number of assumptions associated with this approach, as follow:

Functional variability. The integration of pottery forms and styles in the technological approach may serve to explain part of the variability of ceramic traditions and the function of a *chaîne opératoire*. For instance, when a distinctive techno-petrographic group (e.g TPG1) in an assemblage of multiple *chaîne opératoire* (e.g TPG2; TPG3; TPG*n*) is related to only one class of vessels (e.g. bottles), then that ceramic tradition (TPG1=bottles) could be explained in functional terms (Roux 2016: 9). This functional explanation would discount the identification of TPG1 with a **distinct tradition and with a social unit**. When the morphological diversity is higher and the technological matchup is not clear, then questions concerning social complexity can be addressed (see below).

Sociological complexity underlying variability in assemblages. The concept of sociological or social complexity is used in this thesis to indicate medium to large social units and a suite of characteristics that include social organisation and/or socio-economic specialisation (Carballo 2013; Carballo et al. 2014; Cowgill 2004; Feinman 1998; Smith 2009). Depending on the variability and number of techno-petrographic groups or *chaînes opératoires* in an assemblage, which indicates its degree of homogeneity or heterogeneity, issues regarding the underling level of social complexity, or the variability of socio-cultural groups, may be addressed (Roux and Courty, 2007, 2013). Three possible models, associated with social units with either low or high variability, can be summarised as follow:

B1. *Homogeneous with low socio-cultural variability*, viz. only one techno-petrographic group, use of local clay sources, and vessels' morphological variability. This scenario likely points to settlements occupied by one homogeneous social unit, which shares the same tradition of pottery making, teaching and learning. At a regional scale, the synchronic overlapping of multiple 'B1'-type assemblages depicts the social mosaic of a region. Homogeneous assemblages suggest the presence of social units producing according to the local demand, and they tend to be found at settlement sites.

B2. *Homogeneous with high socio-cultural variability*, viz. a few techno-petrographic groups, the use of one or a few clay sources located in close proximity to the studied site, multiple vessels' morphologies. This scenario points to settlements with diverse, multi-layered social units, the understanding of which relies on contextual data (e.g. cities, colonies, functional use of a sites).

B3. *Heterogeneous with low or high socio-cultural variability*, viz a low or high number techno-petrographic groups marked by mixed petrographic groups, associated to the use of multiple clay sources distributed across the region (low variability) or beyond (strong variability), and multiple vessels' morphologies. These type of heterogeneous assemblages identified at one settlement points to the movement of containers and probable movement of consumers originating from a broader regional area. The understanding of these type of site most likely depends on quantitative and contextual data (e.g. trade and exchange, importing vessels, marketplaces, pilgrimage, religious sites, etc.). Heterogeneous assemblages likely suggest a ceramic production by multiple social units spread over a large area or region(s), and are indicative of sites possibly associated with congregations of different social units.

2.5 Diachronic perspective: transformations and innovations

The following two chapters will present in detail sites and collected samples, aiming to emphasize the changes and continuity of Indus settlements and ceramic traditions. For a diachronic perspective, the *chaîne opératoire* approach can be used to trace the *transformation* of traditions and technologies over time and the history of the associated communities. This is achieved by attempting to identify and understand the types of learning and *transmission* mechanisms that were in operation, which in turn allow investigation of the underlying social dimensions. As mentioned above (also see Chapter 3), the interpretation of such mechanisms and related social dynamics in Indus archaeology has not been the focus of much research so far (Ceccarelli and Petrie In press; 2018). Specifically, in this thesis the first objective is to identify patterns of cultural succession in the *chaîne opératoire*, so as to outline affiliation between assemblages (Haudricourt 1987; Riede 2006; Schlanger 1994). If technological traditions are characterised by inherited technical gestures, it is possible to confidently establish historical continuity (Roux 2016). Otherwise, the appearance or development of new social units, the fading of previous groups and/or reconfiguration of communities can be considered (Roux 2013).

Within the framework of transmission and reproduction of ceramic traditions, the mechanisms behind technological '*innovations'* or resistance to innovations are particularly complex to explore in the archaeological record and require a dynamic approach (Roux 2003a; 2013). A suitable framework for the study of changes and continuity of technological traditions requires the consideration of technical trends, the social context and the reasons that brought a new technological tradition to appear in a specific context. For instance, the development and adoption of new technologies, decorative styles, and vessels' morphologies are not necessarily an homogeneous process, and the potential for resistance to innovations within a region over many centuries could also be considered. Aspects of material agency and human choices in the processes of adopting and transmitting technological knowledge (Petrie 2011), and the social mechanisms behind resistance should also be taken into account, particularly in relation to observations made within and amongst variable regional traditions.

Understanding technological transformations and the mechanisms responsible for the reproduction of traditional practices is particularly important in the context of Indus communities due to the major socio-political and environmental changes that affected the Indus zone at different stages in the development of its social complexity (see Chapter 2). For instance, the thesis directly or indirectly touches upon theories regarding the *collapse* of *complex societies*, and the nature of this process in the Indus case specifically (Petrie et al. 2017a; Tainter 1988; 2006a; 2006b). This is due to the fact that such concepts are frequently used to unpack the de-urbanisation phenomenon of Indus large-size settlements, which may have had an impact on aspects of rural life and traditions. Beyond the framework of collapse theories, the concept of *resilience* (Bicho et al. 2017; Bradtmöller et al. 2017; Holling and Gunderson 2002; Redman 2005; Rosen and Rivera-Collazo 2012) will be also used here.

In summary, the (a) historical continuity of technological traditions, the (b) materialisation of innovations, and the possible (c) social changes, including the appearance, reconfiguration, resilience and disappearance of social units will be the main focus of the diachronic interpretations presented in this thesis.

2.6 Synchronic perspective: people, region and landscapes

The sites selected for this study make it possible to contribute conceptually to the understanding of a regional picture of the distribution of ceramic products and the degree of shared technological traditions in northwest India. Such is the potential of synchronic observations, mostly concerning the distribution and consumption of ceramic vessel/artefacts, as well as the learning network and relational landscapes. The distribution of ceramic vessels/artefacts will be only partially addressed in this thesis. The study of distribution concerns regions or social spheres within which ceramics are produced, spread, or may have moved along with their consumers (Neves 2008; Petrie et al. 2007; Pierret et al. 1996; Tite 1999). In this thesis, the study of movement of vessels limitedly concerns rare, non-recurrent quantities of likely exogenous ceramic traditions identified at the studied rural site, which might be indicative of the movements of containers from other villages and/or urban settlements. Aspects of ceramic distribution will not be profusely investigated in this thesis, due to the nature of the available dataset and assemblages. However, it is acknowledged that this type of study is indeed possible to develop in the future, if technological data from more neighbouring villages and urban settlements within the same macro-region are integrated into the dataset used for this dissertation. However, as mentioned above, learning mechanisms and relational landscapes lay at the core of studies on technological transformations and variability of social units.

2.6.1 Community of practices and relational landscapes

The concept of landscape as used in this study may refer to both the qualitative physical environment and to the quantitative socially-constructed actor-network dimension (Ingold 1993: 154). In the latter sense, landscapes are considered not as the result of actions, but to emerge through the actions (Ashmore 2004; Gregson and Rose 2000: 441; Whatmore 2006; 2017), and are sustained by persistent individual actions. Socially-constructed landscapes are continuously being made (Jervis 2014: 110–11), and represent a network of meanings and relationships connected to multiple dimensions and experiences of space (Gregson and Rose 2000). Given the dynamic nature of social landscapes, they are often seen as fluidly interlocking with other landscapes, multiple spheres of knowledge, memories and actions. The concept of social landscape will be here integrated with communities of practice theories to characterise social relations and boundries among communities and producers beyond single settlements.

From the point of view of learning and sharing technical skills, *communities of practice* (CoP) theories are good for describing the situation of a given landscape actively constructed and perceived by people sharing "a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in an area by interacting on an on-going basis" (Wenger et al. 2002). Basing this concept on the idea of 'embodied' learning and knowledge as above described (Contu and Willmott 2003), CoP draws on social learning theory (Contu and Willmott 2003; Lave and Wenger 1991; Roberts and Vander Linden 2011; Roberts 2006; Wenger 1998), which sees the transmission of knowledge as something emerging in social contexts and mutating over time. According to CoP theories, members of a learning community share a sense of belonging and reciprocal participation, with identity and its social construction being important aspects. Key to the paradigm is the fact that members of a community of practice are, first of all, practitioners, which require time and sustained interaction to gain a certain shared set of skills and corpus on knowledge (Cummings and Van Zee 2005: 10).

In this thesis, the concepts of socially constructed landscapes and *community of practices* have been chosen over *learning networks* theories (Engel 1993; 1997) due to the context of the data collected. A learning network is usually believed to be formed by actors who undertake tasks broadly associated with the three processes of: learning policy, planning or programming, and the qualification process, through which the learners acquire the relevant qualifications (van der Krogt 1998). Even though the CoP and learning-networks theories are conceptually similar and share most aspects, learning networks are more institutionalised, while communities of practice are 'unregulated exchange mechanisms' (Cummings and van Zee 2015). Wenger (1999) has emphasised that communities of practice are more 'informal', and tend to escape formal descriptions and control. Since the available contextual data does not allow us to say whether Indus crafters were consciously and formally institutionalised a given landscape of practices, *community of practices* theories are preferred here. For better understanding the difference between certain similar cocepts used in this thesis, such as *community of practice*, *social unit*, and *population*, a simplified scheme is presented in figure 2.3 below.

Finally, in order to understand connections between communities, similarities between social units need to be considered, as well as degrees of '*embeddedness'* of the network connecting social units. Embeddedness is defined as how individuals or groups choose to interact with a large number of individuals or just a few (Borck et al. 2015: 37; Collar et al. 2015). For instance, via a qualitative approach to the study of similarities and diversities of recipes and manufacturing techniques of the ceramic assemblages between settlements (Roux 2016), it is possible to get an insight into *embeddedness of networks,* and may suggest interactions between communities at different scales. In this respect, ceramic assemblages can be analysed in terms of techno-petrographic homogeneity versus heterogeneity so as to ascertain variability of socio-cultural groups (see above Section 2.4).

2.7 A theory of ceramic landscapes

The study of ceramic production is an ideal way to explore the formation and sustainability of social landscapes, especially when study of raw materials provenance and technological traditions are involved. On one hand, the identification of 'local' ceramic traditions, using locally available raw materials, can provide a view over the perception of, knowledge about, and interaction with physical landscapes by potters. On the other hand, the study of technologies and shared technological traditions can be used to explore the learning mechanisms associated to the reproduction of a corpus of skills, knowledge and models within a site and its surrounding region. The concepts of socially constructed landscape of practices and *community of practices* are here used to formulate a theory of *fluid ceramic landscapes*. As a theory, *fluid ceramic landscapes* will be use to explain certain phenomena concerning ceramic industries at Indus sites, which will be explored in the second part of this thesis. As a concept, based on theories of *technological traditions*, CoP and social landscapes, fluid *ceramic landscape* is defined as follows:

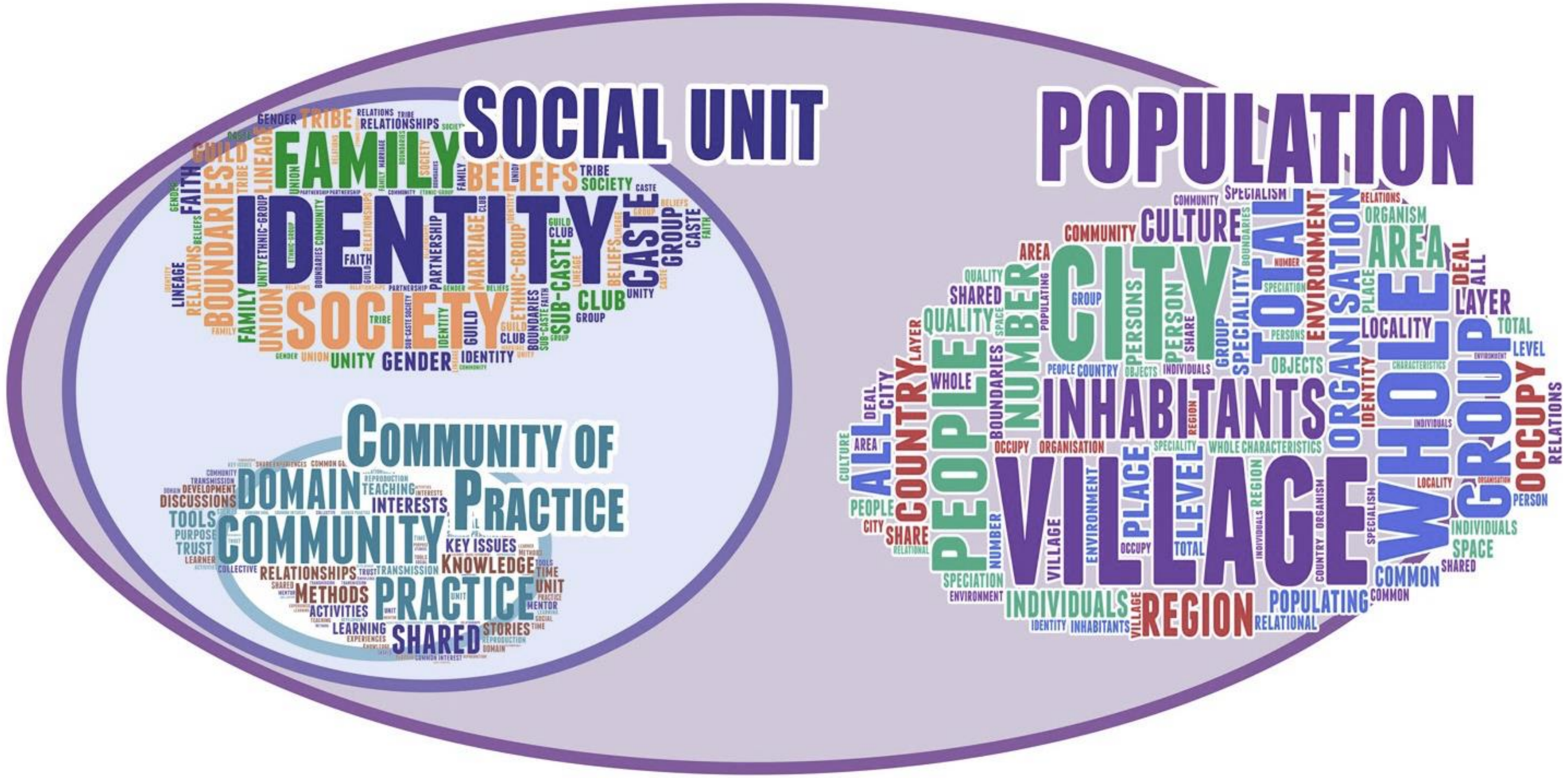
a. *Ceramic landscapes* are constructed, sustained and experienced by communities of potters, which share a *technological tradition*;
b. Members are concerned with a set of problems and contribute to deepen knowledge and expertise in an area through social interaction. 'Embodied' learning, skills and knowledge are transmitted between its members. Transmission of knowledge emerges in social contexts and mutates over time. It is characterised by a sense of identity and reciprocal participation;

c. A ceramic landscape falls within the boundaries of social units, and represents a social unit and its action sphere;
d. Time and sustained social interactions allow the transmission of a certain set of skills and corpus on knowledge. This process is one of the main factors responsible for the *resilience* of and *transformations* in a given ceramic landscape;
e. In keeping with the communities of practice model, they are intended as characterised by informal, unregulated exchange mechanisms, and tend to escape control (see Cummings and van Zee 2015);
f. Synchronic and diachronic ceramic landscapes may overlap and interlock with each other, may coexist in multiple variable contexts, and yet keep their own sense of identity and relation to a specific social unity. In this sense, they are seen as porous or *fluid* and multi-dimensional rather than rigid social units (Howard 2000; Diane Enns 2007). I will argue that these ceramic landscapes and social units are reactive and therefore constantly *fluid* (Raynor 2006: 4–6), rather than being static units sharing static cultural values, consciousness and beliefs, and yet they are capable of constructing and maintaining their own sense of identity; and
g. Multiple ceramic landscapes can coexist and share a given time/space dimension, and they are *not* considered as exclusively independent, and do not unavoidably get replaced by or replace each other.

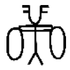
2.8 Summary

This chapter has offered an alternative theoretical framework to the most conventional ones that have been often used in the study of ceramic materials produced and consumed by Indus communities. This theoretical framework proposes to identifying ceramic traditions by means of the *chaînes opératoire* approach, so as to address aspects of technological transformations and innovations over time. It will be taken one step further to explore the variability of social units at the studied sites, as well as the relational landscapes responsible for the reproduction, change and resilience of technological traditions and associated social units. Thus, the aim of this study will be to identify the *ceramic landscapes* that characterised the occupational phases of the studied Indus settlements and the regions they occupied.

Figure 2.3 The simplified diagram and tag clouds are here presented to clarify the meaning and use of certain concepts defined in Chapter 2 such as 'community of practice', 'social unit', and 'population', as intended in this thesis.



Chapter 3. Ceramic technologies, the Indus Civilisation and northwest India



Parts of this chapter have been published during the PhD programme (see Ceccarelli and Petrie, 2018; In Press; Singh et al. *including Ceccarelli A., 2018a; 2018b).*

3.1 Introduction

The ancient pottery recovered from sites occupied by Indus Civilisation populations has been subjected to a considerable degree of scrutiny and subsequent publication (e.g. Ceccarelli and Petrie, In Press). However, the production of protohistoric ceramics in the Indus River Basin and surrounding areas are still far from being completely understood. For archaeologists, pottery is one of the most significant sources of data, not only due to the durability and abundance of ceramic artefacts in the archaeological record, but also for the wide range of information on ancient societies that can be inferred from its study. This chapter aims to provide a comprehensive assessment of the approaches to ceramic studies and the results so far achieved in the Indus zone (i.e. henceforth used to refer to the geographic area where Indus Civilisation populations lived; see Figure 3.1), as well as introducing the studied region and archaeological sites. It is divided into four broad sections.

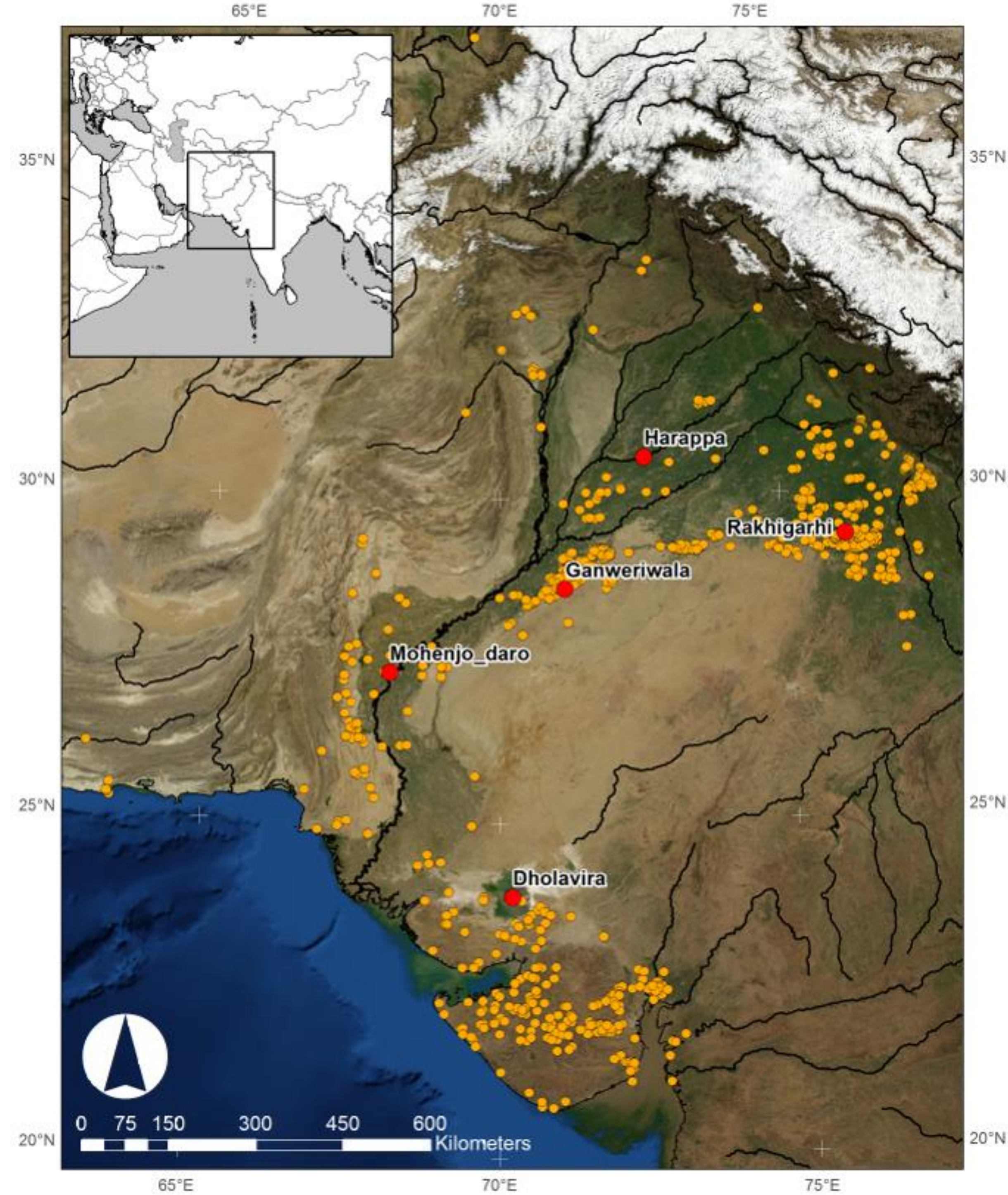
The first section will provide an overview of the approaches to ceramic studies, outlining how some themes of archaeological research have developed in the Indus zone, and how it is now timely to investigate certain research questions. It explores the three main methods that have dominated the field: (a) morphological approaches, where pottery assemblages are grouped according to macroscopic attributes; (b) scientific approaches, where ceramics are understood in terms of their composition and production technologies; and (c) ethno-archaeological approaches, where the practices of modern potters are assessed to inform our understanding of the practices of past pottery. This targeted groundwork (a) will explore issues related to documentation and interpretation of pottery, b) will review the use and development of geochemical and petrographic methods for the study of South Asian ceramic traditions, with special emphasis on assemblages produced and used by Indus Civilisation communities (2500-1600 BC), and c) will focus on the direct historical paradigm and related achieved results. This approach will clarify why certain methods and materials have been selected for the presented study (see Chapter 4).

The second section of this chapter will review discussion of the transmission and transformations of technological knowledge and skills, gathering data and results from the Neolithic to the Indus Urban Period. This is a necessary assessment of the current knowledge that makes it possible to set up research questions related to the development of regional ceramic industries and multiple coeval ceramic traditions, with a special emphasis on ceramic production in northwest India. This assessment will also clarify the need for the adopted theoretical framework as presented in Chapter 2. It will be used to define the concept of *Indus ceramic landscapes*, where the nature and variability of ceramic networks in certain regions of the Indus zone is systematically considered. Special emphasis will be put on the prevailing evolutionary paradigm that seems to have dominated the interpretation of such data.

The third part will outline our current understanding of ceramic technologies and traditions of the Indus Urban period. Available data on raw materials processing and procurement, manufacturing techniques, surface treatments and firing technologies will be systematically presented, with the intention of delineating ideas about variability and uniformity in ceramic production processes, as well as pinpointing controversies and gaps in the literature.

The final section will describe the archaeological sites that were selected for this thesis, as well as their surrounding landscapes. This will serve to introduced the studied region and how the selected settlements can contribute to understand certain periods of the Indus Civilisation in northwest India. First, an overview of the geomorphology and hydrology of the studied regions will be presented. This will place the archaeological sites into their environments, and shall serve as a preliminary step to introduce the study on raw materials and provenance of ceramic artefacts (see Chapters 4 and 5). The author was part of the *TwoRains* team involved in the excavation and documentation of material from two of the three sites, and co-ordinated the processing and analysis of archaeological ceramic materials, which were collected from each context and recorded systematically. Materials were selected from significant contexts in order to observe continuity and change in ceramic traditions across the Pre-Urban (or Early Harappan, c.3200-2600 BC), Urban (or Mature Harappan, c.2500-1900 BC) and Post-Urban (or Late Harappan c. 1900-1300BC) periods.

Figure 3.1 The Indus zone. Map showing distribution of Indus sites and five Indus urban settlements during the Urban period (Petrie et al. 2017a).



The site of Lohari Ragho I produced material which served to explore the transitional phase from the Early to the Mature Harappan period. The sites of Masudpur I and Alamgirpur contributed to gaining a detailed understanding of the transition from the Mature to the Late Harappan period, and add additional insights as they are located in two different regions. Lohari Ragho I and Masudpur I are situated in the immediate hinterland of the large Indus urban site at Rakhigarhi, while Alamgipur is located some distance to the east and was selected to provide an impression of the easternmost fringe of the Indus zone.

The choice to present an extensive, detailed overview of selected aspects of Indus ceramics studies was driven by the need to systematically reconsider some of the generally accepted ideas revolving around Indus pottery and related social mechanisms, and to highlight certain significant gaps in our knowledge. Thus, this chapter represents the cornerstone of this thesis, as is shows the origin and ramification of certain themes that will be indirectly or directly addressed throughout this study.

Table 3.1 Someregional pottery traditions during the Indus Urban period.

Ceramic Tradition	References (e.g.)
'Classical Harappan Pottery' or Red Harappan Ware	(Dales and Kenoyer 1986; Dangi and Uesugi 2013; Quivron 2000; Rao 1963; Thapar 1975; Uesugi 2011a; 2013)
Kulli Harappan	(Possehl 1986)
Punjabi Harappan	(Possehl 1999a)
Eastern Harappan	(Possehl 1999a)
Quetta Phase	(Fairservis 1956)
Late Kot Dijj	(Dani 1970)
Micaceous Red Ware	(Dimri 1994; Herman and Krishnan 1994; Rao 1963)
Sorath Harappan	(Herman 1989; Possehl and Herman 1987; Rajesh and Krishnan 2017; Sen 2009)
Prabhas ware	(Ajithprasad and Sonawane 2011, 200; Dhavalikar and Possehl 1992; Nanavati et al. 1971; Subbarao 1958)
Padri Ware	(Rajesh and Krishnan 2017; Shinde 1992; 1998)
Indus Bara Ware	(Sharma 1987; 1989; Sharma and Sharma 1982; Uesugi and Dangi 2017)
Savalda culture	(IAR 1959, 16–17; Shinde 1990)
Haryana Harappan	(Parikh and Petrie 2016)
Glazed Reserved Slip Ware	(Krishnan 2002; Krishnan et al. 2005; Mackay 1938)
Lustrous Red Ware	(Bhan 1994; Bhan et al. 1994; Rao 1963; Rissman et al. 1990)
Cut Ware	(Dales and Kenoyer 1986, 57; Lal et al. 2015, 405–7; Mackay 1938, 181; Marshall 1931, 465)
Jhukar-like Pottery (Post-Urban)	(Allchin 1982, 242; Casal 1964; Dales and Kenoyer 1986, 229; Fairservis 1975; Mackay 1943; Majumdar 1934; Possehl 1977)

3.2 Morphological and typological approaches

Morphological examination of ceramic vessels is the most common and fundamental analytical approach used to understand archaeological ceramics worldwide. The main features taken into account are vessel forms, macroscopic assessment of fabrics, and surface features (Orton and Hughes 2013; Rice 2015). Interior and exterior surfaces can provide details on decorative styles, as well as manufacturing and finishing techniques, which often involves the interpretation of macro-traces on the walls of vessels (Roux 2016; Roux and Courty 1998; Wright 1989; 1991). This can be associated with the principle of 'controlled analogy', viz. comparing the micro-fabrics and macro-traces on the surfaces of ancient, experimental and ethnographic ceramic vessels (see Roux 2016: 7). Such an approach contributes to identify, and to some extent to establish, attributes considered to be significant indicators of particular manufacturing techniques. This technological and typological classification of 'wares' based on their visual and external attributes can help, with a certain degree of accuracy, to answer questions on provenance, production, use, and distribution of ceramics (Sillar and Tite 2000; Tite 1999). On social, cultural, and economic levels, this traditional approach can be taken one step further, to reconstruct the histories of ancient communities and craftsmanship.

Classifications based on morphological examination have been abundantly used in Indus archaeology, and this approach is presented in most excavation reports. The initial accounts of Indus and related ceramics were elementary description of artefacts (Hargreaves 1929; Stein 1929). Marshall's (1931) volume on Mohenjo-Daro contains a pottery report, but Ernest Mackay's (Mackay 1930; 1938; 1943) monumental publications on Mohenjo-Daro and Chanhudaro, Sindh, were the earliest to incorporate observations on a number of macroscopic features of Indus ceramics, including the study of pastes, decoration, dimensions, and frequency of occurrence, as well as making reference to possible manufacturing processes and functions. The latter aspects were also investigated through a comparative analysis of ancient pottery production and modern ceramic traditions in Pakistan, which was one of the most remarkable characteristics of Mackay's work.

In many ways, Mackay's analysis of ceramics laid the foundation for subsequent publications that discussed ceramics of the Indus period, but the breadth of his approach was not consistently followed. For instance, some of the renowned typological ceramic studies were developed in the early phases of Indus archaeology by N. G. Majumdar (1934), M.S Vats (1940), Richard Francis Strong Starr (Welker and Starr 1941), Sir Mortimer Wheeler (1966) and J. P. Joshi (Joshi 1972). Even though this type of analyses gradually focused more on material found in stratigraphic excavations, they concentrated mostly on morphological aspects, and were lacking certain specifics concerning methods. For example, scholars who undertook similar studies often had inconsistent documentation and unclear stratigraphic provenance of materials, and frequently organised their material by unclear classificatory methods (Manchanda 1972; Nigam 1979). Thankfully, there have been studies that present a consistent methodology, such as the works of Rao (1969; 1963), Dales and Kenoyer (1986), Herman (1989) Quivron (1993; 2000), and Uesugi (Uesugi 2011a; 2011b; 2002), which are in many ways the highpoint of typological studies on Indus pottery.

A comprehensive understanding of Indus ceramics has partially suffered from the predominant use of a typological approach, and has had to overcome four recurrent issues: (a) assumptions about a lack of variability of craft production; (b) inadequate theoretical frameworks used for the interpretation of ceramic assemblages; (c) the condition of ceramics found at archaeological sites; and (d) inconsistent documentation strategies.

3.2.1 Typologies and regional diversity

Assumptions about the lack of variability in ceramic industries are closely connected to use of a typological approach, and to an unproven – yet widespread – perception that Indus ceramic traditions were uniform. The words of Piggott (1950) still echo soundly, and the attributes he gave to Indus pottery have influenced the archaeological research until recent times, and the phrases "stagnation and uniformity" and "monotonous regularity" are just two examples of the general traits he associated to ancient industries and artefacts. The assumption of uniformity and regularity has led to an imprecise recording and uneven analyses of pottery (Dales 1991; Dales and Kenoyer 1986; Shaffer 1992). The impact of this thinking is clearly encapsulated in Rao's (1969: 257), statement that "We all know that the Harappan ceramic wares are uniform throughout the vast region covered by the Harappan Civilisation". The assumption that the Indus Civilisation was characterised by homogeneous cultural manifestations has led to simplistic hypotheses about other categories of material (Possehl 1998; Rao 1969; Shaffer 1992). In the last thirty years, however, scholars have begun to advocate for different interpretations, where environmental and cultural heterogeneities in the Indus zone are given a pivotal role (Chakrabarti 1988; Joshi et al. 1984; Petrie 2017; 2013; Petrie et al. 2017b; Possehl 1982; 2002: 62; Vishnu-Mittre 1982; Weber et al. 2010).

3.2.2 Differing theoretical frameworks to the interpretation of ceramic assemblages.

A second problem has sprung from the nature of interpretation schemes. In South Asia, archaeological ceramic materials are often used to build seriations based on 'phases' and 'periods', but they have typically been overlooked as a medium through which an understanding of the social aspects of ancient communities can be gained. A great deal of attention has been given to the most notable types of pottery that are archetypal of specific archaeological horizons, with a tendency to discuss either painted pottery, or those wares that have had some type of cultural identity attributed to them. Typological observations of pottery types have been used to identify phases of cultural development, movement of people, and archaeological periods (Ajithprasad and Sonawane 1993; 2011; Joshi 1972; Rao 1963; Sonawane and Ajithprasad 1994; Soundararajan 1962; 1962).

Indus pottery is often presented via catalogues of wares, organised by phases and periods, and these data have been used in a relatively limited way to address questions about the behaviour and 'social processes' of communities who produced and used the ceramic materials. Scholars who have employed Indus crafts as a medium for understanding behaviours of ancient communities, have examined topics such as craft traditions and transmission of skills and knowledge (Kenoyer 1996); use of local raw materials (Blackman and Vidale 1992); ceramic pyrotechnologies and Indus urban social unity and hierarchy (Miller 1999; Pracchia and Vidale 1990); craft specialisation, standardisation and control (Agrawal 2009, 148–50; Kenoyer 1989; Ratnagar 2001; Wright 1991); the organisation of craft production (Miller 1994); urban segregation of working areas and stratification (Kenoyer 1992; Kenoyer and Vidale 1992); movement of goods and exchange (Kenoyer 1997; Méry and Blackman 1996); symbiotic relationships between Indus ceramic technologies and other contemporary industries (Anderson-Gerfaud et al. 1989); Indus urban social structures (Miller 1997b); and theoretical and methodological issues of material culture studies in the Indus zone (Bhan et al. 1994). The adopted theoretical framework presented in Chapter 2 aimed to emphasised the importance of nuanced approaches in the Indus context.

3.2.3 Fragmentary assemblages

A third problem that ceramic specialists in the Indus zone have to face is the paucity of complete vessels from the vast majority of sites. Ceramic vessels, especially that from non-grave contexts, are most commonly found in fragments at urban and rural settlements, and quantifying and documenting materials in a comprehensive manner therefore becomes challenging. Some methods for presenting semi-quantitative and qualitative data of ceramic assemblages are often unsuitable for documenting incomplete vessel forms. For instance, the classificatory techniques based on the ratio among parts of whole vessels (e.g. metrical indices concerning ratios between body height/body diameter/basal diameter), such as the methods proposed by Dales and Kenoyer (1986), Jenkins (1994), Uesugi (2011a: 171), and Dangi and Samunder (2013) for the study of Indus ceramics, are only suitable when complete vessels, or almost-complete vessel's profiles are present in assemblages. The adopted solution to this problem is presented in Chapter 4.

3.2.4 Documentation strategies

The final issues that hinders the study of ceramics in the Indus area is are with approaches to sampling and documentation, which are frequently marked by unclear strategies. According to Krishnan (Krishnan and Rajesh 2014: 235), there has been ongoing debate in South Asia about the best approaches to the illustration, documentation, proper storage schemes, and excavation methods related to pottery. These issues have been long standing, and their resolution is also impacted by the enormous number of sherds which tend to be unearthed at South Asian sites. Mackay (Mackay 1938: 174) observed that because of the great amount of pottery recovered at Mohenjo-Daro, "It is quite impossible to give a very detailed description of each type. [...] Only pieces of especial interest are described in detail". Solutions to this challenge are widely available, and examples of feasible and effective classificatory schemes are abundantly found in the literature (Orton and Hughes 2013: 275; PCRG et al. 2016).

3.3 Archaeometry and analytical techniques

It has been claimed that the chemical and physical properties and manufacturing processes of Indus ceramics have not been subjected to rigorous scientific investigation (Dales and Kenoyer 1986: 62), but a range of geochemical and petrographic studies on Bronze Age pottery types have been carried out during the past decades (Ceccarelli and Petrie 2018; Krishnan and Rajesh 2014). The integration of such scientific approaches, or archaeological sciences (Martinón-Torres 2018; Martinón-Torres and Killick 2015), has the potential to lead to a comprehensive understanding of ceramic production, use and distribution, which in turn can provide insight into a range of factors related to ancient Indus societies and economies (for the adopted approchaes in this thesis see Chapter 4).

3.3.1 Compositional and technological studies in the Indus zone

Early stages of Indus archaeology. The use of scientific approaches to ceramic analysis in South Asia started in the early 1930s and is connected to the re-discovery of the Indus Civilisation. Early studies included geochemical analyses on materials from Harappa and Mohenjo-Daro. Chemical analysis by M. Sana Ullah (Vats 1940: 468) and Pascoe (Marshall 1931: 685) focused on the chemical elements in clay pastes used for pottery making at Harappa and Mohendo-Daro respectively. Further analyses were conducted on material from Mohenjo-Daro, with Sana Ulla studying the chemical composition of slips and paints pottery (Dales and Kenoyer 1986: 64; Marshall 1931: 688–89), Plenderlaith (1931) providing the first microscopic observations on the surface decorations of the so-called Reserved Slip Ware (RSW), and Hamid formulating hypotheses on the nature of grey pigments of Grey Ware Vessels and contributing to the compositional analysis of raw materials used in ceramic manufacture (Marshall 1931: 331, 689–90). This pioneering work is still mentioned with regard by modern scholars (Krishnan et al. 2005: 136) and laid the foundations for subsequent studies on raw materials, decorative pigments and slips. The need for more comprehensive scientific investigation and a better insight into provenance and nature of clays and non-plastic inclusions of Indus pottery became crucial with the recognition of the true extent of the Indus Civilisation, and when the range of regional variability started to be recognised (Dales and Kenoyer 1986: 62).

The Post-Independence period. The period after Independence saw the spread of a new trend that motivated scientific studies in the archaeology of South Asia. In the 1960s, the application of analytic methods on metallurgical slags provided the first significant study on provenance and production of Chalcolithic copper artefacts from Ahar, Rajasthan (Hooja and Kumar 1995; Nagar 1966; Possehl et al. 2004; Sankalia 1969; Hegde 1969). In the same years, the compositional and technological study of North-Black Polished Ware (NBPW) was also attempted (Hegde 1962). Such analytical studies echoed soundly in the Subcontinent and led to similar research projects. Such approaches were described as "New Trends in Archaeology" at the Fourth Annual Congress of the Indian Archaeological Society (Deo 1972: 129, 133, 188), where the benefits of mineralogical and chemical analysis were briefly summarised.

Until the 1980s, the work of Hegde (see Ceccarelli and Petrie 2018; Hegde 1975; 1962; 1966; 1979; also see Krishnan 2002) on NBPW and Painted Grey Ware stood as the primary evidence for the re-emergence of scientific approaches to the study of archaeological ceramic materials in India. It is worth emphasising that these publications have been frequently considered as being rare and exceptional scientific studies concerning the chemical and physical properties, and the manufacturing processes of South Asian pottery. Dales and Kenoyer reiterated the views of Shepard (1956) and Matson (1982) in pointing out that the analysis carried out by Hegde stands alone, stating firmly that "South Asian ceramics have not been subjected to rigorous scientific investigation" (Dales and Kenoyer 1986: 62). Such a view has remained remarkably popular (Chakrabarti 2006: 179), though scientific research on Indus pottery has continued in the meantime.

Current perspectives. With the rise of processual and post-processual archaeology, and the recognized value of scientific techniques for the study of artefacts, approaches towards and perceptions about ceramic materials started to change radically across the globe in the 1980s (Boivin and Fuller 2002; Fuller and Boivin 2002). In South Asia, the works of several scholars played a pivotal role in the field of ceramic analysis, and represent an exception to the main trend of traditional pottery studies. The chemical and petrographic studies undertaken by Hegde, Herman, Panjwani and Krishnan on Indus Ceramics mainly deal with provenance, manufacturing techniques and pigment analyses of material from sites in modern Gujarat, such as Vagad, Ratanpura, Lothan and Nageshwar (Krishnan 1986; Krishnan and Hegde 1988; Panjwani 1989; Krishnan 1992; Herman and Krishnan 1994). The chemical analysis of ceramics by Majumdar (1969) on Black and Red Ware, and the X-ray diffraction studies of Gogte (1989; 1993; 1996) further helped to develop the field. These works tended to concentrate on the materials and processes for producing ancient pottery. However, works such as of the study of the Glazed Reserved Slip Ware by Krishnan et al. (2005), which combines chemical and petrographic methods for an integrated methodology (see Tite 1999: 195), also address certain social aspects of Indus craftsmanship in producing deluxe vessels.

Amongst researchers using a similar combination of methods, and focusing mainly on Gujarati sites, it is worth mentioning the work of Bhagat-Kar (2001) and Shirvalkar (Shirvalkar and Joshi 2008), which dealt with Indus ceramics and Padri ware in Gujarat, while Mishra (2000) and Kajal (2001) presented a scientific analysis of ceramics from Balathal in Rajasthan, and Nagwada and Ratanpura in Gujarat, each investigating fabric composition and ceramic provenance. It is notable that some of these studies emerged from doctoral theses, and some dissertations are still unpublished, for example the work of Dheerendra Pratap Singh (2015) on Indus materials from Bahola, Haryana (Singh R.N. 2012) and Alamgirpur, Western Uttar Pradesh.

A small number of similar research projects by western scholars have been recently undertaken in South Asia. The most notable cases are the works by Bouquillon (Bouquillon et al. 1996), Chandler (2001) and Roux (1992). Bouquillon completed a combined mineralogical and chemical study of unfired and fired Indus vessels from Nausharo, Balochistan, Pakistan (on Nausharo also see Jarrige 1991; Quivron 1994; Mery 1994; Quivron 2000). Analyses demonstrated the value of archaeometric techniques for assessing continuity of ceramic recipes from the Pre-Urban to the Urban Indus period at the site (Bouquillon et al. 1996). Chandler (2001) conducted a sizable petrographic analysis of ceramic from the Pre-Urban Indus period in north western Pakistan and intended to provide a basic understanding of the nature of inter-site socioeconomic communication. He set out to obtain data through the use of a portable petrographic analysis kit combined with chemical analysis (Chandler 2001). Focusing the analysis on two urban sites, Rehman Dheri (Gomal plain) and Harappa (Pakistani Punjab), and two smaller sites, Taraki Qila and Lewan (both Bannu basin), Chandler (2001) demonstrated that no evidence of exchange of pottery vessels between the three regions could be observed; however, a certain degree of exchange of knowledge, technology and innovations was proposed. Roux and Courty's analyses of archaeological ceramics from Kalibangān (Roux 1992; Courty and Roux 1995; Roux and Courty 1998; also Thapar 1975; Madhu Bala 2003; 2015) was combined with analysis of comparative experimental pottery to identify wheel-fashioning methods on the basis of surface features and micro-fabrics, which in turn provide evidence of the complex sequences involved in the forming processes of Indus vessels.

3.4 Ethno-archaeological approaches

Archaeological interpretations often depend on inferential reasoning, and ethnoarchaeological research can be used as a valuable tool to build stronger discussions related to material culture patterning, especially concerning prehistoric social agents and technological choices theories. (Donnan and Clewlow 1974; Kramer, 1979: 4; 1985; Schiffer 1987: 229, 230; Schwarz 1978: p. vii). A number of archaeological questions can benefit from an ethnographic work, ranging from subsistence and settlement strategies; social organisation and belief system; site formation, and craft production. This brief section will solely present studies dealing with ceramics, technologies, and systems of production, and how these studies helped to improve our understanding of the Indus Civilisation. Several research papers have already extensively reviewed other peripheral topics (see Sinopoli 1991; Mohanty and Mishra 2002).

3.4.1 Parallel histories: changes and continuity

One of the most recurrent trends in the ethnographic works in the South Asia context is the presumed idea of continuity within 'surviving living traditions'. A number of scholars have pushed forward theories of unaltered continuity of character and craft practice in the Subcontinent, along with its enormous time depth stretching back to the Indus Urban period (e.g. Allchin B. 1994; Krishnan and Rao 1994). Due to the perception of historic continuity, ethnographic and archaeological investigation in the Subcontinent have mostly looked for direct similarities, comparative materials and socio-cultural parallels (e.g. Allchin 1985). Well-known are the studies on stone bead production, shell bangle working and pottery production, which suggested a four-thousand-year direct continuity between the Bronze Age and modern India and Pakistan (e.g. Possehl 1981: 39-47; Kenoyer et al. 1994: 281; Kenoyer 1984: 325; Saraswati 1978: 102-109; 1979; Nagar 1969; 1970). Little room was, thus, left for observations on changes and differences, with rare opportunities to move away from direct correspondences between ancient and modern human behaviors.

The above approach to ethnoarchaeological investigation bears a few problems that can be pointed out when the interpretation of data achieved via the direct historical approach is examined. Some of these challenges of this approach are undoubtedly controversial, and have been carefully assessed by Jaya Menon (2006: 258). It assumed that: (1) an unbroken cultural continuity could be identified archaeologically; (2) craft traditions have not undergone any major changes in the course of their development; (3) cultural and technological choices that motivate the use of certain materials, tools and techniques in craft production also remained unchanged; (4) no significant technological innovations affected a specific industry; and (5) functions, consumption patterns and the significance of certain materials as cultural phenomena and social and economic mechanisms that structure and underlie a specific industry remained unaltered for millennia.

Researchers have questioned the reliability of material similarities, suggesting that physical parallels are not sufficient to demonstrate direct past and present socio-cultural correlations. Recently, the studies of Kramer (1979; 1985; 1997), Shils (1981), Wylie (1982), and Ratnagar (2000: 62) opened the debate around the direct historical approach of ethnoarchaeology, and the importance of changes and transformations in the process of transmission of knowledge within persistence traditions. Evidence that both changes and continuity must be viewed in their broader social and economic contexts have also been provided by Jayaswal (1984; 1986), Birmingham (1975) and Miller (1982; 1985).

3.4.2 Indus ceramic ethnoarchaeology

Ethnography in South Asia is considered to have a unique potential for archaeology, and can bring positive benefits that crosses the research boundaries. The generally accepted view is that South Asia represents one of the richest and most accessible regions for ethnographic investigation, especially concerning craft and technologies (e.g. Kosambi 1967; Griffin and Solheim 1990; Allchin 1994: 1-5). Thus, when looking at modern production of terracotta and earthenware ceramics in India and Pakistan, a number of social aspects have already been investigated by ethnographers and archaeologists. Studies have focused on the organization of ceramic production and ceramic manufacturing techniques (e.g. Aiyappan 1947; F. R. Allchin 1959; 1978; Ansari 1960; Bose 1982; Cort 1984; Das Gupta and Syamchaudhuri 1966; Saraswati and Behura 1966: 48-75; Kramer 1990; Nagar 1970; Roux 1985-6; 1989a; 1989b; Rye and Evans 1976; Sinopoli 1988; Sinopoli and Blurton 1986); ceramic vessel forms and ceramic use (Birmingham 1975; Miller 1982; 1985); centralised sponsorship of craft production and figurine industry (Blurton 1987; Jayaswal 1984; 1986; Jayaswal and Krishna 1986); household production (Varma and Menon 2017); use of the potter's wheel and gender (Degoy 2008: 204); clay sources and social boundaries (Stark et al. 2000); distribution systems and social relations among potting communities (Kramer 1990; 1991; Miller 1981); and more. However, few ethnoarchaeological studies have been undertaken specifically to gain a better understanding aspects of Indus Civilisation ceramic technologies, with studies started from the earliest stages of its rediscovery. Here we will present three case studies: the first two follow the direct history approach; and the last one aims to understand certain specific traits of craft specialization and transmission of skills, not directly linked to ancient behavioral patterns.

The first ethnographic work used to better understand Indus archaeological materials was by Ernest Mackay (1930), who worked with families of potters at Balrej, not far from Mohenjo-Daro. He observed several aspects of modern pottery production, putting special emphasis on two techniques, and suggesting analogies with Indus tools and manufacturing techniques: specifically the use of a rare type of potter's wheel, the foot-wheel of Sind; and the use of *chappana* or *tapla* (paddle) and *kunaro* or *pella* (anvil) for finishing vessels during the shaping stage. He argued that modern ceramic crafts "survived in Sind and a few other places in northern India probably due to a tradition that has been handed down from the people of Mohenjo-Daro and not to a new introduction of the art" (Mackay 1930: 135), and this is comment has had strong echoes across the subsequent century. For example when M.S. Vats (1940: 275) published Indus ceramics from Harappa, he simply referred to Mackay's equation to "present day practice in Sind and Punjab", also emphasising that these remarks "apply with equal force to the pottery of Harappa which is in all main essentials identical with that of Mohenjo-Daro". This is an iconic example of the direct historic approach.

Similarly, another instance was provided by Kenoyer, who compared both ancient and contemporary pottery industries in India and Pakistan as examples for 'surviving living traditions' and decentralised systems of production. Kenoyer (1998: 6) argued that a number of crafts traditions in modern Pakistan still bear characteristics of Indus crafts, pointing out that raw materials and techniques of manufacture "remain unchanged" and "involve basically the same technology as that used by the Indus artisans". He finds similarities also at the level of state control over ceramic distribution, which allegedly has continued to be structured mainly on the basis of kin networks, and state or governmental institution may only impose a limited tax on the sale of vessels in urban markets or when shipped across regions (Kenoyer 1998; see also Vidale 2000: 26; Rye and Evans 1976). Some of these ideas are still remarkably widespread and contributed to the crystallisation of concepts of both synchronic and diachronic uniformity, as well as the blurred perception of a linear technological development of Indus cultural materials (see below).

A radically different approach was followed by V. Roux, who conducted ethnoarchaeological research on ceramic production in northern India (Roux 1989a; Roux and Corbetta 1989). The main aim of her work was to observe apprenticeship and learning mechanisms behind the transmission of modern pottery-making skills, as a tool for exploring the development of craft specialisation throughout the Indus Pre-Urban and Urban periods. Roux correlated the production of wheel-made pottery with fully developed craft specialisation, and non-wheel-made pottery with less developed (or absent) degree of specialization (Roux 2003b). For Roux and Corbetta (Roux and Corbetta 1989: 7–8), the documentation of the increasing occurrence, improved quality, and larger size of wheel-made vessels in the archaeological record throughout the Indus Pre-Urban and Urban periods suggest the emergence and development of craft specialization. Two critiques have been made to her methods and interpretations: first, it was pointed out that she seems to rely on archaeological evidence from one stie one, i.e. Amri (see Casal 1964); and second, by equating the development of individual skills with the emergence of specialised production within complex societies, it was also pointed that she seems to propose that if wheel-made vessels equals specialisation, then non-wheel-made ceramics equals non specialisation; in contrast, this is not always found in all ethnographic and archaeological cases (see Sinopoli 1991).

Following a similar approach, Roux also contributed to a clearer understanding of tools and forming techniques found at the Indus settlement at Kalibangān, which is further explored in Section 3.7.3. With its efforts to moving away from the direct historic approach, Roux's method inspired the ethnoarchaeological investigation undertaken in Haryana and Uttar Pradesh as part of the present study (see Chapters 4 and 5).

3.5 Technological development in the Indus Zone: transmission and transformations

The concept of a linear evolution of ceramic technologies has had a significant impact on archaeological research at several levels, and issues concerning theoretical frameworks often adopted for the interpretation of archaeological data in South Asia have already been outlined (see Sections 3.2.1 and 3.2.2; also Ceccarelli and Petrie 2018). Culture historic paradigms have remained prevalent, and there has been a tendency to focus on certain styles and types of artefacts to build seriations and identify archaeological 'cultures', which are often equated to ethnic groups or major phases of socio-political transformation. This section aims to assess studies of technological transmission and transformation, considering the underlying tendency among researchers to adopt *demic* diffusion-based interpretations. The first part reviews the development of ceramic technologies from the Ceramic Neolithic up to the Indus urban period to understand how certain academic themes have developed. It will particularly discuss how more 'evolved' technologies have been typically seen to have been adopted by ancient producers, homogeneously replacing 'older and less sophisticated' manufacturing methods, mostly in view of possible functional or economic gains. The second part will focus on ceramics from northwest India, and explore evidence/previous consideration of variable regional technologies and resistance to innovations.

3.6 Cultural evolution and 'demic' diffusion

A range of literature has suggested that certain styles and manufacturing techniques were 'discovered' at early stages of social complexity in South Asia, and consistently 'evolved' through time, reaching a pinnacle of sophistication during the Indus urban period. This reconstruction is particularly clear in studies focusing on the use and spread of fine clay pastes, coiling techniques, and more generally the use of rotational devices in ceramic industries (Kenoyer 1993; 1998; Wright 1989; 1991: 78–82). In the following section, the concept of a social evolutionary paradigm refers to theoretical frameworks used for the interpretation of archaeological materials that seem to follow simplistic evolutionary biological models for explaining cultural changes (Bentley and Shennan 2003; Kohler et al. 2004; Shennan and Wilkinson 2001). A social evolutionary approach implies that human technological traditions consist of information and ideas (or 'cultural traits') that are stored in human brains, and passed on to other individuals through social learning (Jordan 2014). In such evolutionary models, cultural traits seem to be unaffected by their local conditions and externalisation in material form (Knappett 2016), and rely on "the hypothesis that contacts between people are necessary and sufficient for social learning to occur"(Roux 2013: 313). Versions of this approach, sometimes overly simplistic versions of this, have been adopted to explain certain phenomena of cultural transmission in the Indus zone, but this is not without problems.

The adoption of technologies and styles is not necessarily an even or contemporaneous process, and the potential for resistance to innovations over many centuries also needs to be considered. Aspects of material agency and human choice in the processes of adopting and transmitting technological knowledge (see Knappett 2016; Petrie 2011: 154; Roux 2010; 2013), and the social mechanisms behind resistance are often not explored, particularly in relation to observations made within and among variable regional traditions.

Table 3.2 Regional pottery traditions in use during the Ceramic Neolithic period (c. 5500-4300 BC).

Ceramic Tradition	References (e.g.)
SSC Ware (Sequential Slab Construction)	Jarrige et al. 1995; Jarrige J. F. 1998; Vandiver 1995: 648-661; Vandiver 1987; Petrie 2011, 2015
Burj Basket-Marked Phase	Fairservis 1956; Jarrige 1998; Wright 1991, Wright 1993

3.7 Ceramic technologies before the Indus urban phase

3.7.1 Ceramic Neolithic (5500-4300 BC)

The origins of ceramic production technologies and their evolutionary trajectories in South Asia are often placed during the Ceramic Neolithic at Mehrgarh (period IIA, previously Period IB; see Jarrige et al. 2005), Kachi Plain, Baluchistan (see Figure 3.2). The earliest known occupational phases at Mehrgarh, also known as the Aceramic Neolithic Period I, were tentatively placed by Jarrige (2008; Jarrige et al. 1995; 2005; 2013) around the 7000 BC, but the absolute dates from these deposits are problematic and ambiguous due to poor preservation (Jarrige et al. 2013; also Petrie et al. 2010a; Petrie 2015). Petrie (2015: 296-7, 304) has suggested that Period I may have started later, at the beginning of the sixth millennium BC, and noted that the nature of the transition to Period IIA seems unclear. The generally accepted terminology 'Aceramic' and 'Ceramic' Neolithic periods has been suggested and largely employed (Jarrige 1998; Jarrige et al. 1995, 2013) resembling the descriptive lexicon also used in the Near East (e.g. Kenyon 1960).

The deposits for Period IIA have reliable radiocarbon dates suggesting a range of *c*.5470-4700 BC. This phase is also marked by a shift from what appears to be non-permanent, mobile, semi-nomadic/seasonal activity, towards less mobility, intensified agricultural activities, and large, extra-household scale storage systems (Jarrige et al. 2013: 113, 149). According to Vandiver (1995), very few fragments of incipient ceramic vessels in the form of early coarse, chaff-tempered pottery were found in the earliest Ceramic phase deposits. During this period, there is evidence for an increased range of craft activities (Jarrige et al. 1995, 2013; Petrie 2015), and an increase in the number of farming settlements in the region (Possehl 1999a). This phase is generally regarded as having the earliest evidence for ceramic production in South Asia, though the earliest ceramics from Lahuradewa in the central Ganges may be contemporaneous (Tewari et al. 2006).

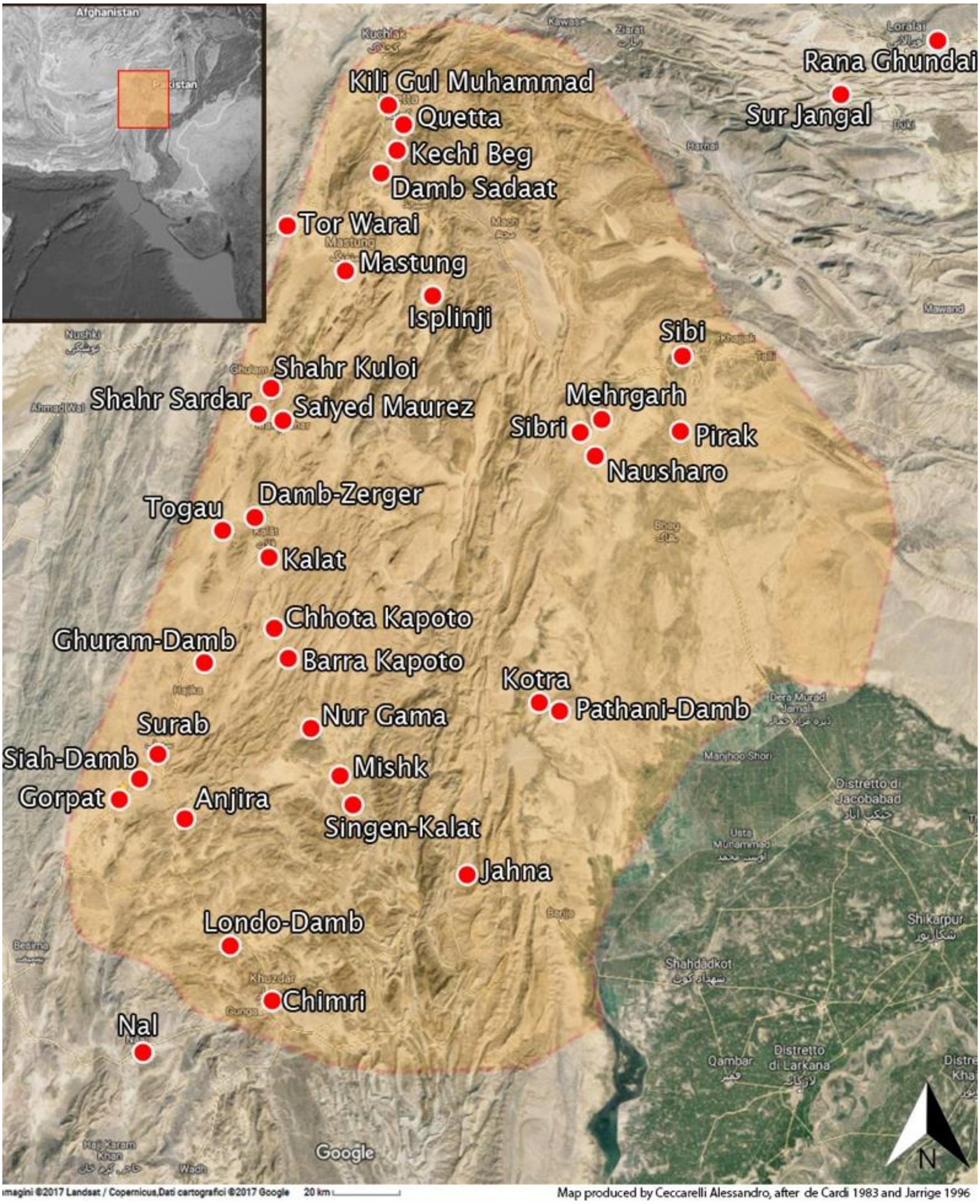
Pottery found at Mehrgarh Period IIA is described as being chaff-tempered, handmade, low-fired ceramics, and it was manufactured using the so-called *SSC*, Sequential Slab Construction technique (see Table 3.2). Vandiver (1985; 1987; 1995) suggested that the physical properties of the organic tempered clay directly affected certain stages of the forming process, leading potters to prefer the use of lumps or slabs of clay rather than 'true' coils (see below Figure 3.3). She also observed a certain degree of similarity to ceramic industries from Tepe Yahya in Iran, Mesopotamia (e.g. Hassuna and Samarra traditions) and Badarian, Tasian and Delta pottery of Egypt (see Vandiver 1985, 1987: 9-35; Jarrige et al. 1995; Petrie 2012). By the end of Mehrgarh Period IIB, the quantity of chaff temper in clay pastes had reduced, potters had started to build walls in strips and bases in less regular slabs, and most wall joins showed characteristic butt-join margins (Vandiver 1995: 651).

Besides *SSC ware*, what is referred to as *Burj Basket-Marked ware* was visible among the earliest ceramics identified in the archaeological record of South Asia (Table 3.2). For this technique, potters used baskets as a mould, and vessels were often coated with a clay slip to hide basket impressions (Jarrige 1998; Wright 1991, 1993; Dales andKenoyer 1986; Kenoyer 1994b; Kenoyer 1998; Petrie et al. 2010b). Similar manufacturing techniques also seems to have been widely used by communities spreading from the Near East to South Asia, as suggested by evidence from Abu Hureyra in Syria, Ali Kosh and Hajji Firuz Tepe in Iran (Voigt 1983; Vandiver 1987: 27–8, 1995; Moore et al. 2000: 201–2; Petrie 2012). Besides obvious inferences regarding diachronic technological developments, comparative studies concerning the distribution of both *SSC* and *BBM* wares facilitate debate around the early development of an interaction sphere across the Iranian Plateau and social, cultural and economic mechanisms responsible for the transmission of knowledge and skill between South and West Asia (Petrie 2011).

3.7.2 Ceramic Neolithic and Early Chalcolithic (4300-3800 BC)

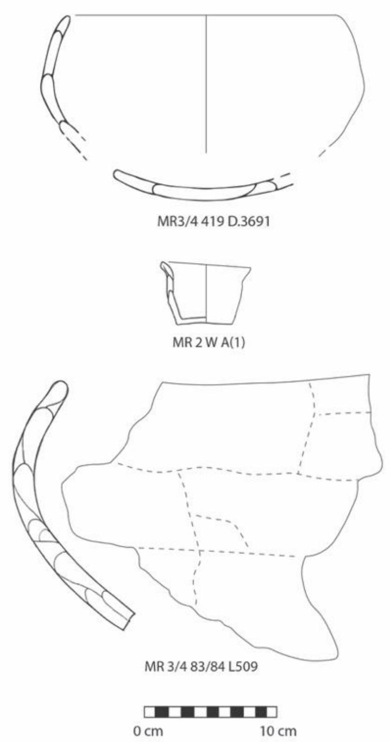
The second half of the fifth millennium BC witnessed the introduction of a number of technological innovations at Mehrgarh, such as the use of fine clay pastes for producing thin-walled vessels, rotational devices, pigments, and painted decorative techniques, as well as an exponentially increased variability in manufacturing techniques within what are essentially rural systems of production. This phenomenon of increased sophistication and intensification of ceramic production was potentially correlated with significant contemporaneous transformations happening at the level of settlement strategies and agricultural activities (Jarrige 1991; Jarrige et al. 2013).

Figure 3.2 Map showing archaeological and surveyed sites in the Kachi Plain, Baluchistan. Some of these sites providedevidence for ceramic seriations. Map by A. Ceccarelli after Ceccarelli and Petrie (in press); De Cardi 1983; Jarrige 1996.



During Mehrgarh Period III, fine-paste red ceramics were developed, and were often coated with an iron-rich clay slip, and display painted decorations. Vessels of this type are variously referred to as *Kili Gul Muhammad* (KGM II-III) and *Togau A* wares, and are broadly similar to material seen at Periano Ghundai A, Sur Jangal I–II, Surab II, Rana Ghundai Ia–Ib, and Sheri Khan Tarakai (Petrie et al. 2010a; 2010b). At Mehrgarh, this period is often described as being Early Chalcolithic (Kenoyer 1992), but many of these other sites were still in effect Neolithic in terms of technologies (Petrie et al. 2010a; see Table 3.3). Mehrgarh Period III is marked by the presence of pottery decorated with geometric and fauna motifs, which bears certain comparable features with Iranian ceramic industries, for example *Soghun ware* from Tepe Yahya VI (Beale 1986). Traces on the walls of sherds suggest the use of rotation for smoothing the interior surface of vessels, which are marked by the presence of parallel, circumferential streaks (Vandivier 1995: 650). The distinctive striations have been understood as evidence for the introduction of *tournettes* or turntables, likely employed during the final stages of pottery manufacture. This technique was likely used for thinning and shaping vessels, and also for applying banded decoration, as vessel walls still appear to have been built using slabs, with most joins showing butt-joins markings (Vandiver 1995: 651). The final stages of the manufacturing process also seem to involve trimming by scraping with a multiple- pointed gouge (Vandivier 1995: 651). Wright (1995: 664) examined the particular sequence of actions necessary to produce the *Togau* pottery, and reaffirmed the incipient use of rotation at Mehrgarh Period III. Overall it appears that *Togau* ceramics were produced using a variety of techniques, with some sherds seeming to bear similar concentric lines identified on the later *Faiz Mohammad* ceramics. Wright (1995: 665) integrated surface observations with the use of C.A.T. scanning and zeroradiography to suggest "production on a fast wheel". However, she emphasised that her interpretations

Figure 3.3 Chaff-tempered ceramics manufactured using the SSC technique. Neolithic Mehrgarh IIA (after Vandiver 1995).



of the results are tentative, due to the fact that: (a) other *Togau* vessels do not show such concentric surface striations, (b) analyses were undertaken on a small number of samples, and (c) the analytical techniques employed were quite novel (Wright 1995: 665). The observations of Vandiver (1995) and Wright (1995) clearly suggest that rotation was at least partially adopted by local potters in some areas, but also suggest that true wheel-throwing technique were not yet being executed.

3.7.3 Ceramic Neolithic and Late Chalcolithic (3800-3200 BC)

The development of variable ceramic forming techniques and polychrome ceramics, such as seen on *Togau* period/ware vessels, does not seem to be an isolated phenomenon, and comparable material is found across the Indo-Iranian region (see Table 3.3 and Figure 3.4). In the first half of the fourth millennium BC, equivalent to Mehrgarh Period III-IV and Kech-Makran Period II, pottery manufactured using coil- and slab- building techniques, as well as the partial use of rotational devices, probably *tournettes*, appeared at Miri Qalat and at Shahi Tump in the Kech Valley (Jarrige et al. 2011; Didier and Mutin 2015; also Mutin 2007; Didier 2013). These technological innovations, likely correlated to changes in clay processing and recipes, were followed by the development of bichrome and polychrome decoration that occurred in various regions during the fourth millennium BC.

At Mehrgarh, the first known examples of bichrome decoration painted in red and black on a whitish background are documented in the last phase of Period III, around 4000-3800 BC (Jarrige et al. 2011: 13; Wright 1995: 665–66). The development of painted decorative techniques in Baluchistan, represented by the *Kechi Beg*–type vessels, was often considered to be a phenomenon of external origin, possibly related to influence from Ubaid 5 pottery in Mesopotamia (Carter and Philip 2010), Namazga II-III pottery and Geoksyur monochrome black-on-red wares from southern Turkmenistan (Jarrige et al 2011, 10-11), or even *J ware* from Māhīdašt (Henrickson 1989). Comparable materials were also found at Surab I-II in the Kalat region (de Cardi 1965: 111-115), Sur Jangal I-II in the Loralai Valley (Fairservis 1959), and in Kech-Makran Period II (e.g. *Miri ware*; Besenval 1994; Mutin 2007). However, given the nature of pigments used for producing the *Kechi Beg* ware, and long lasting use of locally available raw materials, an indigenous, independent development of painted designs in the Kachi-Bolan Plain has also been suggested by Jarrige (2011). However, the possibility of hybridity of influences and practices could also be considered.

Table 3.3 Some regional pottery traditions in use from c. 4300 to 3200 BC.

Ceramic Tradition	References (e.g.)
Miri Ware (Kech-Makran II)	Besenval 1994
Zari Ware	De Cardi 1959
Anjira Ware	De Cardi 1959
Mian Ghundai Dark Rim Fine ware	De Cardi 1983
Togau Style (Togau A-E)	Jarrige et al. 1995; de Cardi 1965: 128-232; Franke 2008: 654
Kili Gul Muhammad KGM-types	Fairservis 1956: 256-257
Sur Jangal Coarse Painted Ware	Fairservis 1959
Loralai Coarse Plain Ware	de Cardi 1983
Sheri Khan Tarakai Wares (SKT A-C)	Khan et al. 1991: 39; Petrie et al. 2010
Kechi Beg Black-on-Buff Slip	Fairservis 1952; Fairservis 1956
Kechi Beg Polychrome	Fairservis 1956: 259, fig. 53
Mesolithic Bagor Ware	Misra 1973

Evidence from many sites seem to indicate not only an increased level of sophistication in ceramic industries during this period, but also the incipient crystallisation of regionalism and regional styles across the Indo-Iranian area (see Table 3.3). Given the protracted chronology of Mehrgarh Period III, *Kili Ghul Mohammad II*, *Togau A*, and *Kechi Beg ware*s have recurrently been considered as the ancestors of ceramic traditions emerging in Baluchistan during the fourth millennium BC (Jarrige et al. 2011). As shown, the development of fine-clay fabrics, coil- and slab- built vessels, the limited use of rotational devices, surface treatments such as applied slips, and monochrome, bichrome and polychrome painted decorations, including certain recurrent geometric and fauna motifs is significant. However, few studies have investigated the social and behavioural mechanisms behind the synchronic appearance of the various ceramic traditions and styles that developed in the region. The available data should perhaps lead to an exploration of spheres of interaction that were in operation across the Iranian Plateau, which appears to have been reinforced in this period (Petrie 2011).

Conceivably, the movement of ideas, technologies, and material culture were also related to certain environmental circumstances. In fact, Jarrige (et al. 1995: 73-74) noted that climate, vegetation, and rainfall patterns possibly affected certain settlement strategies in proximity of alluvial basins, which required a degree of resilience through seasonal mobility (also see Petrie and Thomas 2012). Material culture similarities at mentioned sites across the Indo-Iranian region also seem to substantiate this view.

With the identification of *Hakra Ware* in Cholistan (Mughal 1997) and consequently the formalisation of a Hakra Ware phase (Shaffer 1992), the importance of characterising South Asian regional traditions became of central relevance (see Table 3.4; Figure 3.4). The identification of almost 100 sites yielding Hakra material revealed a surface collection that presented a combination of cultural materials, including ceramics, fragments of copper objects, terracotta figurines and bangles, and shell beads (Mughal 1997; Possehl 2002). Ceramics ascribed to Hakra assemblages present a variety of shapes, surface treatments and decoration, which are used to define sub-types such as *Hakra Mud Appliqué*, *Hakra Black Burnished*, and *Hakra Incised* (Mughal 1997; also Mughal 1974; 1982; 1990).

Unfortunately, the characterisation of Hakra Ware suffers from two prominent issues yet to be fully solved: the first being a lack of detailed analysis of the ceramic wares and other cultural materials from stratigraphically secure contexts; and the second being a lack of absolute chronology. Understanding the chronology and technological development of *Hakra Ware* would be particularly interesting given the large variety of tools and techniques currently believed to have been employed in the production of these vessels, ranging from hand-made to wheel-fashioned pottery. Most of the material collected by Mughal (1997) that has been used for defining this tradition came from non-excavated sites, typically surveyed areas (Possehl 2002: 35). Early phases of occupation identified in stratigraphic excavations at Jalipur and Harappa are somewhat helpful in this respect, since they appeared to yield *Hakra*-like pottery (Mughal 1974; Kenoyer and Meadow 2000), though it is notable that they have less diversity in terms of technology. Additional site reports and ceramics catalogue from these sites will likely contribute to tackling these issues.

The Hakra ceramic industries show some technological and stylistic similarities with materials from sites identified in Baluchistan and Cholistan. For instance, ceramic wares recovered at Sheri Khan Tarakai, especially SKT ‘B’ and ‘C’ wares (Petrie et al. 2010b: 82-84), and comparable material from the Ravi phase at Jalipur and Harappa Mound AB and E (Kenoyer and Meadow 1999; 1997) suggest that there was some degree of sharing of technological knowledge across regional ceramic traditions. These indications of knowledge sharing imply the existence of a form of craft network during the fourth and third millennia BC, which enabled the transmission of ideas and innovations between Balochistan, the

Bannu and Gomal regions, and Cholistan and Punjab. Some of the mechanisms responsible for the intra-regional dynamics of subsistence practices, interaction and ideologies in these areas have been discussed elsewhere (Khan et al. 2010).

Although the chronology, distribution, and nature of the Hakra tradition has not yet been clarified, several scholars have proposed an eastern spread of this material, suggesting that it reached into Haryana in northwest India. What have been labelled as Hakra sherds have been identified at Kalibangān, Bhirrana, Kunal, Girawad, and Farmana (e.g. Madhu Bala 2003: 103; Rao et al. 2005; Kumar 2005: 197; Dangi 2006; Shinde et al. 2008). The identification of Hakra occupational phases at sites in Haryana is typically based on observations on ceramics, particularly sherds showing *mud appliqué* surface treatment. It has been suggested that this evidence indicates a particularly 'early' chronology for pre-Indus and Indus pre-urban sites in Haryana, placing them on the easternmost periphery of the Hakra horizon (Shinde 2011c: 263). However, it is worth mentioning that the application of a coarse slurry, an applied rustication, or *mud appliqué*, on the surface of vessels is found not only on Hakra ceramics, but also in Sothi-Siswal, Ravi, Kot Diji, Tochi-Gomal and Harappan pottery assemblages (Petrie et al. 2010b; Uesugi 2011: 99), which makes it a particularly unreliable chronological marker.

A number of regional manifestations of the Hakra tradition, including the 'Ravi aspect of the Hakra phase', show most of the distinctive features of *Hakra ware*, including manufacturing techniques, surface treatments and certain shapes (Kenoyer and Meadow 2000). For instance, Ravi ceramics from Harappa mound AB period 1A were largely hand-built vessels, bearing traces of possible slab or coil construction, with the majority of forms being shallow bowls, deep bowls, carinated vessels, or thick-walled pots covered with a coarse clay slurry mixed with lime-*kankar* or calcrete (calcium carbonate) nodules and fragment of pebbles (Kenoyer and Meadow 2000). Some Ravi vessels from Harappa bear polychrome decoration, using whitish, red-brown or purple-brown pigments, typically portraying geometric and floral motifs (Kenoyer and Meadow 2000), and the bird and net motifs in this period are comparable to earlier decorative elements found at Sheri Khan Tarakai (Petrie et al. 2010b), Tochi-Gomal phase material from the Bannu and Gomal (Durrani 1988; Jan 2012; Naseem and Jan 2016; Petrie et al. 2007), and Rehman Dheri Periods 1 and 2 (Durrani 1988; Durrani et al. 1991). Comparable material is also found in assemblages from Kot Diji (Khan 1965; Mughal 1970), Jalipur I and II (Mughal 1974).

Figure 3.4 Togau (1-7), Kechi Beg (8-11) and Hakra wares (12-21) (after Fairservis 1956; Mughal 1997; Possehl 2002; Jarrige 2011).

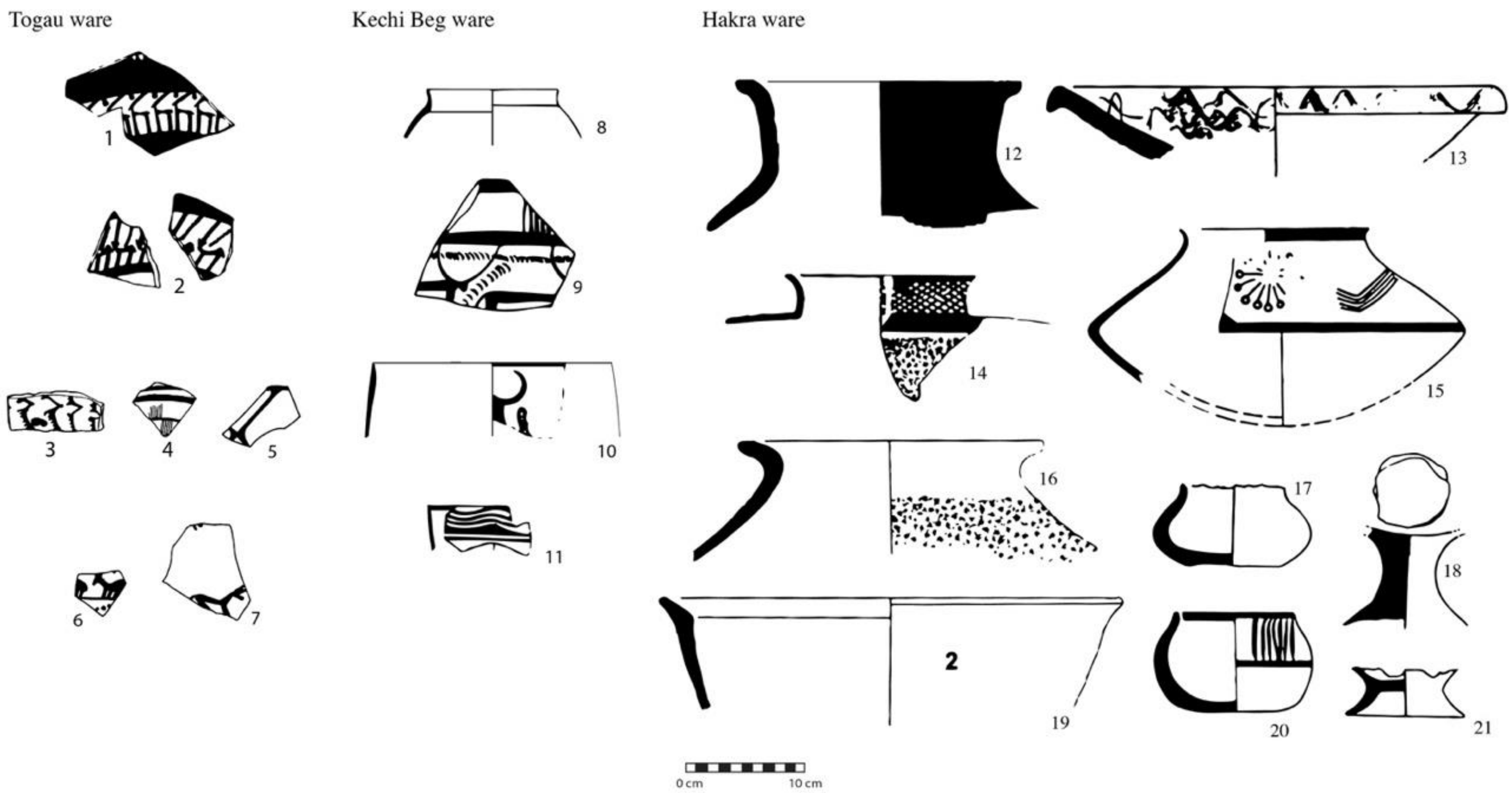


Table 3.4 Regional pottery traditions dating from c.3200 to 2600 BC.

Ceramic Tradition	References (e.g.)
Nal Polychrome Ware (Amri-Nal)	Franke 2008: 661-662; Fairservis 1975: fig. 40; 5-7; Franke-Vogt 2005: fig. 60; Uesugi 2017
Kot-Diji (KD I)	Khan 1965: 42-43; Jarrige 1996
Sothi-Siswal	Uesugi 2011a; 2011b; Uesugi 2017; Garge 2010
Damd Sadaat	Fairservis 1956
Hakra Ware	Mughal 1997; Possehl 1999; Dalal 1980; Mughal 1982; Bhan and Shaffer 1978;
Kalibangān Fabrics A-F	Madhu Bala 2003; Nigam 1996, Madhu Bala 2015: 405-407
Ravi	Kenoyer and Meadow 2000
Anarta	Krishnan and Rajesh 2015
Early Padri	Shinde 1998
Pre-Prabhas	Rajesh et al. 2013
Faiz Muhammad Grey Ware	Wright 1984; Jarrige et al. 1995; Casal 1961; Jarrige et al. 2011.
Wet wares	Shar and Vidale 2001
Emir Grey	Fairservis 1956: 86; Wright 1984; Besenval et Didier 2004
Quetta Ware	Fairservis 1956: 255- 256; De Cardi 1983
Kulli Ware	Casal 1966, Possehl 1986
Tochi-Gomal phase	Khan et al. 2000; Petrie et al. 2007, 2008

3.8 The eastern fringe: Haryana and Uttar Pradesh

Besides certain archaeological implications that will be emphasised in the last part of this chapter, understanding classification schemes of regional ceramic traditions in North-Western India, such as the Hakra, Sothi-Siswal, Kalibangān, and Bara Wares, plays a critical role in the present study (see Appendix H: Table H.1).

3.8.1 Regional Pre-Urban or Early Harappan ceramic traditions (3200-2600 BCE)

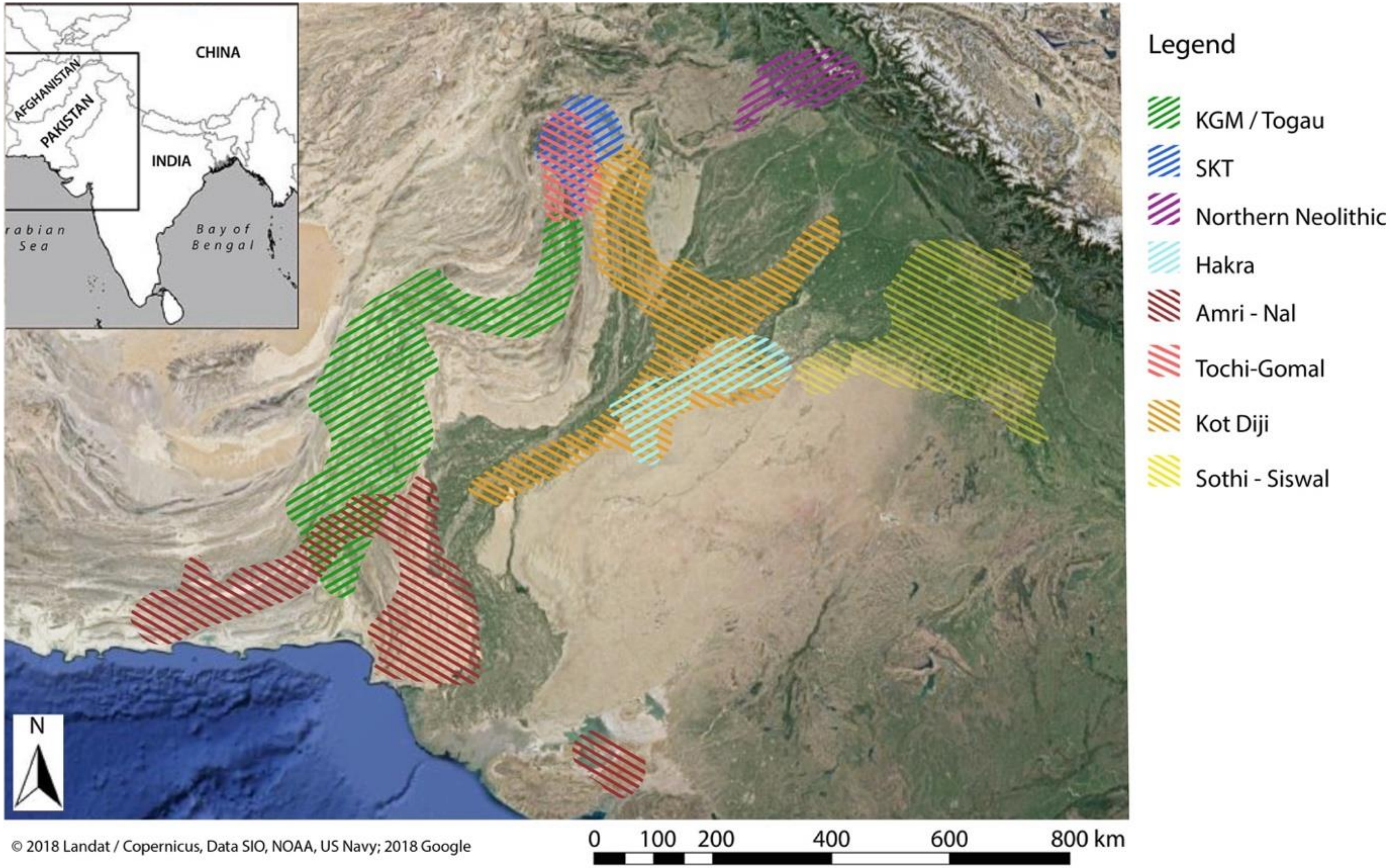
There appears to have been very few or perhaps no major technological changes during the transition into the Early Harappan or Pre-Urban period. Possehl (2002: 40) stated that the paradigm already established in the Chalcolithic phases further "expanded rather than modified" into synchronic regional traditions. However, it has also been suggested that during the pre-urban period, e.g. the Kot-Diji phase, significant innovations, such as a 'true' fast-wheel, were adopted for pottery production for the first time in certain areas (Kenoyer

1998: 151). However, as mentioned above, it is also possible that this development did not take place until the Indus urban period, and the extent to which such rotational devices were used in different ways across the diverse regions of the Indus zone needs to be clarified.

Following the *Togau*, *Sheri Khan Tarakai*, *Hakra* and *Ravi* manifestations, four main regional phases have been identified: *Amri-Nal* (Baluchistan, Makran, southwest Sindh, Kohistan and Northen Gujarath), *Kot-Diji* (Northen Sindh), *Sothi-Siswal* (Punjab and Haryana, India), and *Damb Sadaat* (Quetta Valley, central Baluchistan), with the latter including the *Faiz Mohammad* and *Emir Grey* wares (Possehl 1999; 2002; Dikshit 2013). The Tochi-Gomal cultural assemblage, characterised by polychrome pottery akin to Nal ware, has also found at sites in the Bannu Basin and the Gomal Plain (Durrani 1988; Jan 2012; Naseem and Jan 2016; Petrie et al. 2007; Khan et al. 2000; Petrie et al. 2007). Each of these regional traditions encapsulates a specific area of distribution of certain types of material culture, mostly ceramics (for references of each tradition see Table 3.4; for areas of distribution see Figure 3.5). The *Sothi-Siswal* tradition of north-west India, which bears some similarities with aspects of *Hakra ware* and emerged in the eastern fringe of the Indus zone, is possibly one of the most significant among the early ceramic industries, and the most relevant for this study.

Similar material was collected at the type-sites Sothi (Tessitori 1917-18; 1918-19; Stein 1942; Dikshit 1979; Dalal 1980; Lal et al. 2003) and Siswal (Bhan S. 1971-1972), and over the past three decades this material has gradually been contextualized following discoveries at Kalibangān (Lal et al. 2003, 2015), Rakhigari (Nath, 1998: 39-45; 2015), Mitathal (Bhan S. 1975), Girawad (Uesugi 2011a), Farmana (Uesugi 2011b), Masudpur I and VII (Singh et al. 2009, Petrie et al. 2009; Parikh and Petrie 2016), and Burj (Singh et al. 2010) and apparently Nawanbans (Saharanpur, Uttar Pradesh) (see Bhan S. 1975; Dikshit 1980, 1984; Garge 2010). There have been several attempts to classify Sothi-Siswal ceramics according to fabric groups, colours, shapes and manufacturing techniques. This has led to the use of multiple terminologies for this regional phenomenon, which are to an extent often understood as synonyms for aspects of the same tradition, including: Kalibangān Fabrics A to F (IAR 1962-63: 20-3; Nigam 1996: 7-14), Eastern Harappan (Possehl 1999) or Haryana Harappa (Parikh and Petrie 2016). Uesugi (2011a; 2011b; Uesugi 2017) and Garge (2010) have provided the most comprehensive analysis of these ceramics to date, and have underlined differences to other regional traditions.

Figure 3.5 Map showing areas of distribution of regional ceramic traditions (after Ceccarelli and Petrie In Press; de Cardi 1983; Jarrige 1981, 1996; Possehl 1999).



3.8.2 Regional Pre-Urban and Early Urban traditions: Sothi-Siswal and Kailbangan

Pottery from Kalibangān (KLB) has been used to provide a classification of pre-urban and urban phase ceramic wares and forms, including manufacturing techniques and surface treatments. Thapar (IAR 1962-63), Nigam (1996: 7-14), Madhu Bala (2003: 101-222), Tandon (2003: 247-264), and Roux and Courty (1998) have adopted a variety of methods to analyse ceramics from Kalibangān, and produced a diverse range of conclusions. The initial analyses by Thapar saw the identification of six classes of ceramics produced during the Indus pre-urban period (*KLB I*), termed Fabrics A to F. Although the term 'fabric' was used for this scheme, the classification method was mostly based on observations of surface treatments rather than composition or clay pastes (see Petrie et al. 2010b). Given this ambiguity, ceramics from KLB I have been rearranged several times (e.g. Nigam 1996; Garge 2010) – using colour of fabrics as new determining factors to identify Red, Buff and Grey Wares. As a result, on one hand the novel classification scheme brought the KLB I ceramics to be directly associated with and equated to Sothi-Siswal ceramic traditions (*Sothi A*), which was organised in a similar manner (see Garge 2010). On the other hand, the various fabrics, wares and traditions that have been differentiated have generated a degree of confusion in the assessment of early ceramics from sites in Rajasthan and Haryana. Given nature of available data, questions regarding diversity within and between regional ceramic traditions and systems of production of the pre-urban period could only be addressed in a limited fashion. Consequently, until the distinctive features of each tradition are fully demarcated, direct comparative studies of synchronic and diachronic ceramic traditions - as we know them today in this area - could lead to misrepresentative results.

Similarly, later pottery from KLB II period has been re-organised into broad classes, namely Buff Ware, Red Ware and Grey Ware (Madhu Bala 2015). There is, however, a lack of clear delineation of differences, such as variation between surface treatments into 'true' slips and self-slips, light or deep red in colour (e.g. Madhu Bala 2015: 319-420). In terms of tools and techniques, authors do not necessary agree on the sequences of actions necessary for producing the pottery found at Kalibangān, suggesting the non- (e.g. Kalibangān Fabric A and D) or limited (e.g. Fabric B and C) use of rotational devices (Madhu Bala 2003; 2015; Courty and Roux 1995; Roux and Courty 1998). For instance, it was first suggested that a potter's wheel similar to modern examples – i.e. the foot wheel of Punjab – was used in the third millennium BC to produce wheel-thrown vessels (Madhu Bala 2003: 101). However, Roux and Courty (1998; also Courty and Roux 1995) have proposed that coiling was extensively used in both periods, and that rotational devices were used to finish the vessel and effectively remove traces of previous phases of the production sequence. Neither of the above hypotheses has benefited from a robust consensus, and they have not been developed further to explore social mechanisms responsible for the introduction of new technologies, as well as for the synchronic use of a variety of manufacturing techniques in local ceramic industries. Similarly, observations on firing techniques vaguely suggest low (c. 400-600°C) to high (c. 930°C) temperatures reached in Indus pottery kilns (Tandon 2003) for firing vessels from Kalibangān.

3.8.3 Regional Late-Urban and Post-Urban traditions: the case of the Bara tradition

Excavation at Ropar (Rupnagar; IAR 1953-54; Sharma 1955-56: 121-129) and Bara (IAR 1954-55) revealed what appears to be a regional type of pottery, which differs from ceramics produced in other areas of the Indus Civilisation during the Indus Urban and Post-Urban periods. Bara ware vessels are often particularly sophisticated in terms of fabrics, forming techniques and surface treatments. They are typically made of fine clay paste mixed with small grain size aplastic inclusions. Bara vessels were generally wheel-finished and slipped, with the slip providing a reddish-brown colour when fired in an oxidising atmosphere, and having a characteristic smooth surface. Based on the assemblages recovered at Ropar and Bara, and observations of material from Alamgirpur, it appears that the most typical shapes of the Bara tradition include globular jars with long neck and flaring rim or with collared rim and globular carinated water jars. The lower body and bases of the jars are often covered by a rough slurry or rustication.

Some common shapes and decorations identified in Punjab, such as classic Harappan and pre-Harappan pottery types, e.g. carinated dishes with flaring rim, beakers, knobbed lid and lid with an out-turned rim, are also found within Bara assemblages (Sharma 1955-56). However, Bara ware seems to lack other iconic Urban period/site shapes, such as goblets with a pointed base, wide-mouthed large storage jars, perforated jars, and S-profiled jars (Sharma 1987; 1989; Uesugi and Dangi 2017). Decoration includes painted designs and pre-firing incision, with the black or dark brown painted motifs mostly being geometric, wavy, zigzag, or looped lines and hatched 'net' (see below Chapter 8, section 8.12.2). Vegetal patterns are also found, while the fish seems to be the dominant common faunal depiction.

3.9 Ceramic technologies of the Indus Urban period

Past studies have attempted to describe the raw materials, tools, and techniques employed by potters during the Urban phase of the Indus Civilisation, with a special emphasis on ceramics from large-size settlements. For instance, the volumes of Mackay (1938; 1943), Marshall (1931), Vats (1940), and Dales and Kenoyer (1986) were the earliest works in this respect, followed by other similar publications (e.g. Blackman and Vidale 1992; Bouquillon et al. 1996; Halim and Vidale 1984; Mery 1994; Miller 1997b; Vidale 1990; Wright 1989a; 1991a; 1993) mostly focusing on ceramics identified at settlements in modern Pakistan. However, given the vast geographic area across which Indus-like ceramics have been unearthed, and also given regional diversities within the Indus zone including variability of ecological niches and functions of settlements, these past studies are not sufficient to consider the debate fully exhausted. Most of our current knowledge arises from studies on materials recovered from sites in Sindh and Pakistani Punjab, the results of which are not easy to transfer to the interpretation of the ceramic traditions in other regions of the Indus zone, e.g. northwest India. A brief overview of what is so far known of pottery production during the Urban period of the Indus Civilisation will now be outlined, serving as a reference for the lexicon adopted throughout this thesis (also see Rye and Evans 1976; Rye 1981; Rice 1987), and to highlight certain issues in the literature which will be challenged in the next chapters.

3.10 Raw materials procurement and processing

At the very beginning of the sequence of actions required for producing ceramic artefacts, sources, procurement strategies and processing techniques are found. In the past century, several studies have focused on raw materials used by Indus artisans, broadly describing certain common patterns of behaviour. The following section is not just about clay, and deals with raw materials, their procurement, processing and mixing. Clay, plastic and aplastic inclusions found in ceramic pastes, sand used as temper or for surface treatments, and pigments used by potters during the Indus Urban period have been described, even though a tendency to generalise is found in the available literature.

3.10.1 Clay

The definition of clay can be easily found in plenty of available publications (see Rye 1981; Rice 1987). When attempting to investigate recipes for producing ceramic vessels, archaeologists tend to focus on two broad themes: (1) the procurement of raw materials (e.g. Quinn 2013: 153), viz. raw material choice, sources, extraction and transportation; and (2) raw material processing and paste preparation (e.g. Quinn 2013: 154-168), which can involve clay purification, addition of temper and/or clay mixing. In the field of Indus archaeology, these types of studies have mostly been either not feasible or neglected. This often resulted in the tendency to accept the idea that fine clay used by Indus potters was abundantly available, required little preparation, and was essentially homogeneous throughout the vast Indus zone (Blackman and Vidale 1992; Miller 1999: 80). This concept has sprung from the presence of clay-rich alluvial plains and major channels in certain areas of ancient Pakistan and north-west India, e.g. the Indus and Yamuna rivers, and the Ghaggar-Hakra fluvial systems, and it is still the prevailing view in the available literature. Similarly, with rare exceptions (e.g. Bouquillon et al. 1996), our current knowledge on Indus clay processing techniques is quite limited, and predominantly based on ethnographic analogies with and observations on modern ceramic industries in the Subcontinent (see Kenoyer 1994b; Miller 1999: 60-61). Studies on inclusions and temper (Rice 1987: 72, 406-413 for an extensive description; Spataro 2003; Druc 1996; Gosselain 2008; Tite et al. 2001; Freestone and Rigby, 1982; Gibson and Woods 1990; Dales and Kenoyer 1986; Miller 1999; Bouquillon et al. 1996; Dales and Kenoyer 1986:42; Miller 1999) and on pigments (Mackay 1938-Ch.XVII:320; Pascoe 1931; Sana Ullah 1931a: 688; Kenoyer 1994b: 359) are also available.

3.11 Manufacture: introducing the debate about the potter’s wheel

There has been debate around the introduction and use of the potter’s wheel in the Indus zone for almost a century, with clearly divided opinions. Two main trends are renowned in the available literature: the first, which was partially introduced above (see above Section 3.7), proclaims the use of the wheel at a very early stage of the development of South Asian social complexity, and the possible use of wheel-throwing techniques on ‘fast’ rotational devices for making vessels as the most common forming techniques of Indus ceramic industries (see Dales and Kenoyer 1986; Wright 1989); the second asserts that rotational devices, such as *tournettes* or turntables, were used only rarely in ceramic manufacture and in a quite limited way, possibly just for the final stage of production (Courty and Roux 1995; Roux and Corbetta 1989; Roux and Courty 1998, 7–8), and multiple ways of forming vessels (e.g. coiling, wheel-coiling, and wheel-throwing) could coexist in the same region. Before presenting a summary of this debate, two significant notes should be made on Indus tools and terminologies.

First, it is essential to note that knowledge about the tools used for producing Indus ceramics is crucial to understand ancient technologies but also social dynamics, but it is currently very limited. For instance, to date we have still not found secure examples of potters' wheels, *tournettes*, pivots, or pits for a kick-wheel, not even from large-scale settlements such as Mohenjo-Daro (e.g. Kenoyer 1986: 64); likewise, other tools such as paddles or anvils have not been securely identified yet (Miller 1999). Thus, examination of vessel surfaces are the sole evidence used to build theories regarding the use of certain types of tools, such as wheels or turntables (see Dales and Kenoyer 1986; Mery 1994:476-477). The use of certain tools and techniques, including rotational devices and rotational energy, affects several parameters of chaine operatoires and their identifications, but also it may reflect broader aspects of technological practice in a region or in a social group. Clarifications on the use of these tools and techniques in the production of vessles may help to clarify the sequence of actions required to produce vessels in the studied region (see 2.3.2), social learning and social interactions dynamics (see 2.5 and 2.6), but also previous missunderstandings concerning the bronze age ceramic technologies of South Asia (see 3.12).

Second, it is equally essential to note that there is variation in the terminology concerning techniques and devices that is used when investigating prehistoric ceramics. Special emphasis can be put on three concepts often confused or used interchangeably: (1) wheel-throwing technique; (2) wheel-fashioning or wheel-finishing technique; and (3) rotational kinetic energy (henceforward RKE), which is the framing concept used to differentiate WT and WF wheel-throwing and wheel-fashioning.

The term (1) 'wheel-throwing' (WT) is often used to refer to a variety of forming techniques using turning tools. In terms of rotational devices, it is occasionally possible to distinguish slow and fast wheels, kick-wheels, *tournettes*, and turntables. All of these tools allow vessels in the process of formation to be rotated so that the potter does not need to move around the vessel; and all of these tools can also be used at any stage of production, from initial forming through modification, finishing and the application of surface treatments. The term 'wheel-throwing' refers to the use of rotational devices for a considerable period of time, and for continuously shaping vessels from clay lumps to the final form (Rice 1987: 132-134). Therefore, in an archaeological or ethnographic situation, the significant technological element for defining 'wheel-throwing' is not the type of tool or the turning device, but the technique (Roux and Corbetta 1989): (a) the use of rotational motor capabilities, which fundamentally differs from the hand-building techniques; and (b) the use of throwing activity for shaping and thinning the walls of a block of clay. This determines the way in which rotational tools are used – fully, partially or not at all.

Second, the term (2) 'wheel-fashioning' (WF) refers to the partial use of a rotational device during different stages of vessel's forming. When vessels are shaped on a rotational device, but not wheel-thrown from a lump of clay, they are said to be formed using wheel-fashioning techniques (Roux 1994: 46- 49; Roux and Courty 1998: 748; Choleva 2012: 351). This method is found in combination with other techniques, e.g. hand-building or coil-building, and wheel-coiling. For instance, when coils are used for making the rough-out during a pre-forming stage of the manufacturing process, RKE is introduced for transforming the vessel into its final shape (see Table 3.5).

The concept of (3) **RKE** in the field of ceramic studies has seen a relatively recent development in the field of archaeological and ethnographic ceramic production and sources of energy. In this context, RKE could be defined as the movement energy an object has due to its spin or rotational velocity around its fixed central axis (adapted after Rodgers and Cavanagh 1984). When investigating pottery industries, specialists usually rely on a clear binary division: techniques using rotative motions - and thus with continuous or discontinuous RKE - for shaping the clay; and those that do not (Roux and Courty 1998; Roux 2003). Besides the possible use of rotative devices, when studying evidence for the use of RKE, several factors should also be considered, ranging from manufacturing (a) methods, (b) phases or portions of vessels, (c) stages of forming process and (d) techniques. These have been described by Roux (2016: 4-6).

Consequently, wheel-fashioning techniques differ from wheel-throwing techniques on three fundamental levels: (a) the amount of *RKE* necessary to produce the vessel; (b) the morphology of the clay mass or rough-out shape of the vessel before using rotational energy; and (c) the moment in which the rotational energy is employed in the forming process (see Choleva 2012). When *RKE* is applied in the final stage of manufacture, it can also be called 'wheel-finishing' technique. The wheel-throwing and wheel-fashioning techniques can produce similar finished products, vessels that are morphologically identical, and can also show similar set of traces on the surfaces (Roux 2009: 197). Thus, the key method for distinguishing such processes is to identify other features that are indicative of preliminary forming techniques. Some of these diagnostic features are described in Chapters 6, 7, and 8 where the adopted macroscopic classification of sherds is described.

3.12 The Indus potter's wheel

3.12.1 Wheel-throwing

Mackay was the first to notice certain surface features of Indus vessels and to suggest the possible use of rotational devices in Indus ceramic industries (Mackay 1938). The indicators used for detecting such techniques have been described in detail by Dales and Kenoyer (1986). They stated that the presence of parallel surface striation, concentric markings on the base of the pottery, and symmetry of vessel's morphology suggest the use of a 'fast' wheel (Dales and Kenoyer 1986: 64). Such visual evaluations lead to the conclusion that the wheel-throwing technique was consistently employed. The authors took this hypothesis one step forward, and described the turning devices that were used by Indus potters –specifically suggesting that a foot-driven double wheel (Mackay 1930) or Pathan wheel (Saraswati 1978: 18), made of two disks connected by a vertical axis and placed into a pit in the ground, was used. This interpretation has been largely adopted for most Indus pottery from Mohenjo-Daro, Harappa (see Wright 1989; 1991: 78-82; Kenoyer 1993; Jenkins 1994; 2000), and Nausharo (Mary 1994).

Despite the fact that the claim that a fast wheel was used is mostly based on visual observations of surface traces and morphology of vessels, and that no potter's wheels or accompanying apparatus have been found to date, the idea that wheel-throwing techniques were used by Indus potters is generally accepted for the whole Indus zone. This view was also strengthened by a perception of linear evolution of ceramic technology in South Asia (see Kenoyer 1998: 151; also see Section 3.7).

Table 3.5 Sequence of actions in wheel-throwing and wheel-fashioning techniques (after Choleva 2012: 351).

Example of wheel-throwing techniques	Example of wheel-fashioning techniques
Centering the clay mass with RKE	Forming the coils with or without RKE
Hollowing the clay mass with RKE	Joining the coils with or without RKE
Lifting and shaping the rough-out with RKE	Thinning and Shaping the rough-out with RKE
Finishing the clay mass with RKE	Finishing the rough-out with RKE

3.12.2 Wheel-fashioning

Studies concerning complex combinations of manufacturing are also found, such as works on pottery sherds recovered in Iran and North-Western India in the third millennium BCE. This approach offered the possibility to explore different yet coexisting ceramic traditions in the Indus zone and neighboring areas, showing the mastery of a variety of techniques in a multi-scale perspective, ranging from regional industries to household production. Moving away from the paradigm of a uniform tradition of 'wheel-thrown' vessels, researchers suggested the partial use of rotational devices, presenting the wheel-fashioning technique as dominant in the Indro-Iranian region, associated with other forming techniques such as coil-building, wheel-coiling, moulding, beating, paddle-and-anvil. The works by Henrickson (1990; 1995) on pottery from Godin Tepe (Iran); Marano (et al. 1992), Meduri (et al. 1993), Vidale, Tosi and Laneri (Vidale and Tosi, 1996; Vidale 1995; Laneri and Vidale 1998) on ceramics from Shahr-i Sokhta (Iran); and Roux and Courty (1995) on Indus pottery from Kalibangān in Haryana are prominent examples. The latter one is possibly the most controversial, suggesting that Indus ceramics in the region were initially "formed by coiling, then shaped on a wheel" (Roux and Courty 1995: 48). This statement has a large number of implications on social, cultural and economic levels, and is in clear contrast with the results and interpretations presented by Wright, Kenoyer and other scholars (Vidale 2000: 78). Roux and Courty's work was, in some ways, revolutionary and, perhaps unsurprisingly, it has been questioned, pushing a certain degree of criticism on methods and materials. It has been pointed out (see Vidale 2000, 79–80) that (a) not all Kalibangān ceramics show evidence for the suggested set of techniques; (b) a limited number of fragmented samples were collected and used in her study; and, for some unclear reasons, the use of a visual approach combined with analytical techniques and experimental archaeology for assessing Indus ceramics was deemd to be "not always a reliable approach".

Despite critiques, the work of Roux and Courty have undeniably reopened the debate around Indus ceramic technologies, questioning certain concepts which were given for settled at that stage of the research. Other forming techniques associated with Indus ceramic industries are listed in Appendix H: Table H.2. Surface treatments in Indus ceramic technologies have been described as being 'more complex than forming techniques' (Vidale 2000: 83), and a list is provided in Appendix H: Table H.3.

3.13 Pyrotechnologies and firing structures

In the process of crafting vessels, the firing stage(s) – and in particular temperatures, conditions and structures – give us important insights into technological choices and manufacturing techniques of ancient potters (see Gosselain 1992). When assessing fired clay pyrotechnogies, researchers need to consider various elements, such as the type of fired objects, drying stages, firing structures and tools, fuel, environmental variability, techniques, and organization of production (see Appendix H: Table H.4 for these types of studies in the Indus context). Undoubtedly, the most comprehensive works that consider these factors in the Indus zone have been presented by Miller (1999), Pracchia and Vidale (Pracchia et al. 1985; Pracchia and Vidale 1990), also a study on fuel by Lancelotti (2018).

3.14 Introducing the studied region: Haryana and Uttar Pradesh

The following sections will introduce the geographical context of the plains of Haryana and western Uttar Pradesh, which will serve to introduce the three sites selected for this study and their archaeological setting presented below.

3.14.1 Geomorphology and hydrology

The fluvial plains of Haryana and western Uttar Pradesh that were occupied by Indus communities are part of the expansive Indo-Gangetic plains. The formation of these plains is often believed to have originated during the Middle Miocene, when the South and East Asian plates collided (Parkash and Kumar 1991), and they have been further modified by fluvial deposits (Pal et al. 2009). Indus populations occupied settlements in these regions from the third millennium BC onwards, mostly establishing the earliest settlements on relict levee and/or dune systems (e.g. Masudpur VII, Haryana), on bedded sand deposits (e.g. Masudpur I and Rakhighari, Haryana), or directly on alluvial deposits (e.g. Alampirpur;

Neogi 2013). The latter case was observed at sites such as Alamgirpur in Western Uttar Pradesh, where alluvial material accumulated in the early Holocene.

This section will provide a geographical and geomorphic overview of the two areas where the studied sites were situated, to understand the interaction between human populations, their activities, and the local landscapes, including the availability of raw materials. This overview lays the ground for considering questions concerning the provenance of pottery, which will make it possible to substantiate assumptions on the use of locally available raw materials in ceramic industries. Preliminary archaeometric observations on off-site soil samples and unfired archaeological mud-bricks have already tentatively suggested the use of local alluvial clay-rich deposits for the production of building materials through the occupation of sites (Neogi 2013: 301; also see Friesem et al. 2011; Nodarou et al. 2008).

3.14.2 Plains of Haryana and western Uttar Pradesh

The plains of modern Haryana, where the archaeological sites at Masudpur I and Lohari Ragho I were situated, are part of an expansive drainage divide between the plains of the Indus River Basin to the west and the Ganges River Basin to the east. The region appears relatively flat and shows occasional low alluvial mounds, solitary dunes and dune chains (Petrie et al. 2009; Saini and Mujtaba 2009). Details concerning the chronologies and formation processes of dunes and alluvial deposits are gradually being accumulated (e.g. Saini and Mujtaba 2009; Maemoku et al. 2012; Durcan et al. 2019). This landscape is believed to have played an important role in Indus settlement strategies (Petrie et al. 2017; Singh et al., 2018b). In terms of its relative position within South Asia as a whole, this area is part of the Himalayan foreland; thus, its geomorphology and sedimentation processes are largely controlled and affected by the Himalayan system, including its hydrology (Giosan et al. 2012; Saini and Mujtaba 2010; Saini et al. 2009; Webb et al. 2011; Pati et al. 2018; Singhai et al. 1991). Despite the unique features of this region, detailed maps showing variable sediments, including clay rich deposits, are currently rare (Courty and Fedoroff 1985; also see Figure 3.6).

The hydrology of the region witnessed remarkable transformations before and during the Holocene, and it was significantly modified by anthropogenic impact on the environment in the past few centuries (French et al. 2014). Extensive networks of modern canals dominate the plains of Haryana, alimented by major rivers such as the Sutlej and

Yamuna (e.g. Figure 3.6). The rain patterns also contribute to the hydrological configuration of the region, forming ephemeral water channels during the winter and summer monsoons seasons (van Dijk et al. 2016; Orengo and Petrie 2017; also Yashpal et al. 1980). Such is the case of a large number of small channels, e.g. the Chautang, Sarsuti, Markanda, and likely the Ghaggar system. The combination of both modern modifications and seasonal hydrological variability has contributed to shape the landscape, altering the characteristics of the alluvial deposits.

The alluvial plains of Western Uttar Pradesh (UP) and Upper Ganga plains, where Alamgirpur (modern Hindon sector of the Meerut district) was situated, are also located within the broader Indo-Gangetic plain, and rest upon the Himalayan foreland basin (Dewey and Bird 1970; Gibling et al. 2005; Singh 1996). Thick layers of Quaternary alluvium, mostly deposited by Himalayan rivers and tributaries, cover the Pre-Cambrian metamorphic and igneous bedrock of the Hindon sector (Bhattacharya and Agarwal 2005; Dhital 2015; Mukherjee 2018). The formation of alluvial deposits in the Meerut district is strongly connected to riverine activity and rainfall patterns. Being located between two major rivers, the Ganges (east) and its second largest tributary, the Yamuna (west), the formation of megafan deposits in the Meerut district is particularly affected by the Ganges and its tributaries (Srivastava et al. 1998; Tandon et al. 2008) Spate and Learmonth 1967; Wells and Dorr. Moreover, the hydrology of this region is also strongly connected with variable climate and weather patterns (Neogi 2013). That is the case, for instance, of the river Hindon, which is a tributary of Yamuna originating from the Upper Siwalik mountains (lower Himalayas), and flows adjacent to the modern village of Alamgirpur and is highly dependent on seasonal rains variations (Rizvi et al. 2016; Bhatia and Kumar 1987; Fagon and Townsend 1915; Joshi 1965).

Figure 3.6 Example of currently available geological maps showing broad description of clay-rich sediments around the village of Alamgipur, Scale 1:250,000 (Geological Survey of India, Calcutta). Yamuna river is shown in the left square.

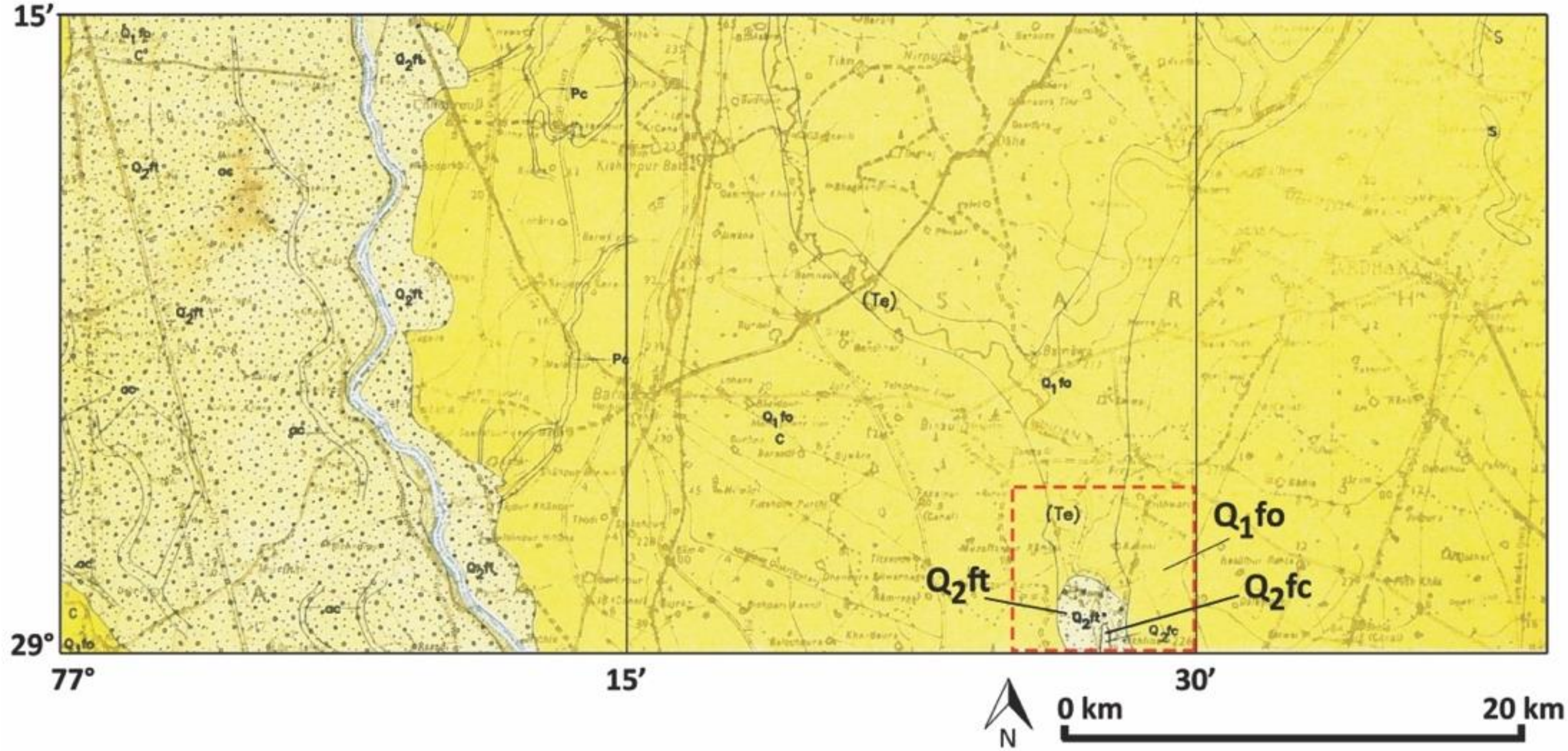


Figure 3.7 Map showing the studied region. Detailed maps of each site are available below.

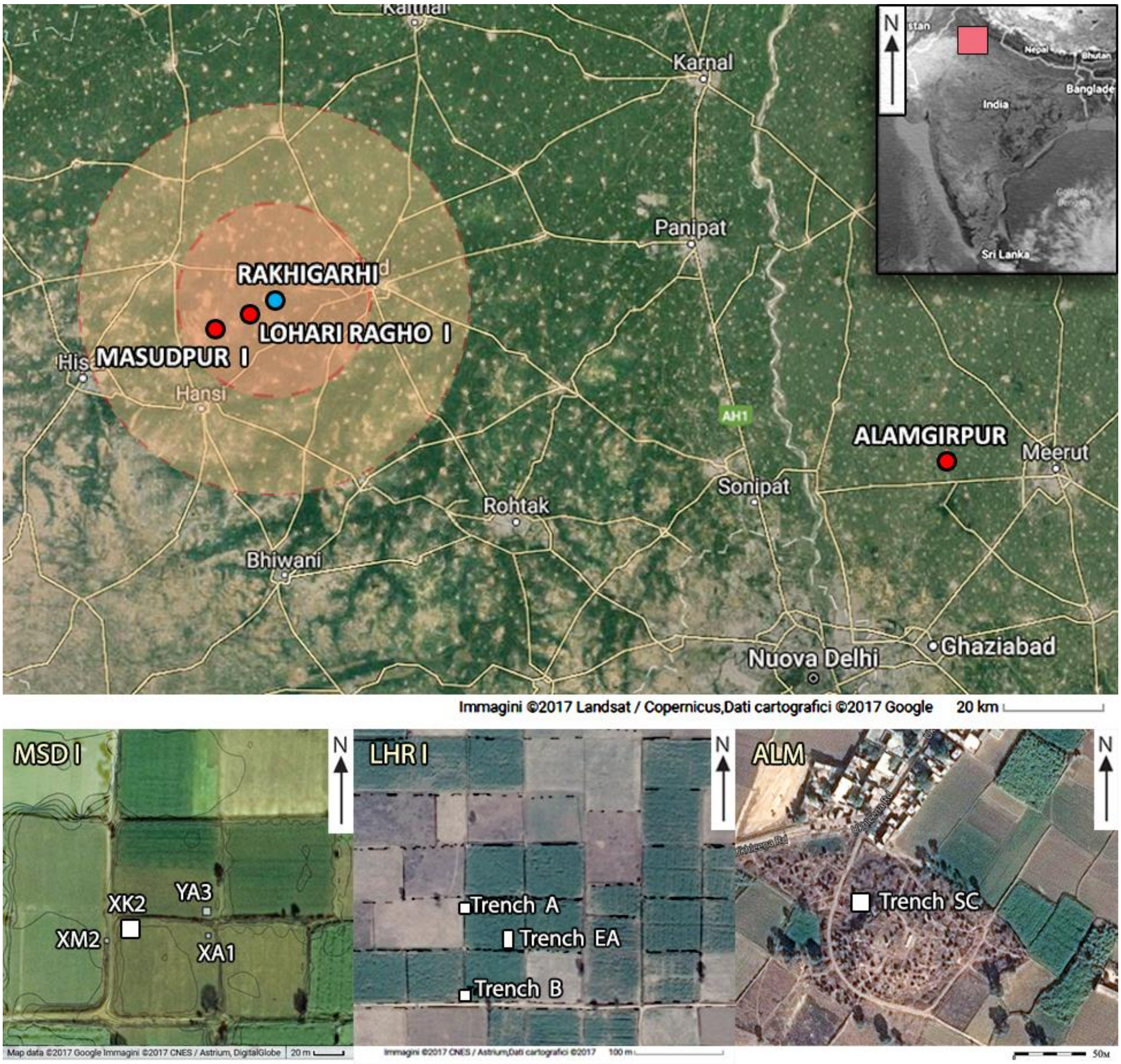


Table 3.6 Sites, coordinates and relative chronologies of the study settlements.

Sites	Coordinates	Pre-Urban	Indus Urban	Post-Urban
Lohari Ragho I (Haryana) Trench EA	29°14'52.4"N 76°02'04.3"E	X	X	-
Masudpur I (Haryana) Trench XK2	29°14'38.2"N 75°59'36.7"E	-	X	X
Alamgirpur (UP) Trench SC	29°00'12.1"N 77°29'03.7"E	-	X	X

3.14.3 Palaeo-hydrography and ancient landscapes

Given the apparently homogeneous geomorphology of the region, in order to identify ancient clay deposits in the plains of Haryana and western UP, modern and ancient hydrography must be taken into account. Debate concerning the hydrology of this region has mostly revolved around the identification of ancient rivers (e.g. Yashpal 1980; Lal 2002; Valdiya 2002). For instance, satellite remote sensing has been the most commonly used means for determining course of palaeo-channels and their impact on ancient landscapes (Ghose et al. 1979; Gupta et al. 2004; Kar and Ghose 1984; van Dijk et al. 2016; A. Singh et al. 2017). Research for the *TwoRains* project is contributing more nuanced understanding of palaeo-channels, changing landscapes and their chronologies in relation to ancient settlements (Orengo and Petrie, 2017; Singh et al. 2018a; 2018b; Walker in prep). This nuanced dataset will be used for the present study, specifically for identifying possible ancient clay sources or fine-grained sediments in proximity to ancient rivers (see Chapter 5).

3.15 Archaeological sites: the three studied settlements

Ceramic material from three archaeological sites have been selected for the present study. Two sites located in Haryana, Lohari Ragho I (LHR I) and Masudpur I (MSD I), and one site located in western Uttar Pradesh, Alamgirpur (ALM), provided archaeological materials produced and used by Indus communities (Figure 3.7). The sites have been selected for their unique stratigraphic sequences and locations, which allowed the proposed research questions to be addressed for this project (see Table 3.6). In this section, an overview of our current understanding of the selected sites is provided, along with a brief summary of unearthed cultural materials and their relative and absolute chronologies. All of the sites in the vicinity of Masudpur and Lohari Ragho are situated in the plains of Harayana and lie between 8 and 16 kilometres from the urban site of Rakhigarhi (E 76° 06.715′, N 29° 17.365′), and are likely to have been situated within its hinterland at least during the Mature Harappan period (Petrie et al. 2009; Singh et al. 2009). Alamgirpur, however, is located in the plains of wester UP and offers a different scenario, being c. 135 kilometres away from the urban site of Rakhigarhi.

Table 3.7 Summary of excavations at Lohari Ragho I (Singh et al. 2018a)

Trench Code	Season	Dimensions	Relative chronology
Trench A	March – April 2015	2x2 m	Early, Early Mature Harappan
Trench B	March – April 2015	2x2 m	More data required
Trench EA (*sounding*)	March – April 2017	2x2 m	Mature and Late Harappan
Trench EB	March – April 2017	2x2 m	More data required
Trench NA1	March – April 2017	2x2 m	More data required
Trench YA1	March – April 2017	2x2 m	More data required
Trench EA (*open area*)	September – October 2017	10x20 m	Early Harappan, Mature Harappan, Historic

3.16 Lohari Ragho I

Several surveys have identified archaeological settlements around the modern village of Lohari Ragho in the Hansi sub-district, Hissar district of Haryana. Two mounds in this area were first recorded by Dhoop Singh and Chanderpal Singh of the Department of Archaeology and Museums, Haryana, who reported a possible Late Harappan chronology (IAR 1981: 16). Unfortunately, their initial work did not indicate the exact location of the mounds. These sites were listed in the compilation of sites by J.P. Joshi et al. (1984; 519), who ascribes 'Lohar Rago' to the Pre-Urban or Early Harappan period. Three mounds were subsequently surveyed and their ceramics were studied by T. Garge (2001; 2006; 2010), who initially identified a slightly different chronology and recorded three sites (LHR I, II and III) further expanding the chronology of the site to the Early, Mature, Late Harappan and Historic periods. He was not able, however, to determine whether these were the same sites recorded by D. Singh and C. Singh or Joshi, and little correspondence between each survey could be found (see Singh et al. 2018a). More recently, the *Land, Water and Settlement (LWS)* project (Petrie et al. 2017a; Singh et al. 2011) carried out the *Rakhigarhi Hinterland Survey* (RHS; Singh et al. 2010) recorded sites in this area, including the mound selected for this study (henceforth LHR I).

3.16.1 Initial soundings in 2015 and 2017

LHR I was surveyed in detail and exploratory soundings were excavated during three main seasons in 2015 and 2017, as part of the *Land, Water and Settlement* and *TwoRains* projects (Singh et al., 2018a). With the assistance of students from MD University Rohtak, topographic surveys and a systematic surface collection was carried out to document the distribution of material culture (Redhouse et al. forthcoming). Subsequently six trenches were excavated (see Table 3.7). These soundings provided a relative chronology of the site, as well insight into its morphology, stratigraphic layout, and degree of preservation. This information made it possible to design and undertake an extensive horizontal excavation of Trench EA in September – October 2017 (see below Figure 3.9).

3.16.2 Open area excavation in 2017: trench EA

The excavations in Trench EA were open area. This location was selected because of the quality of the stratigraphy revealed in Sounding EA, which suggested that architectural features belonging to different occupational phases would be preserved. In keeping with the methods used for the Land, Water and Settlement project excavations (e.g. Petrie et al. 2009), a 'single context' recording method was used to document the exposed horizontal areas (*cf.* Barker 2003; Drewett 2011; MOLA 1994). During the five week season, an area of 20 x 10 metres was exposed, but most efforts were directed to a 10 x 10 m area (Figure 3.9). A total of 97 stratigraphic contexts were identified and documented, belonging to at least three phases of occupation, ranging from the Early to the Mature Harappan period (Singh et al. 2018a). The revealed deposits include architectural remains, a number of distinct occupational areas, and clear evidence of structural collapse (see Figure 3.9). There was also evidence for later Medieval occupation intruding into the earlier deposits (Singh et al. 2018a).

Figure 3.8 LHR-I contexts selected for the present study (see appendix A). the chart shows the quantity (grand total 1,095) and percentage of Pre-Urban or Early Harappan (PU) and Early Urban or Early Mature Harappan (EU) ceramics recorded during the in-depth analyses of ceramic materials at BHU.

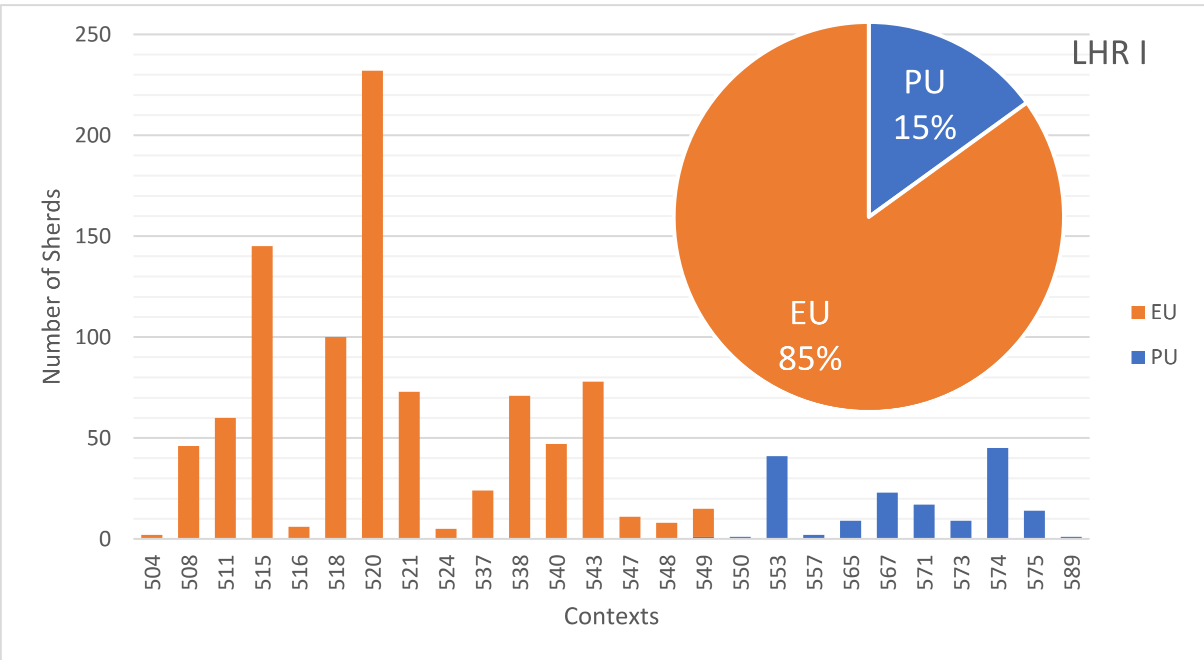


Table 3.8 Summary of excavations at Masudpur I and VII (after Petrie et al 2016; Tewari and Dimri, 2015, pp. 62–64).

Trench Code	Season	Dimensions	Relative chronology
MSD I/XA1	April - May 2009	3x3 m	Mature and Late Harappan
MSD I/YA3	April - May 2009	5x5 m	Mature Harappan
MSD I/XM2	April - May 2009	3x3 m	Mature and Late Harappan
MSD I/ XK2 (*open area*)	January – February 2018	10x10 m	Mature Harappan, Late Harappan, and Historical period

During the excavations, each deposit was either screened using a 2 mm sieve, or hand sorted, and all cultural material was collected. Soil samples were also collected for flotation, and ceramics and other cultural material were also recovered in this fashion (Singh et al. 2018a). A total number of 27,500 pottery sherds, weighing 359 kg, and 242 smallfind antiquities were documented in the field using an electronic ODK database (see below Section 4.2.1). Detailed registration, drawing and sampling for technological and compositional assessment were subsequently carried out by the author in October and November 2017 at Banaras Hindu University, Varanasi (see Chapter 4).

The assessment of the cultural material confirmed the results from previous exploratory soundings. Ceramics from the excavated areas included both Early and Early Mature Harappan vessel forms (Figure 3.8) . Overall, the ceramic assemblage brings certain typological and stylistically parallels with material from Early Harappan and Mature Harappan sites at Masudpur VII, Girawad and Farmana (Uesugi 2011a; 2011b; Parikh and Petrie 2016;). As will be discussed further in Chapter 6, a small number of fragments of the so-called 'Classic Harappan black-on-red' pottery were identified, reconfirming that this particular ware appears to be rare outside of urban centres, at least in northwest India (e.g. at Farmana; Uesugi 2011). It is notable that such pottery is present at Lohari Ragho I, but was not recovered during the initial excavations at Masudpur VII and Masudpur I, which are located only a short distance away (Parikh and Petrie 2016; Petrie et al. 2017; Chapter 7).

3.17 Masudpur I

Early documentation of archaeological sites in proximity of the modern village of Masudpur, Hissar district Haryana, was similar to Lohari Ragho. Dhoop Singh and Chanderpal Singh reported four sites (MSD I, II, III, and IV) with possible Harappan, Late Harappan, and Historical occupation (IAR 1980-81: 16-17), but this initial documentation did not indicate the exact location of the Harappan mounds (Petrie et al. 2009). The sites were again reported by J.P. Joshi et al. (1984: 519), who ascribed the ancient settlements at 'Masaudpur' to the Mature Harappan and Late Harappan periods, this time including one set of approximate coordinates for the four mounds (also reported in Joshi et al. 1984, p. 511; also see Kumar M. 2009; Kumar R. 2008; Possehl 1999). A preliminary survey by the *Land, Water and Settlement* project in March/April 2008, and a more detailed local survey in April/May 2009 contributed to determine the exact location and cultural material associated with thirteen mounds in close proximity of the Masudpur village (Singh et al. 2008; 2010; Petrie et al. 2009, 2017).

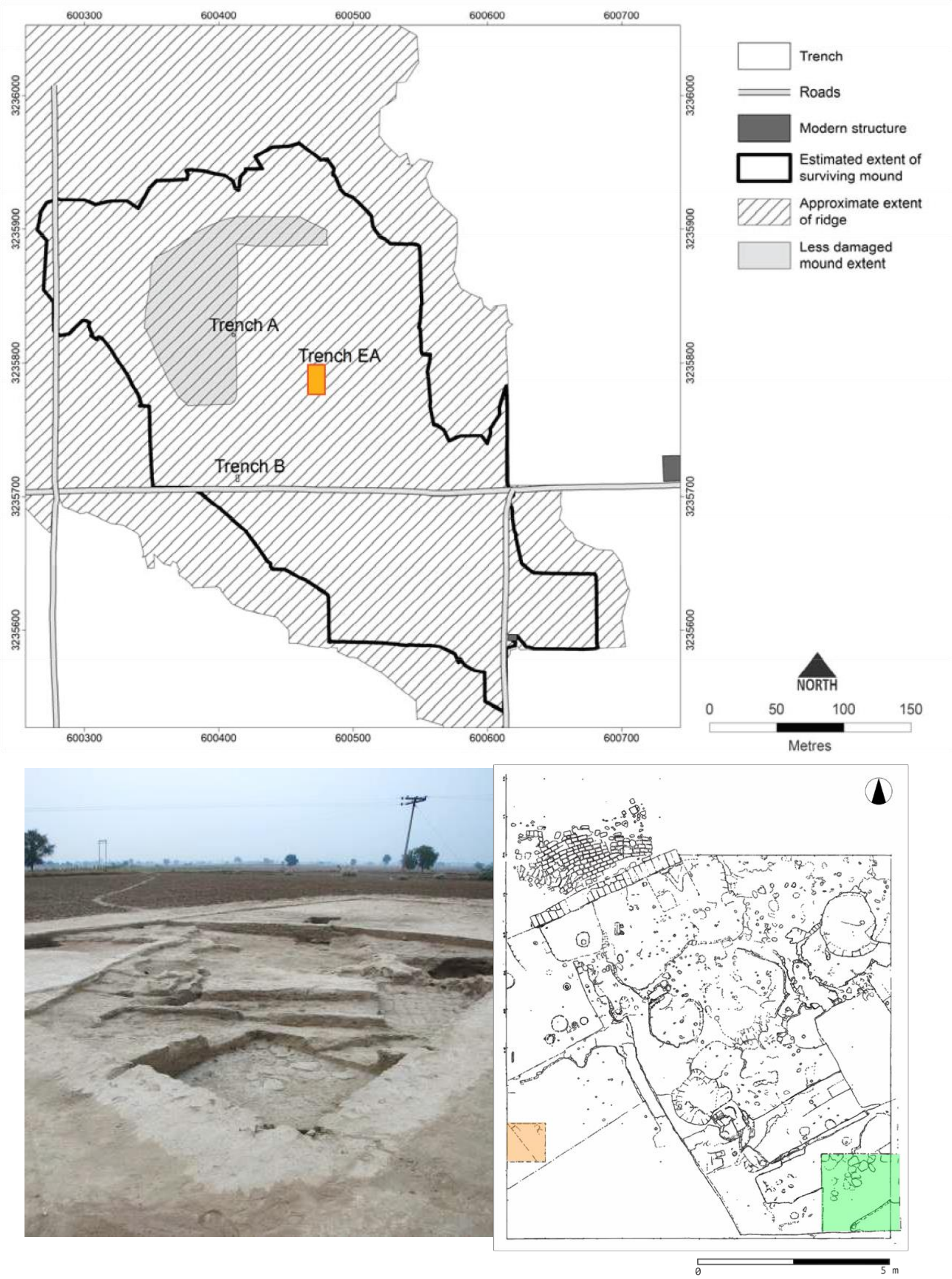
3.17.1 Initial soundings in 2009

Two sites were chosen for topographic survey and the excavation of trial trenches. The archaeological sites now labelled as Masudpur I (Sampolia Khera) and Masudpur VII (Bhimwada Jodha) provided surface evidence for occupational phases likely affiliated to the Indus Civilisation period (Singh et al. 2008: 81; Petrie et al. 2009; see Table 3.8). At Masudpur I (MSD I), three soundings were excavated and produced faunal, botanical and ceramic materials affiliated to the Mature and Late Harappan periods (Petrie et al. 2016; also Joglekar et al. 2017; Petrie et al. 2009; Singh et al. 2009). More specifically (Singh et al. in press): *Trench MSD I/XA1* revealed nine different phases of occupation; *Trench MSD I/YA3* was excavated adjacent to XA1, and exposed four stratified occupational phases; and *Trench MSD I/XM2* was placed in an area on the western side of the mound and revealed up to ten distinctive phases of occupation, including a mud-brick structure (see Table 3.8). The sounding excavated at Masudpur VII, *trench YA2*, provided a similar picture (Petrie et al. 2016; Joglekar et al. 2016; Parikh and Petrie 2016; Tewari and Dimri 2015: 62–64). This preliminary work allowed (to be design and undertaken) a subsequent extensive horizontal excavation of the mound in 2018.

3.17.2 Open area excavation in 2018: MSD XK2

A second season of extensive horizontal excavation was undertaken in January and February 2018 as part of the *TwoRains* project (see preliminary report Singh et al. in press b). Trench XK2 was opened adjacent to the XM2 sounding, which in 2009 revealed evidence for well-preserved architecture and occupation deposits dating to late Mature Harappan and Later Harappan periods (Figure 3.10 and 3.11).

Figure 3.9 Lohari Ragho I site plan. Location of Trench EA is marked in orange. 5.3b. Photo of excavations in Trench EA (taken from SE corner of trench facing NW); 5.3c. Plan of Trench EA, with the location of soundsings shouwn in orange and green (Singh et al. 2018a).



The trench extended across an area of 10 x 10 metres, and the same single context recording method was used to document the archaeological contexts. During the five-week season, a total of 126 distinct stratigraphic units were identified, relating to at least four occupational phases– which span both the Mature Harappan and Late Harappan phases. The explored trench revealed architectural remains, distinct activity areas including storage areas, disposal pit, possible firing areas and food preparation areas. A smaller, deeper slot was excavated within the open area to ascertain the stratigraphic relation of deposits and explore earlier occupational contexts (see Figure 3.10).

A preliminary assessment and documentation of ceramic materials was carried out in the field (see Chapter 7). A total of 34,000 pottery sherds, weighing 653 kg, were documented using an electronic ODK database (see below Section 4.2.1). All ceramic materials were processed in the field, and detailed registration, drawing and sampling for technological and compositional assessment were subsequently carried out by the author in March and April 2018 at Banaras Hindu University, Varanasi.

The preliminary assessment of the cultural material confirmed the results from the first season of exploratory soundings. The ceramics from the excavated area included both Mature (Early Urban and Late Urban) and Late Harappan vessel forms (see Figure 3.12). Overall, ceramic assemblage has certain typological and stylistically parallels with material from Mature Harappan and Late Harappan deposits at Masudpur I (2009), Masudpur VII, and Farmana (Parikh and Petrie 2016, in press; Petrie et al. 2009; Singh et al. 2009; Uesugi 2011a). As will be discussed further in Chapter 7, a small number of fragments of the so-called 'Classic Harappan black-on-red' pottery were identified, reconfirming that this particular ware appears to be rare outside of urban centres, at least in northwest India (e.g. at Farmana; Uesugi 2011). As noted above, fragments of such pottery was present at Lohari Ragho I, but none recovered during the initial excavations at Masudpur VII and Masudpur I (Parikh and Petrie 2016, in press; Petrie et al. 2017). The new finding suggests that this material was being used at Masudpur I, but affirms that it was not being used in substantial quantities (see Chapter 7).

Figure 3.10 Section showing stratigraphic sequence from sounding excavated in the South-East corner of MSD I, trench XK2. See below sounding marked by a green square in Figure 3.10. Drawing by A. Ceccarelli.

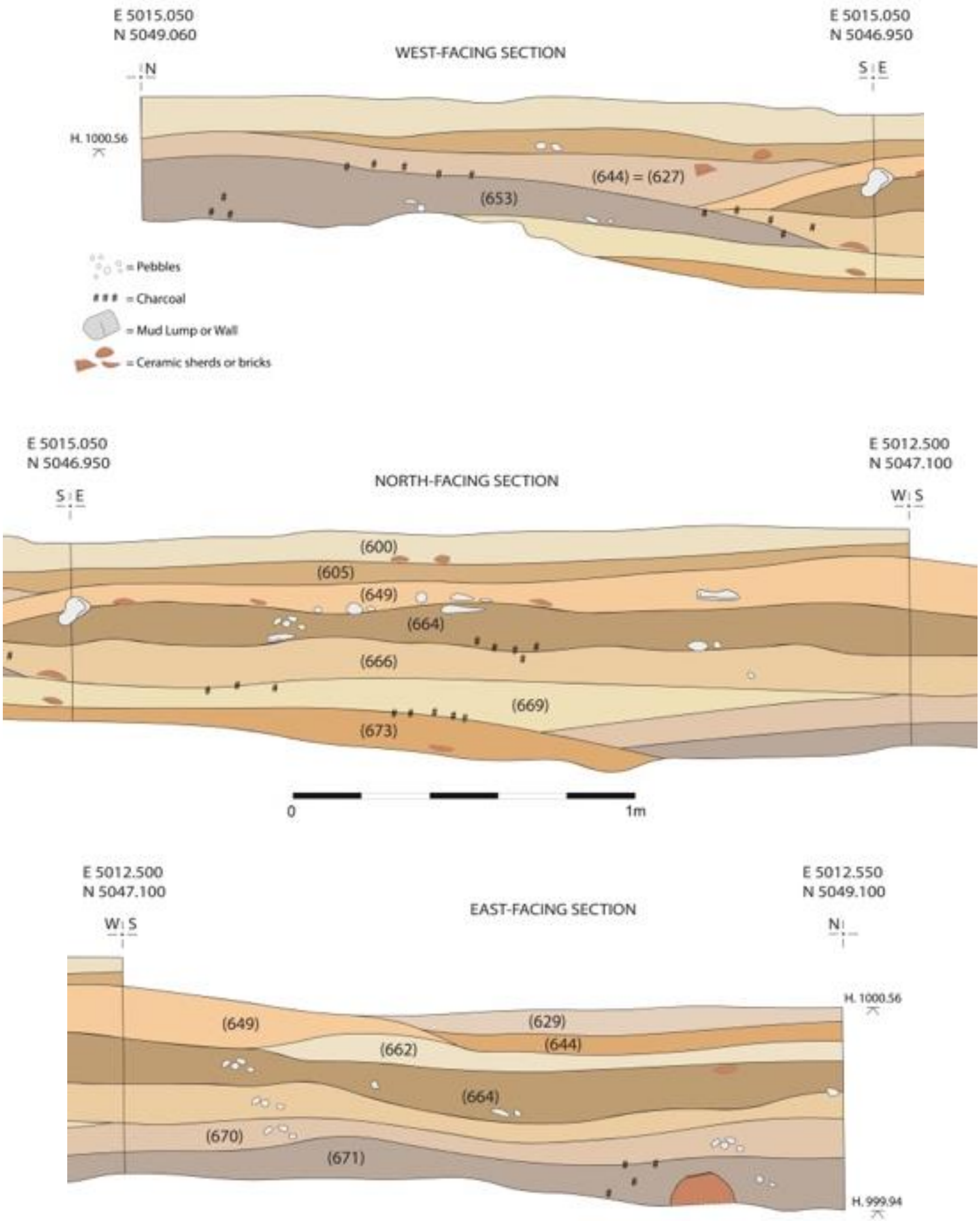


Figure 3.11 Contour plan of Masudpur I, with trench XK2 represented by blue square; 5.6b. Photo taken from north side of trench XK2 facing south; 5.6c. Plan of trench XK2 (Singh et al. 2018b).

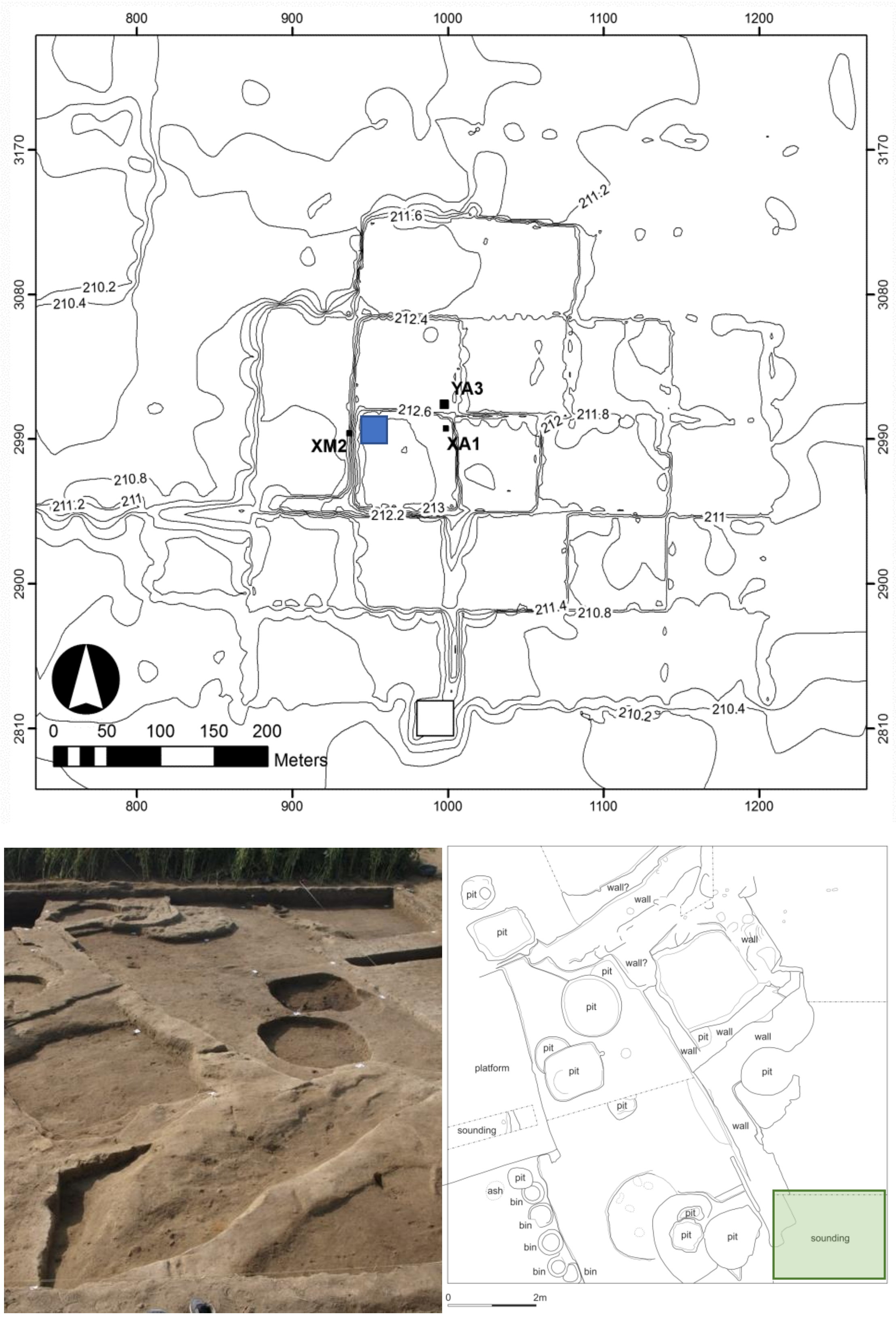
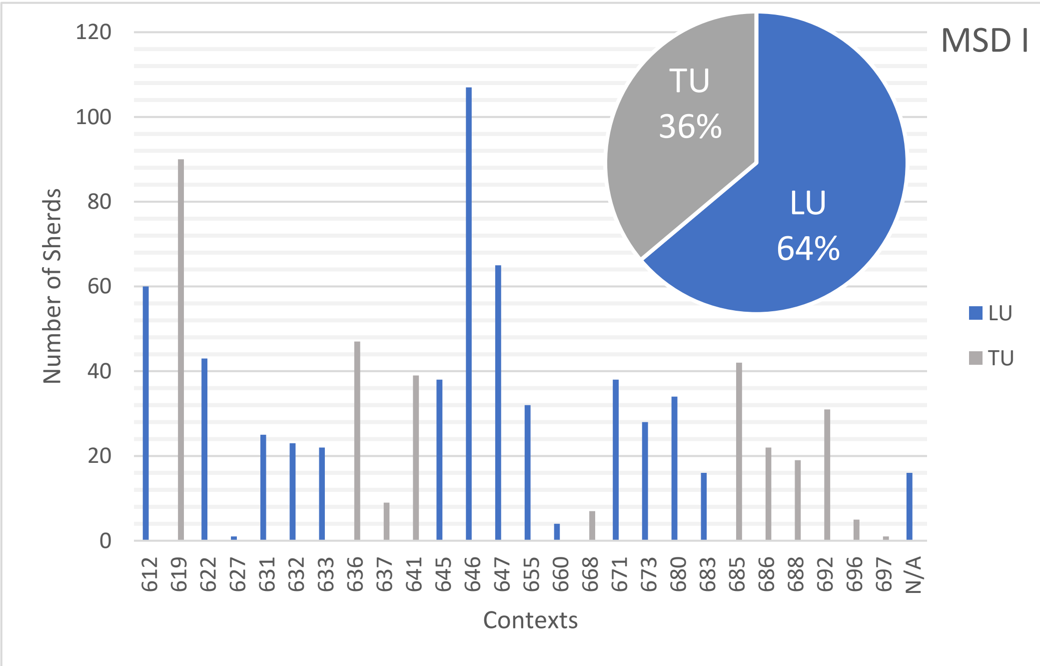


Figure 3.12 MSD I XK2 contexts selected for the present study (see Appendix A). The chart shows the quantity (grand total 864) and percentage of material from the Transitional Early-Late Urban phase (TU) and Late Urban phase (LU) ceramics recorded during the in-depth analyses of ceramic materials at BHU, Varanasi.



3.18 Alamgirpur

Alamgirpur is located in Meerut District, Uttar Pradesh, about 2.5 kilometres east of the modern course of the Hindon River, a tributary of the Yamuna River. The mound, locally known as *Parasuram-ka-Khera*, today measures about 60 metres east-west and 50 metres north-south, and is situated adjacent to the modern village, whose population mostly engaged in agricultural activities.

3.18.1 Previous excavations

The site was firstly excavated in May 1958 by the Regional Camp Committee of the Bharat Sevak Samaj, which brought to light a corpus of material culture, including pottery and a number of small finds possibly affiliated to the Indus Civilisation (IAR 1954; IAS 1981). Y. D. Sharma of the North-Western Circle - currently known as Srinagar Circle - of the Archaeological Survey of India was the first to identify a possible Indus affiliation for the fragmentary assemblages. Sharma's subsequent excavation in 1959 confirmed the suspected chronology of the site, revealing a four-fold occupational sequence, and highlighting that each period was marked by a clear break in occupation in-between each phase (IAR 1954: 195; 1955; Sharma 1989).

3.18.2 New excavations: including trench SC

The most recent excavations at Alamgirpur were initiated by Banaras Hindu University in 2008 and have made it possible to reassess the occupational sequence and material culture of the site (Singh et al. 2013). A total of five trenches (ZA-1, ZA-2, ZB- 1, ZB-2 and YD-2) and one sounding were excavated during that season. The Section Cutting or SC trench was excavated into an exposed section of the western slope of the mound (see Figure 3.13). This trench provided organic remains and cultural material from stratigraphically secure contexts which were used for the present study (Singh 2014).

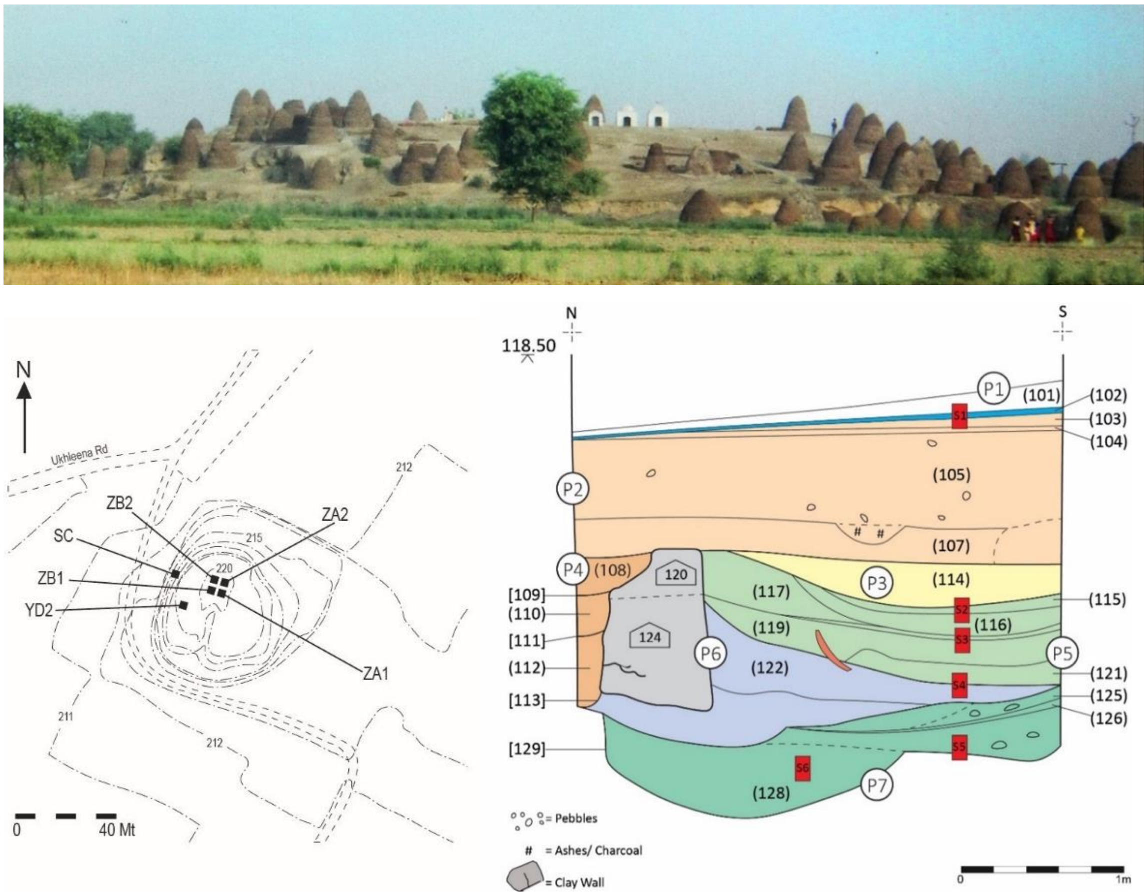
The earliest phase of occupation at Alamgirpur was identified in Trenches YD2 and ZB2, and according to the radiocarbon dates, it occurred in the mid- part of the Indus Urban phase. For the purpose of this thesis, the revaluation of stratigraphic sequence of trench SC and material culture of Alamgirpur was necessary and will be briefly summarised. Section Cutting *(ALM-SC)* revealed seven phases of occupation from the Mature to the Late Harappan period, and PGW period (after Neogi 2013: 201; Singh et al. 2013):

a. Evidence for the earliest anthropogenic impact is provided by a pit cut into the natural soil, which was subsequently filled by a deposit yielding Indus cultural material (Period I-B, Phase 7). Early appearance of Indus-like materials seem to date to the Late phase of the Urban period;
b. This was followed by the major phase of occupation: a mud-brick wall was erected, used and reused over a protracted period (Period I-B, Phases 6-5). Preliminary assessment of pottery from this phases seems to point to Indus regional industries;
c. A sequence of pits was cut to the North and West of the wall (Period I-C), filled with deposits yielding Indus Post-Urban materials;
d. Above these pits were a series of homogeneous deposits, including compact deposits that were topped by a rammed floor (Period I-C, phase 2) was identified.

Table 3.9 Reassessment of Alamgirpur periodisation in trench SC (after Singh 2014).

PHASES	PERIODS	TRENCHES	SC UNIT	UNCAL. DATES	CAL. DATES
Phase IV	Late Medieval period	YD2, ZB2	n/a	Further data required	
Phase III	Early Historic period	YD2, ZB2	n/a	2458 ± 25 BP	754-414 BC (95.4%)
Phase II-B	Post-Indus period (or PGW)	YD2, ZB2	n/a	Further data required	
Phase II-A	Post-Indus Transition	SC, YD2, ZB2	(101), (102)	Further data required	
Phase I-C	Indus Post-Urban period	SC, YD2, ZB2	(103) to (114)	3508 ± 26 BP	1903 -1749 BC (95.4%)
Phase I-B	Indus Late Urban period	SC, YD2, ZB2	(115) to (128)	3652 ± 28 BP	2135 -1942 BC (95.4%)
Phase I-A	Indus Urban Period	YD2, ZB2	n/a	3760 ± 33 BP	BC (95.4%)

Figure 3.13 Alamgirpur mound (Long. 77°29'3.42"E; Lat. 29°0'12.36"N) and West facing section of trench SC (Singh et al. 2013).Diagram shows the reassessed occupational sequence and phases. Geoarchaeological samples are presented (red squares), as well as context.



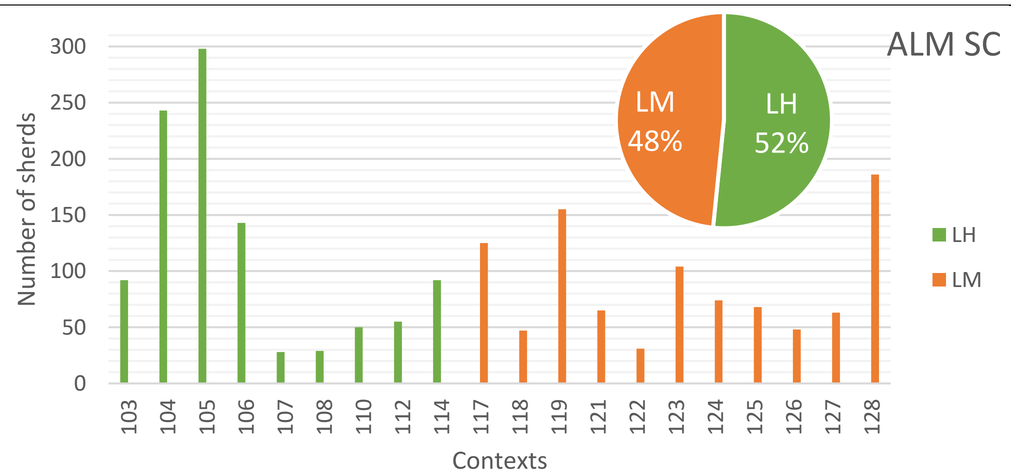
All ceramic materials from the excavations were processed in the field, and detailed registration, drawing and sampling for technological and compositional assessment were subsequently carried out by the author in March 2016 and July-August 2017 at Banaras Hindu University, Varanasi. The preliminary assessment of the cultural material only partially confirmed the results from previous exploratory soundings (Figurs 3.13 and 3.14, and Table 3.9). The ceramics from the excavated areas included both Mature and Late

Harappan vessel forms, and show differences to the contemporary material discovered at Masudpur I trench EA. Overall, the assemblage brings certain typological and stylistically parallels with material from Mature Harappan and Late Harappan excavations at Bara and Ropar and to an extent the material from Farmana (Chakrabarti et al. 2006; IAR 1954; 1955; Joglekar 2009; Sharma 1955; Sharma and Sharma 1982; Sharma 1989; Singh et al. 2013; Singh 2014; Uesugi 2011a; see Chapter 8).

3.19 Discussion and conclusions

This chapter was divided into two distinctive sections discussing aspects of archaeological investigation and ceramic studies in South Asia, as well as the three studied sites and their contexts in northwest India. In the first part of this chapter the use of morpho-stylistic, geochemical and petrographic methods, as well as ethnographic approaches applied to the study of Indus ceramics and closely related craft traditions were presented. Some problems related to ceramic analyses have been pointed out, including certain assumptions on the lack of variability of craft production; the different ways in which ceramic assemblages are mostly interpreted; the fragmentary conditions of ceramics found at archaeological sites; and storage and documentation strategies. Amongst them, one of the most crucial issues is the need for nuanced approaches for the collection of quantitative or semi-quantitative data from fragmentary ceramic assemblages.

Figure 3.14 ALM SC contexts selected for the present study (see Appendix A). The chart shows the quantity (grand total 864) and percentage of Late Mature Harappan (LM) and Late Harappan (LH) ceramics recorded at BHU, Varanasi.



Although often claimed otherwise, there have been a number of pottery studies on South Asian material that have employed analytical techniques, but they seem to be limited to certain geographic areas (e.g. southern Rajasthan and Gujarat). In many ways, the field of scientific analysis of ceramic materials can be seen to be as old as the rediscovery of the Indus Civilisation itself. Partially introduced in the first part of this chapter, and further explored in the second part, is the tendency to follow two paradigms for the interpretations of ceramic assemblages and technologies. The first being the identification of archaeological phases which rely on ceramic seriations and chronologies based on stylistic and typological observations, mostly following a cultural-historic approach (see Trigger 1989; Lyman et al. 1997; Ceccarelli and Petrie 2018: 93). The second encapsulates a linear evolutionary trajectory of technological developments.. Understanding different techniques in ceramic industries has implications which lay well beyond the mere description of archaeological phases, technological and economic aspects of prehistoric communities. A necessary development of the field relies on the use of various theoretical perspectives to address social questions. More specifically, to move away from culture historical interpretations (see Trigger 1989) and mere seriations (see Lyman et al. 1997) based on cultural materials, and to use material culture as a medium for understanding social, and economic dynamics.

The overview of technological changes from the Neolithic up to the Indus urban period has served to demonstrate how scholars have attempted to present the picture of more sophisticated technologies homogeneously taking over older, less advanced techniques – mostly in view of possible functional or economic gains within systems of production. The general assumption is that these consistent phenomena happened according to principles of *demic diffusion* (see Roux 2013: 320–24), where new approaches were more or less "suddenly" adopted by most communities and spread simultaneously thought the Indus zone. In simplistic evolutionary models, cultural traits seem to be unaffected by their externalisation in material form (Knappett 2016), and rely on 'the hypothesis that contacts between people are necessary and sufficient for social learning to occur' (Roux 2013: 313).The critique to this approach is mostly oriented towards two points. First, such cultural evolutionary interpretations leave little room for exploring the role of the material environment as an active participant in the constitution and transmission of cultural knowledge. Secondly, there are many recorded archaeological and ethnographic instances in which communities may 'learn' about or get in 'contact' with a new trait or technique, but *choose* not to adopt it (e.g. Roux 2013: 313; Wengrow 2011). Consideration of these two factors will allow the reassessment of traditions, technological choices and economic aspects of prehistoric ceramic production, including issues of standardisation of pottery and variability of socio-cultural groups (see Choleva 2012; Kingery 1984). This is the starting point for the theoretical framework chosen for the present study, which has been presented in detail in Chapter 2. Besides theoretical implication, this review served to introduce certain types of ceramics which will be subsequently mentioned in the next chapters.

This chapter served not only to examine technological development, but also to assess the extent to which ceramic diffusion and learning mechanisms have been studied so far. Incipient forms of intra-regional interaction spheres in the Indo-Iranian area have been observed since the Chalcolithic phases. It is still not entirely clear the nature of and mechanisms behind these interactions; nevertheless, the role of mobile or semi-nomad populations and seasonal mobility through changing environments have been addressed (e.g. Jarrige et al. 1995: 73-74; Petrie et al. 2010b; Khan et al. 2010). There has been very limited consideration of ceramic variability within regions and between rural communities during the pre-urban and urban periods of the Indus civilisation (see Petrie et al. 2018). However, detailed studies on interaction networks that show Indus medium- and large-scale sites at their intersecting nodes are available (e.g. Law 2005, 2011). So far, our current knowledge of Indus material culture is mostly based on observations from assemblages recovered at medium to large-scale sites, and the dynamics operating in Indus villages still remain underexplored (Petrie et al. 2017, 2018). This is particularly the case when it comes to understanding ceramic technologies and the nuanced dynamics of social interaction that took place between rural potters, and between potters and the populations making use of their products.

Finally, this chapter has introduced and described the geomorphology and hydrology of the plains of Haryana and western Uttar Pradesh, and contextualized the three selected sites and their archaeological setting. The selected sites and their contexts here presented have provided evidence for relative and absolute chronologies of the archaeological ceramic materials affiliated to the Early, Mature and Late Harappan period. Even though the entirety of ceramic assemblages were examined from these sites, only limited contexts and samples were chosen for this project. Ceramic samples, contexts and methods that have been used in this thesis will be outlined in the next chapter.

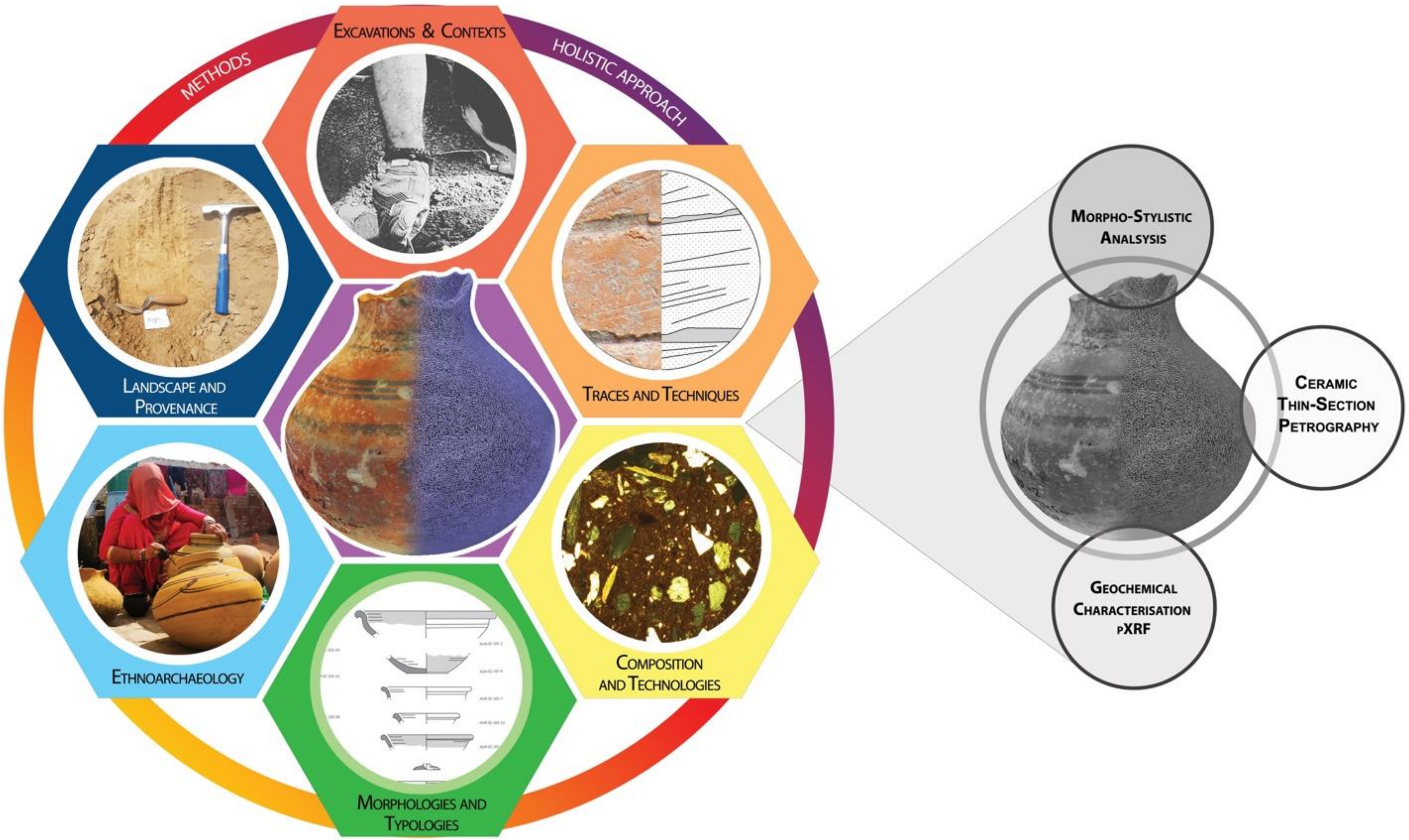
Chapter 4. Methods and materials: a holistic approach

4.1 Introduction

The research in this thesis combines a number of analytical methods. These techniques include morpho-stylistic, also referred to as 'traditional' or macroscopic, observations, quantitative and semiquantitative archaeometric analyses, and ethnoarchaeological approaches (see Figure 4.1). The archaeometric techniques include thin-section ceramic petrography, p-XRF and WD-XRF geochemical analysis, Fourier Transform Infrared spectroscopy (FTIR), and X-ray powder diffraction (XRPD) mineralogical analysis. These methods are combined in a holistic approach, which aims to observe both compositional and technological aspects of Indus ceramics, and permits the identification of the sequences of actions (*chaîne opératoires*) that reflect technological choices and traditions (after Roux 2016; see Chapter 2).

These archaeometric methods are amongst those most used for the identification of specific physical characteristics of ceramic materials. Importantly, these techniques fulfil their potential when used in a coordinated and holistic way to answer archaeological questions that go beyond the description of artefact structures, compositions and manufacturing techniques, and make is possible to understand the organisation of craft production (Tite 1999:201; Shimada 2007; Shimada and Wagner, 2007; Duistermaat 2016). For instance, an integrated or *holistic approach* advocates the use of combined methods, borrowing from various disciplines. The four major components of this approach are (Duistermaat 2016:10): (a) the use of materials from multiple sites to produce regional studies, which include clarifications on ancient landscapes; (b) identification of production sites or provenance of materials; (c) an interdisciplinary cooperation between experts, e.g. archaeologists and geologists; and (d) the integration of combined archaeometric techniques, along with experimental archaeology and archaeological ethnography (e.g. Day et al. 2006, 2010). Data obtained through this combined approach can be used to understand the behaviour and 'social processes' of communities who produced and used the ceramic materials (Dobres and Hoffman 1994: 213).

Figure 4.1. A Holistic approach to ceramic analysis. Diagram showing the combination of techniques adopted in this thesis for the study of Indus ceramics.



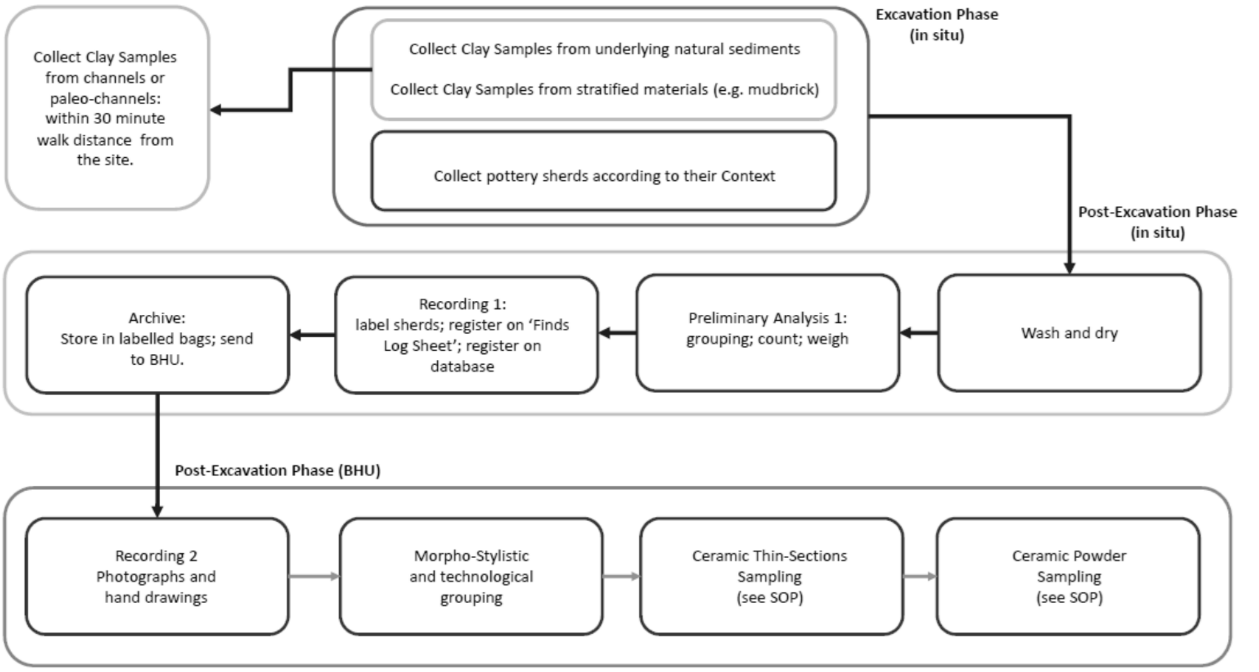
4.2 Techno-morpho-stylistic analysis

The preliminary assessment of fabrics, manufacturing techniques, decoration and firing techniques has alredy been briefly mentioned in the above Section 3.2. Methods for interpreting macro-traces proposed by Roux and Courty (1998) and the guidelines suggested by Orton (2013), Rice (2015), the PCRG and CIfA (PCRG 2010; CIfA 2014; PCRG, SGRP and MPRG 2016) have been adopted throughout. Complete assemblages from the selected sites and trenches were recorded, in order to consider issues related to abundance and taphonomic processes. Vessels are generally found in a very fragmentary condition at Indus rural settlements, and considering the paucity of complete vessels, the methods proposed by Dales and Kenoyer (1986), Jenkins (1994) and Uesugi (2011) for the study of South Asian ceramics, could not be adopted. For the same reason, it was not possible to adopt the full approach proposed by Roux (2010) for reconstructing each stage of forming sequences. During and after the excavation phase, there were two distinctive stages in the collection, study and documentation of ceramics (see Figure 4.2), which are summarised below.

4.2.1 Preliminary techno-morpho-stylistic assessment

The first stage of ceramic collection and analysis during fieldwork was carried out in accordance with previously designed methods and strategies established by project directors Dr Cameron Petrie and Prof. Ravindra Nath Singh (see Appendix F, SOPs). The aim of the fieldwork collection and preliminary processing was to produce a comprehensive, secure, and consistent documentation of the pottery assemblages so that they can be easily accessed and analysed by specialists involved in the project and others that may conduct subsequent research (see PCRG, SGRP and MPRG 2016). This process involved recording ceramic sherds according to their individual archaeological contexts, which included the selection of samples for residue analyses, washing and drying the remaining material, a preliminary assessment and grouping according to techno-morpho-stylistic features, counting and weighing of the material in those groups and recording them in an 'ODK Database' designed and installed on a Samsung tablet (see Figure 4.3), and then storing it in labelled bags and boxes (see Appendix F, SOPs). A total of 27,502 (359.82 kg) sherds from Lohari Ragho I and 34,002 (652.88 kg) sherds from Masudpur I were documented. The excavation archive is currently kept at BHU, Varanasi.

Figure 4.2 Ceramic analysis critical pathway. Three main stages of fieldwork in Haryana and Uttar Pradesh, India are here identified. See Appendix F for the comprehensive standard operating procedures (SOPs).



4.2.2 Detailed techno-morpho-stylistic assessment

The second stage of analysis took place at the materials laboratory of the AIHC and Archaeology Department at Banaras Hindu University. Ceramic sherds from selected contexts were sorted and described keeping in mind the approach for determining *chaîne opératoires*, where the identification of *technical groups* is the first necessary step (see Chapter 2). Besides the typological classification, this stage focus on the technological study and description of ceramics, including the fabrics, and macro-traces, which provide evidence for manufacturing techniques, surface treatments and firing conditions (see below Table 4.1).

Of the material from all excavated contexts and whole assemblages, a limited number of sherds were selected for detailed macroscopic analyses (see below Table 4.2). Fabrics were first classified in terms of their grain size, but observations about their macroscopic composition (e.g. inclusions, voids, and colours) was also reported. Technological observations were also documented, including the presence of evidence for (a) wheel-throwing, (b) wheel-fashioning or wheel-finishing, (c) coiling and wheel-coiling, (d) sequential building and moulding, (e) paddle-and-anvil use, (f) trimming and scraping, (g) cord wrapping, (h) functional and decorative surface treatments, (i) use of pigments, and (j) pyrotechnologies. When sherds showed similar fabrics, manufacturing techniques, surface treatments and firing condition macroscopically, they have been ascribed to a *technical group*.

Each ceramic fragment processed in detail was labelled with their site code, trench and context number, and a unique sherd number (e.g. *MSD/XK2-612-9*), and recorded as an entry in a database. Photos were taken of the interior and exterior of sherds on a uniform background, and diagnostic and painted sherds were drawn on tracing paper, so that they could be scanned and digitised using Adobe Illustrator CC 2018. Specific sherds were then selected of the basis of chronology, context, *technical-group* and shape representativeness for producing ceramic thin-sections and powder samples. In doing so, where possible, a minimum of 10 samples per techno-group (per occupational phase, per site) were selected, to make sure that data and observations concerning these techno/groups could be statistically significant.

Table 4.1 Main entries of ceramic database per site.

Site	Site code
Trench	Trench code
Context	Context number
Relative Chronology	Provisional, tentative chronology (e.g. Pre-Urban; Early Urban; Late Urban; Post-Urban)
Absolute Chronology	radiocarbon dates (when available)
Sherd N.	Sherd number
Fabric	Fabric type
RKE	Evidence for rotative tools or motions
Slip	Applied Slip
Techno-Group	Code of Technical group
Thickness	Thickness in millimetres
Dimensions (X-Y-Z)	Width, height and length in millimetres
Painted	Painted motives
Diagnostic	Type of diagnostic sherd (e.g. rim; base; handle)
Rim Type	Type of rim (e.g. out-flaring; everted; upright)
Base Type	Type of base (e.g. flat; concave; ring)
Diameter Rim/Base	Diameter of rim or base
% Rim/Base	Percentage of available rim or base
Comments	Other comments
Shape	Description of Shape
Photo	Photo available
Drawing	Plate and drawing number
Thin-Section	Samples for thin-section petrography
Powder samples	c. 5 grams sample for geochemical and mineralogical analysis

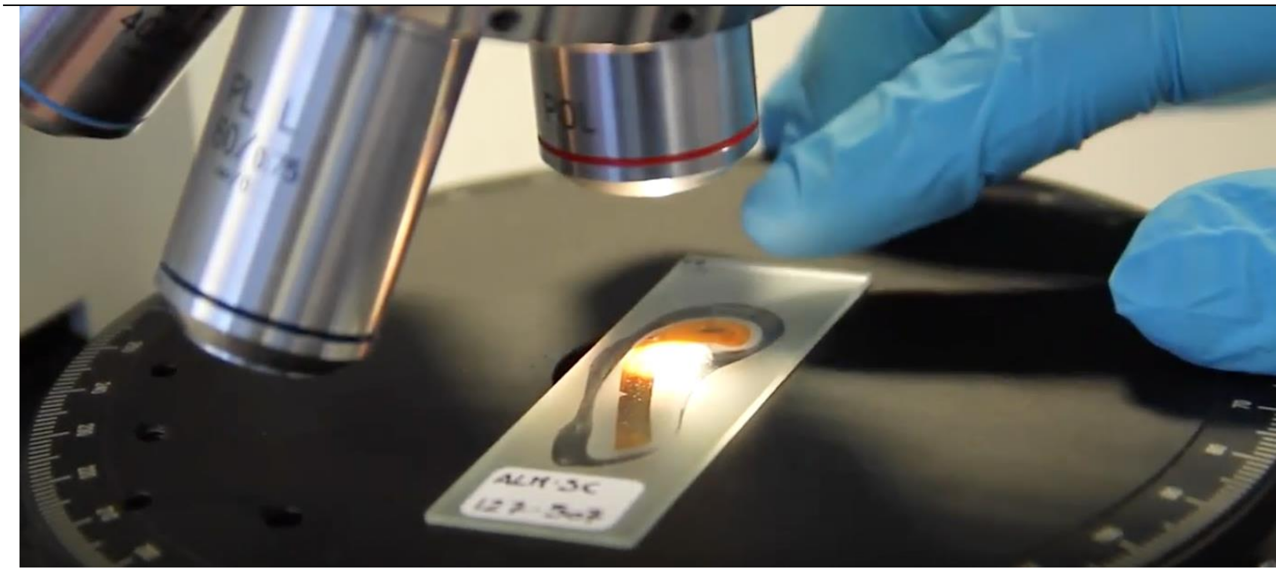
Figure 4.3 Structure and levels of the specifically designed ODK database for *in situ* recording of cultural material.

type	name	label
today	today	Form Date
start	start	Form Start Time
end	end	Form End Time
begin group	site_information	Site Information
text	site_id	site_id.
integer	context_id	Enter the context_id.
select_multiple artefact_categories	artefact_categories	What kinds of artefacts were found in the context?
select_one yes_no	registered_artefacts	Are there any artefacts to register from this context?
select_multiple recorder	recorder	Select recorder.
end group	context_information	

begin repeat	ceramics_group	Ceramics Group
begin group	ceramics_information	Ceramics Information
text	site_id_ref	site_id
integer	context_id_ref	context_id
select_one techno_group	techno_group	Technical Group:
select_one paste_type	paste_type	Paste type
select_multiple tempers	tempers	Apparent tempers:
select_multiple surface_treatment	surface_treatment	Select surface treatment.
select_one sherd_thickness	sherd_thickness	Select the sherds' thickness:
select_one sherd_shape	sherd_shape	Sherd Shape
select_one period	period	Do the sherds in this group belong to a recognisable period
select_one high_med_low	high_med_low	How certain is the techno-group characterisation?
integer	sherd_count	Enter sherd count.
integer	sherd_weight	Enter sherd weight (g).
text	ceramics_notes	Record any additional notes.
image	ceramics_group_photo	Take a preliminary photo of the ceramics group.
end group	ceramics_information	Ceramic Group Information
end repeat	ceramics_information	
begin repeat	stone_group	Process a stone group.
begin group	stone_information	Stone Information
text	site_id_ref2	site_id
integer	context_id_ref4	context_id
select_one stone_artefact_type	stone_artefact_type	What is the stone artefact type?
select_one stone_material_type	stone_material_type	What is the stone material type?
integer	stone_count	How many stone artefacts are in this group?
integer	stone_weight	Enter the weight of this group (g).
text	stone_notes	Enter any additional notes.
image	stone_group_photo	Take a preliminary photo of the stone group.
end group	stone_information	Stone Group Information
end repeat	stone_group	

list_name	name	label
artefact_categories	ceramics	Ceramics
artefact_categories	stone	Stone
techno_group	cbm	CBM
techno_group	tc_cake	TC Cake
techno_group	bits	Ceramic bits
techno_group	misfired	Misfired
techno_group	red_slip	Fine wheel-finished Red Slipped
techno_group	chai	Fine wheel-finished Chai Slipped
techno_group	deep	Fine wheel-finished Deep Red Slipped
techno_group	choco	Fine wheel-finished Chocolate Slipped
techno_group	carse_rust	Coarse Rustication
techno_group	rust	Kankar Rustication
techno_group	rough	Light Rustication or Roughened
techno_group	ext_waves	Fine wheel-finished Exterior Waves
techno_group	int_waves	Fine wheel-finished Interior Waves (Kali D)
techno_group	comed_b	Fine wheel-finished Exterior Combed Brown
techno_group	comed_r	Fine wheel-finished Exterior Combed Red
techno_group	non_slipped	Fine wheel-finished non-slipped Red
techno_group	choco_2	Fine non-wheel-finished Chocolate
techno_group	non_slipped_2	Fine non-wheel-finished non-slipped Red
techno_group	red_slip_2	Fine non-wheel-finished slipped Red
techno_group	fbb	Fine Black Burnished
techno_group	bicho	Fine Bichrome or Polichrome
techno_group	organic_paste	Coarse Organic Paste
techno_group	grafiti	Grafiti - Indus Script
techno_group	mudbrick	Unfired mudbrick
paste_type	fine	Fine
paste_type	coarse	Coarse
paste_type	other	Other
tempers	quartz	Quartz
tempers	organic	Organic
tempers	grog	Grog
tempers	iron_nodules	Iron nodules
tempers	kankar	Kankar
tempers	other	Other
tempers	indeterminate	Indeterminate
yes_no	yes	Yes
yes_no	no	No
high_med_low	high	High
high_med_low	medium	Medium
high_med_low	low	Low
surface_treatment	red_slip	Red Slip
surface_treatment	pink_slip	Pink Slip
surface_treatment	grey_slip	Grey Slip
surface_treatment	black_slip	Black Slip
surface_treatment	chai_slip	Chai Slip
surface_treatment	reserved_slip	Reserve Slip
surface_treatment	chocolate_slip	Chocolate Slipped
surface_treatment	black_paint	Black Painted
surface_treatment	polychrome	Polychrome
surface_treatment	bichrome	Bichrome
surface_treatment	outer_incision	Outer Incision
surface_treatment	inner_incision	Inner Incision
surface_treatment	wavy_incision	Wavy Incision
surface_treatment	inner_d	Inner 'fabric D'
surface_treatment	arrow	Arrows
surface_treatment	impressed	Impressed
surface_treatment	perforated	Perforated
surface_treatment	rustication_light	Roughened or light rustication
surface_treatment	rustication_medium	Rustication Kankar
surface_treatment	rustication_coarse	Rustication Coarse
surface_treatment	appliqué	Appliqué
surface_treatment	silica_inclusions	Silica quartz Inclusions
surface_treatment	other	Other

Figure 4.4 Example of a ceramic thin-section from the archaeological site at ALM trench SC (127-507) produced for this study.



4.3 Thin-section ceramic petrography

Ceramic petrography involves the description, classification and interpretation of fabrics, applying principles of thin-section petrography of rocks, aspects of geology and the sub-discipline of sedimentology for the description of rocks and soil micromorphology. Technically this method is a compositional analysis approach, and aims to study the materials that ceramics are made from (Quinn 2013: 39), and microstructural features of ceramics (Whitbread 1989; 1995; Peterson and Betancourt 2009). Besides giving information about mineral composition and clay pastes used in the production of ceramics, petrographic studies enable the identification of manufacturing processes often not visible at a macroscopic level. This method allow the investigation of ceramic recipes, including raw material processing and paste preparation, but also ceramic forming techniques and firing technology (Freestone 1995). Ceramic petrography and interpretation of mineralogical composition were some of the main drivers in provenance studies of artefacts and investigation of the movement of materials (e.g. Lombard 1987; Goren 1995; Ixer and Vince 2009; Quinn 2009; Quinn et al. 2010, 2017). Petrographic data and interpretations have also been used to tackles questions related to transmission knowledge (e.g. Whitbread 2001).

The production of ceramic thin-sections mostly followed the guidelines provided by Quinn (2013: 23-29; 2018), which is a modification of standard geological techniques (see Humphries 1992). This process is described in detail in Appendix F (SOP). After considering the identified technical groups and diagnostic sherds, samples were selected to produce ceramic thin-sections no thicker than 30 microns (μm), which were then observed under an optical microscope (see above Figure 4.4). The substantive difference to Quinn's and Humphries' guidelines was the necessity of producing thin-sections in Varanasi. Therefore, the first phase had to be altered, and inspired by the approaches of Chandler (2001) and Goren (2014), a portable laboratory was developed. The portable kit made it possible to produce ceramic thin-sections of 1 millimetre (mm) thickness (see Ceccarelli 2017). The stage of grinding them to c.100-500 μm took thickness place at the Department of Earth Sciences, University of Cambridge, where a *Buehler PetroThin Machine* was used. The final polishing stage allowed to reach the c.30 μm thickness and was undertaken in the Geoarchaeology Laboratory of the Department of Archaeology, Cambridge. This method was employed to produce a total of 354 ceramic thin sections, of which 318 were used in this study due to their quality or chronological relevance of the samples. Protocols for the production of thin-sections and an overview of the portable laboratory are presented in Appendix F.

The thin-sections produced using this method were studied under a Leitz/Leica 12 Pols polarizing microscope and grouping was carried out by switching between thin-sections at low magnification (x25 and x40) in plane polarised light (PPL) and cross polar (XP) (Quinn 2013:73). The descriptions of petrographic groups and characterisation (see Appendix B) mainly deal with observations concerning ceramic fabrics. Each fabric is composed by three main components, i.e. (1) inclusions, or particles larger than 10 μm, and (2) voids within a (3) clay matrix, or particles smaller than 10 μm. Given the textural and miscrostructural peculiarities of ceramic thin sections, they are classified and characterized using a visual and descriptive approach (Quinn 2013: 73). A modified version of the descriptive system (Whitbread 1989; 1995) developed by Quinn (2013: 80) was adopted.

Taking consideration of the combination of inclusions, voids and matrix, thin-sections were divided into different *petrographic fabric classes* or groups. The full description of each petrographic group, nature and frequency of inclusions and voids, texture and matrix according to the revised Whitbread (1989) protocol is also available in the mentioned Appendix F. Inclusions are described according to standard sedimentology procedures including sorting, distribution, abundance, size, roundness and orientation of grain shape (Bullock et al. 1985; Brewer 1976). The identification of non-opaque minerals in ceramic thin-sections follows the same principles from optical mineralogy (Adams and MacKenzie 1994;

Adams et al. 2017; Phillips and Griffen 1981; Gribble and Hall 1992). Voids are described on the basis of their size (modal diameter of largest void), concentration percentage, and shape, e.g. channel, planar, vesicles or vughs (e.g. Brewer and Sleeman 1988: Table 5; Stoops 2003: 64). The clay matrix is described according to its degree of homogeneity, optical activity, and arrangement of clay minerals. A detailed description of each thin-section, including clay matrix, pores and inclusions of each samples is provided in Appendices A and B. The relationship between *technical groups* and *petrographic classes* in the assemblages from each site is described in Chapters 6, 7, and 8.

4.4 Geochemical characterisation

Geochemistry is an independent means of characterisation and classification, though the results could, and should, be integrated with other analytical techniques where possible. In this thesis, petrographic results have been combined with the data from chemical analyses to carry out a comprehensive compositional characterisation of the ceramics. Instrumental geochemical analysis of archaeological ceramics are used to identify the existence of compositional groups. This allow to examine the influence of elements on the classification of compositional groups and relate it to other archaeological information to address questions concerning raw material provenance and processing of the ceramics (Pollard et al. 2007; Quinn 2013: 111). This method can be used for the characterisation of the bulk elemental composition of the ceramics and the detection of chemical patterning that could reflect the existence of ceramics made within different raw materials and paste preparation methods or recipes. A number of factor can influence chemical compositional data of archaeological ceramics, e.g. variation and alteration in the production process of raw materials used, natural variability in clay sources and batches of clay, but also potential post-depositional alterations (Hein and Kilikoglou 2017).

Mindful of restrictions concerning movement of cultural artefacts and the availability of funding, chemical analyses were carried out using specific methods and on a limited selection of samples. The number of samples were, however, abundantly sufficient to reinforce petrographic data. The benefits of the integrated and complementary use of geochemical and mineralogical data has been plentifully demonstrated (e.g. Day et al. 1999), and appears to be ideal for defining compositional variability in pottery assemblages (e.g. Day et al. 1999, 2011; Stoltman et al. 2005). The integration of geochemical and petrographic data allows us: (a) to understand whether different compositional groups correspond to geological samples, technological groups, or both; and (b) to clarify and confirm petrographic results. Thus, even though geochemical data are more suited for determining composition rather than manufacturing techniques, it is a useful integrative method for classifying ceramic fabric groups based on pastes (Arnold et al. 1991; Neff 1993; Bexter et al. 2008). More broadly, this approach is largely used for exploring questions related to clay sources, pottery provenance, regional traditions and the movement of artefacts.

There is a large variety of chemical analysis techniques that can be employed for the study of archaeological ceramics. Some of the most commonly used methods for geochemical characterisation include instrumental neutron activation analysis (INAA), scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS), inductively coupled plasma mass spectrometry (ICP-MS), and X-ray fluorescence spectrometry (XRF), as they are often considered the best analytical techniques for quantitative measurement of major and trace elements (Peacock 1970; Tite and Maniatis 1975; Wilson 1978; Maniatis and Tite 1981; Schackley 2011; Bishop and Blackman 2002). Among the various geochemical techniques suitable for prehistoric ceramics, Portable X-Ray Fluorescence (pXRF) (see below Figures 4.5 and 4.6) spectroscopy have been chosen for this study. The reasons that motivated this choice, an overview of the employed methods, and selected samples shall be presented below.

Table 4.2 List of samples. A limited number of contexts and sherds were selected for detailed analysis, representative of whole assemblages.

	Sherds (total)	Petrography	pXRF	Relative Chronology
Sample numbers per sites and periods	Site: LHR – EA			
	1,095	42	40	Indus Pre-Urban
		58	59	Indus Early Urban
	Site: MDS – XK2			
	846	100	97	Late Urban / Post-Urban
	Site: ALM – SC			
	2,250	55	38	Indus Late Urban
		63	54	Indus Post-Urban
	Geological samples (clay rich deposits, see below Figure 4.6)			
	n/a	n/a	59	

4.4.1 pXRF, Portable X-Ray Fluorescence Spectroscopy

In order to identify compositional groups, pXRF was used on ceramic powder samples. X-ray fluorescence spectroscopy allows the identification and quantification of a broad range of elements through bulk geochemical composition (Artioli and Angelini 2010; Artioli and Quartieri 2016). Portable or handheld instruments hold significant potential for the rapid analysis of large numbers of ceramic samples (Speakman et al. 2011; Hunt and Speakman 2015; Holmqvist 2016; Wilke 2017). There are concerns about the quality of data from portable devices (Speakman and Shackley 2013), the effect of the heterogeneity on the characterisation of the bulk chemical composition, and their ability to cope with the heterogeneity of coarse ware sherds (Tykot et al. 2013). Nevertheless, its use for relative analysis, viz. determining relative compositional groups, has been tested and provided consistent reliable results (e.g. Ceccarelli et al. 2016).

Figure 4.5 Left: pXRF Olumpus Innox-X Delta Premium analyser used for procesing powder samples and three XRF sample cups or cuvettes of loose powder. Right: dried samples of clay rich deposits from MSD-I trench XK2.

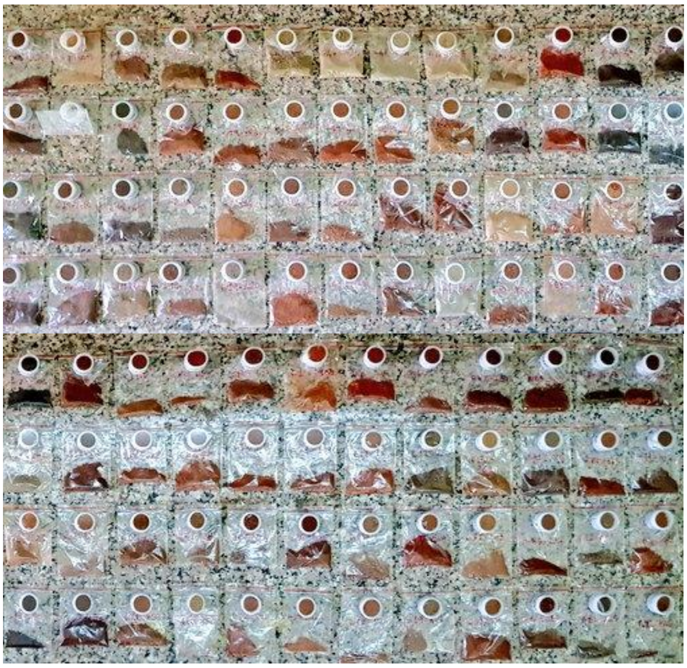
The surfaces of the sherds were abraded with silicon carbide paper to remove any possible surface contamination, or with a rotating tungsten carbide drill in cases where decorative slip layers were present. Sherds were subsequently crashed and ground to fine powder (< 1 ml grain size), and the resulting powders were placed in sample cups or cuvette

(Chemplex Industries, Inc. XRF sample cups 30.7x22,9 mm) with a 4 µm prolene film (Chemplex Industries Inc. Polyprophylene thin-film). The choice of preparing powder samples cups in India and bring them to the laboratory in the UK instead of running pXRF analysis directly on sherds was preferred in order to overcome three main issues: (a) sample cups are a solution to limited mobility or movement of ceramic vessels from India to the UK; (b) powder samples minimise issues of possible surface contamination of sherds; and (c) powder samples minimise issues of heterogeneity caused by large inclusions or areas of clay mixing.

All selected samples were analysed using an Olympus Innox-X Delta Premium hand-held device using a Rh source and a 2 mm Al filter (see Figures 4.5 and 4.6). Analysis was undertaken at 40 kV for 120 seconds live time. The Brukker ARTAX software was used to deconvolute the resulting spectra to correct for the individual Fe absorption/enhancement of each element in non-calcareous pottery, as well as specific spectral interferences, including Rb Kß/Y Kα, Y Kß/Nb Kα and Sr Kß/Zr Kα. A Rayleigh scatter distance correction was used to account for the possible uneven structure of powdered particles of ceramics. The resulting net counts were converted into concentrations via an in-house calibration developed at UCL Instutute of Archaeology (i.e. UCL Ceramics 1 pXRF calibration for ceramics with low calcium) using a series of homogeneous fired spiked clay samples with four concentrations of the elements Fe, Ga, Nb, Rb, Sr, Ti, Y and Zr (Wilke et al. 2017; Burton et al. 2019). These bespoke reference samples were developed specifically for pXRF calibration due to the absence of natural geochemical reference materials with just one interfering element of variable concentration and the effected elements having a fixed concentration (Wilke 2017). The spiked samples have a clay matrix that is representative for mass absorption of mid-Z elements in a broad range of clay and other aluminosilicates with a total matrix composition of elemental O, Al and Si greater than 90%. In addition to the nine spiked elements, the calibration also measured Ca, Co, Cu, K, Mn, Pb and Zn, providing data on a total of 15 elements.

The performance of the Olympus Innox-X Delta Premium and the in-house calibration UCL Ceramics 1 pXRF calibration for the 15 recorded elements (Ca, Co, Cu, Fe, Ga, K, Mn, Nb, Pb, Rb, Sr, Ti, Y, Zn, Zr) was determined by analysing 14 powdered certified reference materials (CRMs) of rock, ore, sediment, soil and ceramic (Appendix E, Table E1) and compared to that of the manufacturer's factory 'Soil Mode' calibration.

Figure 4.6 Ceramic powder samples from MDS I and cuvettes of loose powder for pXRF Olympus Innox-X Delta Premium hand-held device.



'Soil Mode' data are not used or discussed further in this thesis, and they were collected with the sole purpose of comparing the calibrations for assessing performance (see Appendix E: Note on accuracy and 'Soil Mode' calibration). The CRMs were placed in a sample cup or cuvette with a 4-micron prolene film, analysed five times and calibrated using the protocol described above.

The averages of the five measurements were compared to the certified values for the standards (Appendix E1) and accuracy was calculated as percentage relative difference using the formula (Appendices E2 and E3): *(measured - certified) / certified) x100.*

The average accuracy for the calibration was also calculated for each element, but using only the measurements for those standards that fall within the range of composition found in earthenware archaeological ceramics (Appendices E4 and E5). The latter was determined using the data in several published geochemical studies, e.g. Day et al. (2011) (Bronze Age Greece), Quinn et al. (2010) (Neolithic Greece) and Quinn and Burton (2016) (Pre-contact California). This process demonstrated that the calibration produced results with an accuracy of 20% relative error or below for 10 elements (Fe, Ga, K, Nb, Rb, Sr, Ti, Y, Zn and Zr). These 10 elements have been eventually used in this study. The results for some elements (e.g. Rb, Sr) is <10% relative error. Details concerning data and assessment of the performance of pXRF data in-house calibration can be found in Appendix C and E.

4.5 Statistical treatment of compositional data

Statistical techniques have been used to process data, including principal component analysis (PCA) and hierarchical cluster analysis (HCA) (see Shennan 1997; Baxter 2006). Brukker ARTAX software was used to deconvolute portable X-Ray fluorescence dataset of each site (see above Section 4.4.1), and a descriptive statistical approach was subsequently applied. In order to describe the central values of data distribution, the variance, the standard deviation, and the coefficient of variation were calculated (see Bland and Altman 1996). Subsequently, the variation matrix and total variation (vt) were calculated (see Aitchison 1986; 1990; Garrigós 1999) so as to identify elements that have the highest variance in the dataset. Following normalisation and log10 transformation, data was processed via multivariate analysis, i.e. principal component analysis (PCA) and hierarchical cluster analysis (HCA).

4.5.1 Log10 Transformation

A log-ratio transformation is often used to counterbalance the dominant presence of quartz/ Si in ceramic samples that may have an impact on other measured elements (see Amicone and Quinn 2015:9; Baxter and Freestone 2006:524). Baxter and Freestone (2006, 512) has extensively discussed the importance and uses of logarithmic transformation. Log-transformed variables tend to become more symmetrical and are converted to a similar order of magnitude. Subsequently, multivariate analysis undertaken to observe potential patterning and geochemical similarity or difference of the analysed samples.

4.5.2 Principal Component Analysis (PCA)

PCA was run on raw data and on log10 transformed (log10) data so as to to investigate multivariate data sets (see Baxter 2003; Shennan 1997). SPSS, a computer-based software package used for interactive, or batched, statistical analysis., was used to carry out the PCA on geochemical data from LHR-I, MSD-I, ALM-SC and soil samples. The first two principal components (PC1 and PC2) were plotted against each other in a two-dimension field to identify possible patterning, outliers and compositional groups. SPSS was also used to produce visual representation of data through graphs, which are available in this thesis. 2D c. 90-95% confidence ellipses was drawn where possible to highlight groups (Monette 1990) - where not possible, hellipses have been hand-drown to highlight the possible groups.

4.5.3 Hierarchical cluster analysis (HCA) and dendrograms

Finally, hierarchical cluster analysis (HCA) was undertaken and the results were plotted as dendrograms. HCA creates groups by linking variables with similarity in the form of a dendrogram, and it is used to show internal cohesion as well as external isolation of the groups. PCA was used as a preliminary processing step for clustering variables in order to 'de-noise' the data (see Calparsoro et al. 2019). SPSS was used to process data using Ward linkage and squared Elucidean distance, and to produce same graphs. The results from both the PCA and HCA were observed so as to understand the significance of patterns, groups and outliers, also comparing them with archaeological, macroscopic and petrographic variables.

4.6 Firing temperatures and pyrotechnologies: mineralogical analysis

Studies of firing temperatures and pyrotechnologies have advanced in the past three decades, and nuanced methods that provide significant data for archaeological interpretations have been developed (see Gosselain 1992; Livingstone Smith 2001a; Tite 1995; 2008). The identification of firing structures, and the identification of maximum firing temperatures and firing conditions can be relevant to determining the technological choices made by ancient societies, as well as variability and diversity among and within ceramic traditions. This aspect of ceramic production will not be extensively investigated here.

4.7 Ethno-archaeological investigation

As part of the proposed holistic approach, besides the analysis of ceramic materials, this project include a ethno-archaeological work. As reviewed in Chapter 3, limited ethnoarchaeological studies have been undertaken in order to better understand the ceramic industries of the Indus Civilisation without sggesting direct continuity with modern communities. In Chapter 3 Section 3.4, three case studies were presented: the first two followed a direct history approach; and the third one aimed to understand certain specific traits of craft specialisation and transmission of skills, not directly linked to ancient behavioral patterns. The first two studies contributed to the forging of some widespread ideas regarding Indus ceramic production, especially concerning the use of the potter's wheel, the paddle-and-anvil technique, and the role of state control over ceramic craft production and distribution.

This thesis employs 'ethno-technological' observations to reconsider these old interpretations, and to move away from direct correspondences between ancient and modern behaviours (Delage 2017; Dyson 1967; Mourer 1986). A similar approach was used by Roux and Courty (1998), who gained a preliminary understanding of tools and forming techniques found at the Indus settlement at Kalibangān. This particular study is explored in Section 3.8.2. Moving away from the direct historic approach, Roux and Courty's ethnoarchaeological investigations inspired the ethno-technological work undertaken as part of the present study. Data and archaeological implications are presented in detail in Chapter 5 of this thesis.

The ethnoarchaeological study was conducted in Uttar Pradesh and Haryana where modern communities of potters live in close proximity to Indus archaeological sites. These regions host hundreds of families of potters belonging to the endogamous *Kumhar* caste (traditional caste of potters), which are also found in modern Rajasthan and other regions of the Subcontinent (Roux 1989a: 8, 71). The choice of working with traditional potters living near sites occupied in the past by ancient Indus communities was dictated by: (1) knowledge of the local spoken language and availability of interpreters, (2) previous ethnographic works undertaken in these regions which could be further developed, and (3) traditional manufacturing techniques as practised by the local potters.

4.7.1 Method of the ethno-technological study

The ethnographic study was conducted with five communities of potters living in Rakhigarhi, Lohari Ragho, Masudpur and Bahola in Haryana, and Alamgirpur in Uttar Pradesh. One or two families of potters still live in each of these villages, producing ceramic vessels on a full-, part-time, or seasonal basis throughout the year. Although the study makes occasional references to lifestyles and genealogies, it primarily focused on obtaining information about local clay sources and processing, but also tools and techniques employed by those *Kumhar* who keep alive the traditional craft. Thus, the term *ethno-technology* is here preferred.

4.7.2 Ethics and informed consent

In order guarantee a high ethical standard and to respect the integrity of interlocutors during the ethnographic study the following protocol was followed. *The* ERC *TwoRains* Ethics document was carried at all times and copies were supplied to the interview subjects in order to obtain their informed consent. The protocol also required the craftspeople to sign a 'Participant Consent Form' attached to the ethics document, by which they would authorize the use of the information they provided, as well as photos and video recordings. permission to take photographs and videos was requested to the interlocutors and their family members. It was explained that notes, photos and videos would be used solely for academic purposes. All forms are available in Appendix G.

4.7.3 Interaction strategies

Two types of interactions were mostly used during the ethnographic data collection: (1) informal dialogues, and (2) semi-structured interviews along with direct observations of ceramic production to gather focused, qualitative textual and visual data. The informal conversations served to facilitate introductions between the participants, the researchers and the interpreter. During this phase the Consent forms were signed, and questions about family stories and genealogies of family members were asked. The purposes of the academic research was outlined, as well as explaining the necessity of having an interpreter to better understand the information provided.

After this, semi-structured interviews explored aspects of clay sourcing, tools and manufacturing techniques, firing tools and techniques, seasonality of production, family histories, as well as questions related to the exogamous sub-castes (*gotra*) within the broader endogamous *Kuhmar* cast. Although a predetermined questionnaire was used to guide the conversation, it mostly followed the steps used by the potters who demonstrated the production of several vessels forms. Often the potters travelled with the researcher to the clay sources and showed clay processing techniques as well. Most of the interviews were digitally recorded, since the interlocutors consented to the use of a voice and video recorders. Questionnaires are available in Appendix G .

4.8 Geological prospection and clay sources

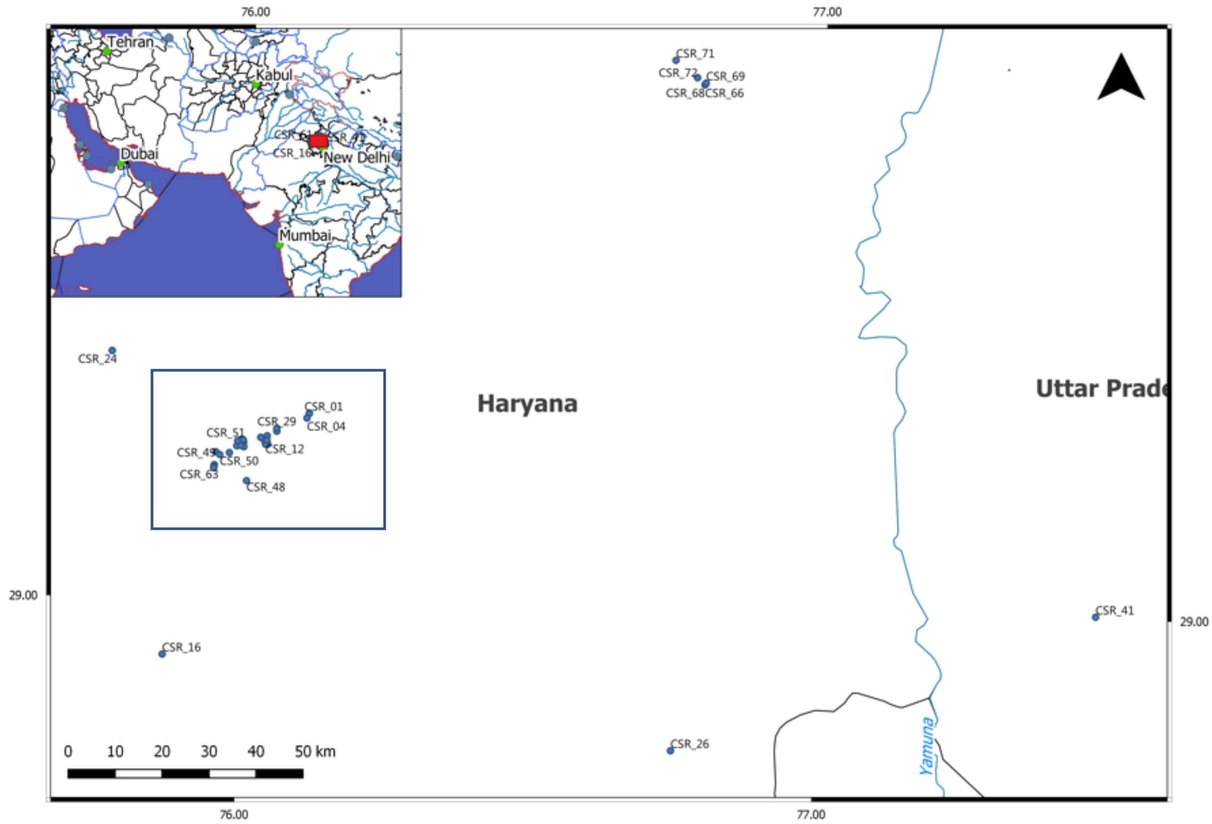
Knowledge of local and regional geology is necessary to obtain information about the occurrence of clay sources, and also to provenance ceramics and thus work out possible imports that may not represent local production. In order to identify ancient clay deposits likely used in ceramic production, direct observations in the field, sample collections, and studies of clay properties and composition are necessary. Raw material sampling involves walking across the landscape searching for naturally occurring raw materials, such as clay or temper, suitable for ancient ceramic producers. This study was carried out in close proximity to the archaeological sites (see below Figure 4.7). Equipment included topographic maps, a compass, a GPS, a geological hammer or a trowel, sample bags, marking pen, camera, notebook and pencil. Most of the procedure presented below follows the guidelines provided by Quinn (2013: 117-146; also see Kiriatzi 2003; Masucci and Macfarlane 1997; Spataro 2011).

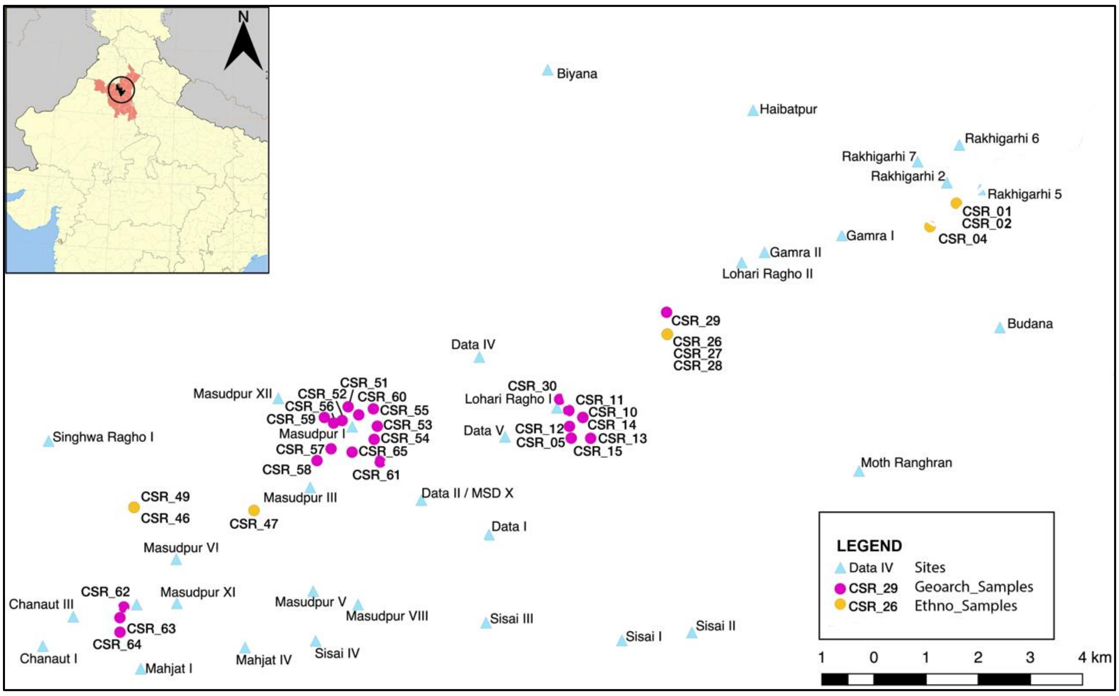
4.8.1 Selecting samples

When it comes to selecting samples, it is important to bear in mind that recent geomorphological processes and land-use changes may mean that different raw material sources were available to ancient potters. Therefore, five types of samples were collected: unfired mud-bricks chronologically/ stratigraphically associated to the ceramic assemblage (contexts; finds); clay sources available in close proximity to the archaeological site; samples from rivers or channels located in close proximity to the site; fired mud-bricks, likely produced locally (finds); and kiln lining.

The identification of clay-rich deposits for sampling was also carried out with the help of geoarchaeology and remote sensing experts, as well as modern communities of potters living in the studied regions. The work of Hector Orengo was crucial for identifying palaeo-channels and reconstructing ancient landscapes around archaeological sites (Orengo and Petrie 2017; 2018). Building on this work in Haryana and Uttar Pradesh, buried palaeo-soils were sampled by geoarchaeologist Walker (et al. 2018) mostly using a tubular soil sampler or hand core auger. These geoarchaeological samples represent the majority of the studied clay samples. A second group of samples was collected in collaboration with the Kumhar cast of potters in Haryana and Uttar Pradesh. The ethno-technological investigation helped to gain a better understanding of available clay sources as well as properties of local raw materials (see Sections 5.3 and 5.4). A detailed description of soil samples, along with their textural features, water absorption properties, LOI, and point coordinates is available in Appendix A, table A4.

Figure 4.7 Top map shows the location of 72 geological samples collected in Haryana and Uttar Pradesh, in close proximity to archaeological sites. Bottom map shows a zoomed view of clay samples collected in proximity to LHR I (csr_14) and to MSD I (csr_54). See Appendix A, table A4 for description of CSR samples. More details in Chapter 5, Section 5.3.





4.8.2 Procedure

Deposits of clay suitable for ceramic production were identified and sampled in the field after a preliminary assessment by eye or with a hand-lens. Clay suitability was assessed by pinching and rolling out a coil of the wet solid, which provided broad indications of plasticity. Considering possible clay processing techniques of ancient potters, a value of suitability was given to each sample. A scale from 1 to 4 was tentatively used to indicate whether soil samples were likely suitable for ceramic production without major modifications (value 4), or were far too sandy or silty and required scrupulous processing (value 1). Collected samples where then recorded on a spreadsheet will a short description and GPS coordinates of the sampling location. They were subsequently bagged and clearly labelled with a sample number (CSR_XY), date and location (see Appendix A).

Figure 4.8 Formed briquettes (above), and dried and fired briquettes (below). See Appendix A, table A4 for description of 73 CSR samples.

4.8.3 Clay samples processing

The subsequent phase took place in the laboratory (G2, West Building) at the University of Cambridge. Each suitable clay sample was ground and sieved through a 200 mm mesh. Each refined soil sample (i.e. CSR_01 to CSR_73) was then measured (volume and weight) and a small portion was collected to produce pXRF cuvettes of loose powder for geochemical analysis (see above Figures 4.4 and 4.6). Afterwards, samples were kept in distilled water for 48 hours, and the new expanded volume of the clay rich mass was measured in order to calculate water absorption properties. The exact measurements and quantities are available in Appendix A, table A4, with their associated description of CSR samples. A small quantity of clay necessary for producing briquettes was collected.

4.8.4 Production of briquettes and firing

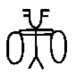
Processed clay samples were used to produce briquettes for further compositional and textural characterisation. Each briquette was formed using a standard mould, which allowed to better measure shape and volume transformation during the drying stage and after the firing process. It required two weeks to slowly dry 59 briquettes and control possible breakage during drying (see Figure 4.8). A final drying stage was required to remove the remaining moisture for the clay pastes, thus samples were kept in a dry and warm environment (c. 40° C) for 12 hours. The volume and weight of each briquette was recorded before and after drying and firing.

The firing stage took place in a controlled environment, using the facilities at the Department of Geography, University of Cambridge. Briquettes were placed in two electric kilns: temperature ramped from 100° to 750° C in sixty minutes, and held at 750°C for five hours. Kilns cooled down for eight hours and kept at 105°C when the samples were being extracted and measured to avoid moist to penetrate and alter LOI . All briquettes were then measured (volume and weight), which also allowed the calculation of the percentage of weight loss-on-ignition (LOI values). Eventually, these samples were not used to produce thin-sections, but to assess the properties of clay-rich deposits, including malleability, shrinkage and brakage before and after drying and firing. All measurements and descriptions of samples are available in Appendix A, table A4.

4.9 Summary

This chapter has presented the holistic approach and materials that have been used to collect data for this study. Macroscopic observations of ceramics have been combined with thin-section ceramic petrographic analyses and geochemical characterisations. Qualitative observations and compositional data have been processed through statistical analysis, more specifically by performing Log10 Transformations and Principal Component Analysis, and producing Hierarchical Clusters and Dendrograms. Data concerning archaeological ceramic material have also been integrated with ethno-archaeological observations, geological prospections of the study region and clay sourcing.

Part Two: Data and results



"Data! Data! Data!" he cried impatiently,

"I can't make bricks without clay."

(Sir Arthur Conan Doyle 1892, 322)

Chapter 5. Ethnoarchaeology, remote sensing and geoarchaeology

A multidisciplinary study of clay sourcing and ceramic technologies in northwest India.

5.1 Introduction

This chapter presents the use of a combination of methods to explore clay sources in northwest India, and to give an account of modern rural ceramic industries. The methods include geo-archaeological sampling, remote sensing satellite imagery, and ethnographic observations of the traditional Kumhar potter cast of South Asia. It will aim to illustrate clay variability in the region and to present ethnographic data concerning manufacturing techniques and clay sourcing. Using mineralogy and chemical composition analysis, it is possible to detect clay source variability and to identify broad geographic origins of raw materials (see Chapter 4). Having traced the provenance of raw materials used in the production of ceramic vessels, archaeologists can suggest the location of production centres, variability in ceramic recipes, manufacturing techniques and traditions, and social contacts and interactions. Samples of clay-rich deposits identified and collected through this multidisciplinary approach will be used to better characterise the composition of the archaeological assemblage discussed in the following chapters, and to identify potential clay sources in the region.

Moreover, ethnographic observations will be used in the last chapters of the thesis to move away from widely accepted and simplistic direct links between modern ceramic industries and Indus Civilisation pottery manufacturing techniques, tools and technologies in the studied region (see above Section 3.4). As discussed in Chapter 3, the community of traditional potters of Pakistan and northwest India has been profusely mentioned in the study of Indus ceramic industries since the early stages of Indus archaeology (see Ernest Mackay 1930: 135; Vats 1940: 275; Kenoyer 1998: 6; Allchin B. 1994; Krishnan and Rao 1994). Analogies, parallel histories, and direct historical continuity between ancient and modern communities of craftspeople have been widely suggested and employed to fill the gap in the knowledge concerning tools and technologies of Indus ceramic production.

The ethnographic study here presented was conducted with five families of potters living in the modern villages of Rakhigarhi, Lohari Ragho, Masudpur and Bahola in

Haryana, and Alamgirpur in Uttar Pradesh (see Figure 5.1). Families of traditional potters still live in these villages, producing ceramic vessels on a full-, part-time, or seasonal basis throughout the year. Although the study makes occasional references to lifestyles and genealogies, it primarily focused on obtaining information about clay sources and processing, tools and techniques employed by those *Kumhar* who sustain and keep alive the traditional craft. Thus, the term ethno-technology is here preferred. Even though this study focuses solely on the clay sources and ethno-technology, there would be a plethora of aspects to explore thanks to the help of the Kumhars . For instance, this study does not want to directly address particularly interesting social aspects, such as mechanisms responsible for the transmission of knowledge within the endogamous cast through generations; the network of crafters sustained by exogamous families and marriages within India; social units, gender identities and the role of women and men in the production of vessels. It does want, however, to indirectly emphasise the importance of encouraging local and global awareness of South Asian intangible cultural heritage and its possible contributions to research. It is also noteworthy mentioning the need of local collaborators and interpreters for a successful interaction with communities speaking local dialects. In particularly, essential was the help of collaborators from BHU, Banaras Hindu University, Department of Ancient Indian History and Culture and Archaeology (AIHC), Varanasi, India.

5.2 The Kumhar potter cast: ethno-technology and ceramic production.

The potters who agreed to participate to this study belong to the endogamous cast of the *Kumhars, Kumbhars* or *Prajapati* (Dumond 1953; Dumont 1972). A number of studies are available that have provided us with an account of the ceramic technologies of such communities (e.g. Marshall, 1931; Starr Richard, 1941; Rawson, 1953; Sinha et al. 1961; Saraswati, 1964; Saraswati, 1979; Jane, 2000; Duary, 2008; Saraswati and Behura, 2010; Sikdar and Chaudhuri 2015). Ceramics produced by the Kumhars are a unique traditional craft of South Asia. Their handmade vessels produced in northwest India (e.g. Rajasthan, Uttar Pradesh, and Haryana) reflect knowledge and artisanship transmitted for centuries through generations. The following descriptions have sprung from previous studies in the region, as well as interviews and observations gathered during the ethno-technological work undertaken with these families of potters. The method and ethics concerning this study have already been discussed in Chapter 4, and forms are available in Appendix G.

Besides the relevance of the ethnographic work for this thesis, a better understanding of the intangible cultural heritage of the Kumhars is needed, due to the gradual decline of this tradition. The slow but consistent shrinkage of these rural practices is often connected to the diminishing demand of ceramic products, as well as the rampant development of modern systems of production in India. Modern industries, as well as new products and markets, appear to be endangering the existence and sustainability of this tradition.

The craft practice is particularly important for the Kumhars communities, since it holds identity shaping agencies. It is transmitted through families, which gives the community a sense of belonging and identity, while maintaining a social function in everyday life. Moreover, traditional vessels and objects crafted by the Kumhars play a key role in cooking traditions and rituals of local communities. New generations of Kumhars keep alive long-lasting traditional crafts of specific types of vessels. For instance, most Kumhars still produce ceramics used during Hindu festivals and rituals, e.g. small lamps used during *Diwali*, the festival of lights, and weddings; typical ceramic water jars (*matka*), milk jars, cooking pots for processing milk and yogurt, and teacups.

5.2.1 Clay procurement and preparation

Family members, men and women of the Kumhars are equally involved in the production processes of traditional pottery. Family members are usually all involved in the collection of raw materials, which is stored, cleansed and tempered at the household. Kumhar families reported that usually clay sources tend to be the same and used for generations, or at least until their memories could recollect (e.g. three generations at least). The sources are usually within 30 minute walk from the workshop, and family members tend to reach these locations via motorbikes or small size trucks (see Section 5.3 below). Raw clay from one or multiple sources is transported to the household, where it is stored in the courtyard or in the streets adjacent the workshop. The processing phase begins with the use of meshes (or *challni*) and water tanks to clean the dry clay (see Figure 5.2:A and 5.2:B). Wooden sticks (or *dhokena*) are also employed to crash dried clay lumps into powder or smaller lumps. Depending on the family's traditions and availability of clay sources, one or more types of clay can be mixed together. Types of clay are usually identified and categorised according to their apparent colour when in wet conditions (e.g. a grey clay generally called *mitti*, being the most commonly used; a dark grey or blackish grey clay called *kali mitti*; a yellow iron-rich clay called *pili mitti;* or a light-grey to whitish grey clay called *saphed mitti*). Both women and men are involved in this refining process, which can last for one or two days. Potters first put the unprocessed clay in a large water tank for 24-48 hours and remove most of organic material, *kankar* and other calcareous nodules from the raw clay (see Figure 5.2:C). Once the purified clay paste is obtained, this is usually stored in the courtyard. Subsequently, the potter moistures it with water for a few hour, or mixes it with dry clay to reach the desired texture. This wet processed clay is subsequently worked for few minutes by hand, feet and beaten before moving to the forming stage (see Figure 5.2:D).

5.2.2 Forming tools and techniques

Each household hosts a nuclear or joint family which owns one or two traditional stone potter wheels, rarely an electric wheel, and a firing pit located in the courtyard or adjected to the workshop. In terms of manufacturing tools, it is possible to identify a large potter wheel, a long wooden stick, paddle and anvil, a bowl full of sand, a bowl full of clay slurry, concave basin which function as moulds, and strings. Some families are now adopting electric potter wheels (or *chaak*), but they reported that they are still using the stone potter wheel, and emphasised that their ancestors used the same wheel found at the workshop. The rotational motion of large stone wheels is given via a wooden stick (or *laathi*), which is places in a hole on the upper surface of the wheel (see Figure 5.2:E).

Two main stages appear to be necessary for forming most vessel types (medium and large size jars). First, the roughout of a vessel is shaped on the wheel, and it is subsequently shaped and thinned using peddle and anvil (see Figure 5.3:H). A slurry or small lump of clay is first put in the centre of the wheel, and a large lump of clay is placed on this (see Figure 5.2:F). Usually, but not necessarily, two people are required to produce vessels and activate the wheel: one assistant (in standing or crouched position) rotates the wheel periodically spinning it with a wooden stick and cuts the formed vessels from the lump of clay using a string (or *soot*); while the potter - in crouched or sitting position - keeps shaping the vessels. A number of small vessels can be produced out of a big lump of clay, and the string is used to cut finished vessels from the lump.

Figure 5.1 Families of potters living in north-west India who took part in this study. The six families currently live in Haryana and Uttar Pradesh, in close proximity to archaeological sites, i.e. Masudpur I, Lohari Ragho I, Rakhigarhi, Bahola, Alamgirpur, and Khanak. Usually, only one family of traditional potters lives in small size villages.

Figure 5.2 Sequence of actions for producing ceramic vessels, including clay cleaning and processing (A-D), setting the potter's wheel in motion and forming vessels (E-I), decorating (J), and firing tools and places (K-L).

Medium and large vessels are further moulded using paddle-and-anvil (or *tapla* and *pella*) technique. The base of large vessels is covered with mica-rich sand to prevent the tools from sticking to the vessel surface. The lower portion of wheel-made vessels is shaped with paddle and anvil in order to produce the distinctive globular shape of milk and water storage jars, while the vessels' walls get considerably thinner. After beating the surface and producing a globular shape, the vessel is put to dry in a large basin with a concave base, resting on a thin layer of mica-rich sand to prevent the vessels from sticking to the basin. The standardised shape of the basins/moulds helps the globular jar to obtain their distinctive shape during the drying process. Small size vessels have a simpler *chaîne opératoire*, and are solely wheel thrown. A lump of clay is put on the wheel, and several small vessels of different shapes are formed out of one lump; each of them is cut off from the lump using a string. Each family has his own little variations of manufacturing techniques, but almost all the Kumhars across regions broadly respect the above described sequences of actions, as well as tools and morphologies of vessels.

5.2.3 Surface treatments and decorations

Several tools and techniques are employed in the last finishing stage, mostly for decorating vessels. As mentioned, the use of sand during the final forming stage can be considered the cause of a first treatment on the lower portion of vessels, which shows a mild roughening or rustication. Being the sand often highly mica-rich in this region, the lower portion of vessels tends to show a glittery look. Iron-rich and manganese-rich clay is used to produce a slurry for the red slip and the blank paint (see Figure 5.2:J). A yellow clay (*pilli mitti*), a black clay (*kali mitti*) and a white clay (*saphed mitti*) powder are used to produce painted motifs on vessels. The yellow, black and white dry clay powder is currently purchased in a local market or collected near ponds in the area. The finished, leather-dry vessels are covered with the yellow-clay slip before firing, which turns red when fired in oxidising atmosphere. Painted motifs are applied on the yellow slip before firing using a thin brush of organic fibres. The process of surface finishing is usually run by women in the family. No burnishing of the external surface is undertaken.

5.2.4 Drying and firing

Vessels are subsequently dried for 24-48 hours. During summers they are stored indoor to protect fresh ceramics from excessive heat. Cow dung, ceramic cylinders for ventilation of the firing pits, broken vessels, and firing pits are required at this stage. Some Kumhar families perform chanting or reciting prayers before starting the firing process, likely for auspicious reasons. The first layer in the pit is made of broken large fragments of jars and ceramic cylinders to improve the ventilation during the firing process (see Figure 5.2:K). Medium and large globular vessels are then placed in the pit, followed by small vessels. The cow dung is the main fuel for firing pottery, which is places on top of the ceramics (see Figure 5.2:L). The firing stage can last 24-48 hours, depending on the size of the assemblage and the pit, and produce the distinctive black painted red vessels characteristic of this region (see Figure 5.3).

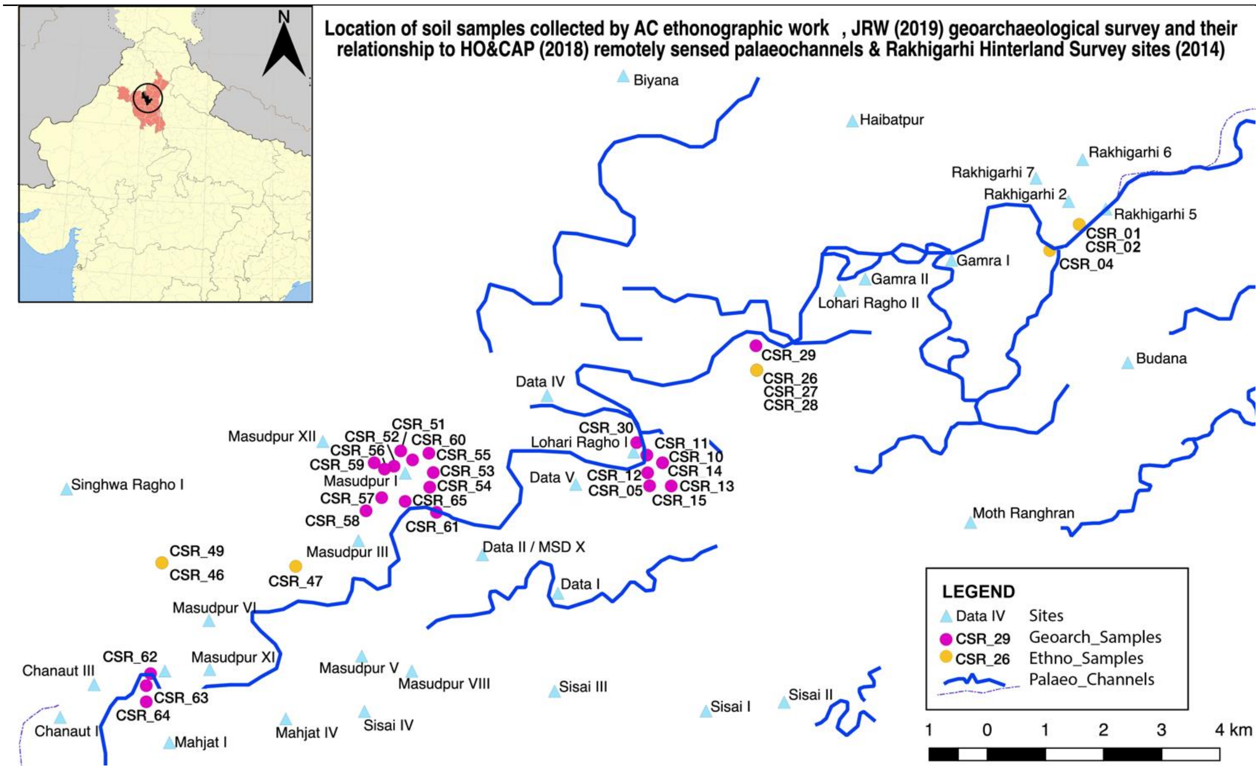
5.3 Clay sourcing: remote sensing, geoarchaeology and ethnography

As mentioned in Chapter 4, the identification of clay rich deposits for sampling was carried out with the combined use of geoarchaeology and remote sensing experts, as well as modern communities of potters living in the studied regions. The preliminary work of Hector Orengo was crucial for identifying palaeo-channels and reconstructing ancient landscapes around archaeological sites (Orengo and Petrie 2017, 2018). Orgengo's nuance remote sensing techniques to identify palaeo-channels and fine grained sediments include a Multi-Scale Relief Model (MSRM), which is a new algorithm for the visualisation of subtle topographic change of variable size in digital elevation models; Seasonal Multi-Temporal Vegetation Indices (SMTVI); and a Normalised Difference Vegetation Seasonality Index (NDVSI). Figures 5.4 and 5.5 show assessments of the palaeo-hydrography of the areas around Lohari Ragho I, Masudpur I, and Alamgirpur. Besides possible ancient rivers crossing the regions, maps include areas were remote sensing (RS) helped locate fine grained sediment (after Orengo et al. 2015). This was integrated with a Seasonal Multi-Temporal Vegetation Index (SMTVI) and Normalised Difference Vegetation Seasonality Index (NDVSI) to increase the visibility of palaeo-rivers and possible silty or clay deposits (after Orengo and Petrie 2017). In fact, the final images show where low topography and moisture accumulation co-occur in low-energy environments, which could have captured fine grained sediment. The area surrounding MSD I and LHR I were analysed using all the above mentioned methods; while the landscape of Alamgirpur offered the most reliable results provided by Multi-Scale Relief Model (MSRM, after Orengo and Petrie, 2018) combined with public Digital Surface Models (DSM) sources at 30 m/px. Building on

Orengo's assessment of palaeo-hydrology in Haryana and Uttar Pradesh (see Figure 5.4 and 5.5), underground palaeo-soils were samples by geoarchaeologist Joanna Walker (et al. 2018) mostly using a tubular soil sampler or hand core auger. These geoarchaeological samples represent the majority of the studied clay samples include in this thesis (see Chapter 4), and their locations is presented in the figures below using the colour code pink (see Figure 5.4, pink CSR points). As mentioned above, a second group of samples was collected in collaboration with the Kumhar potters in Haryana and Uttar Pradesh, who possess a meticulous vernacular knowledge of clay sources in the region. This latter ethno-technological investigation helped to gain a better understanding of available clay sources as well as properties of local raw materials (see Chapter 4). Areas within c.2.5 km or 30-minute walks from the sites have been primarily targeted. A description of soil samples is available in Appendix A: table A4. This samples gathered with the help of local communities of potters are indicated in Figures 5.4 and 5.5 below using the colour code yellow (yellow CSR points).

Figure 5.3 Workshop at Masudpur. Left: Paddle-and-anvil and bowl of mica-rich sand; right: finished globular jars.

Figure 5.4 Maps showing location of soil samples in close proximity to Rakhigarhi, Masudpur and Lohari Ragho. See Appendix A, table A4 for description of CSR samples. Map below shows a the area around Lohari Ragho and Masudpur sites.



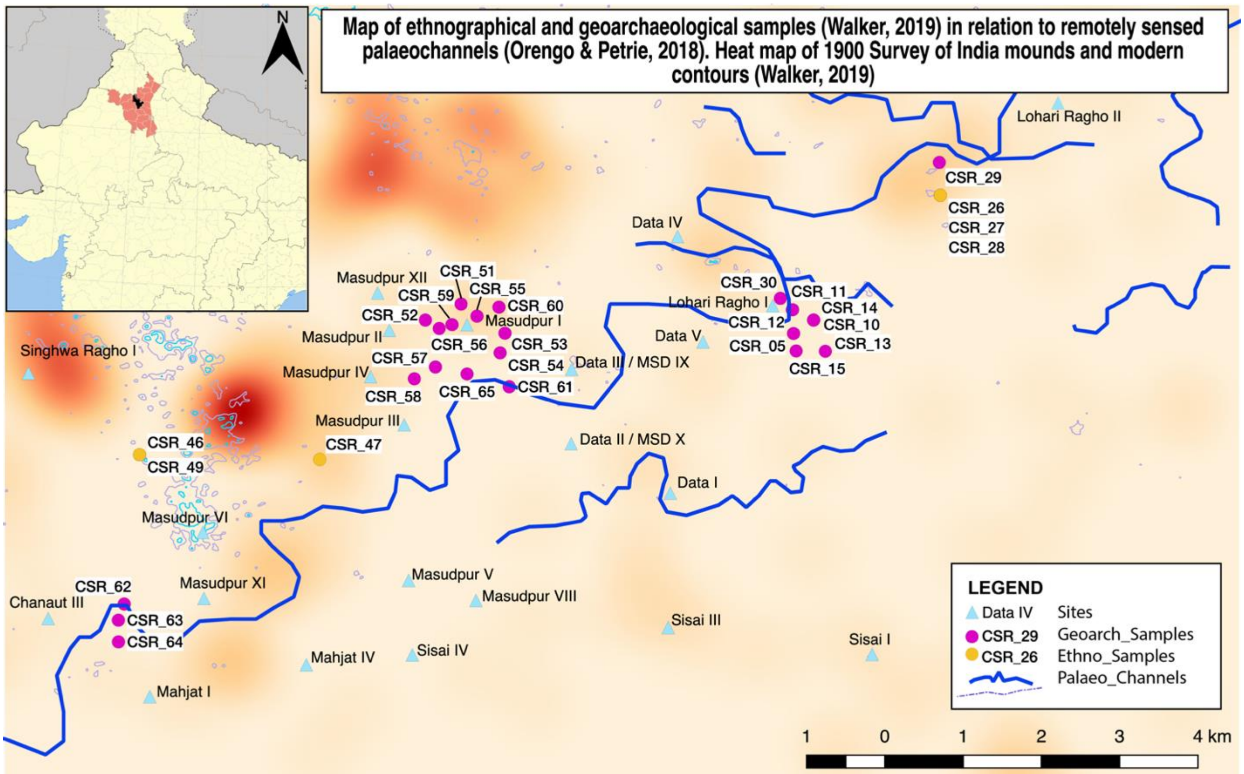
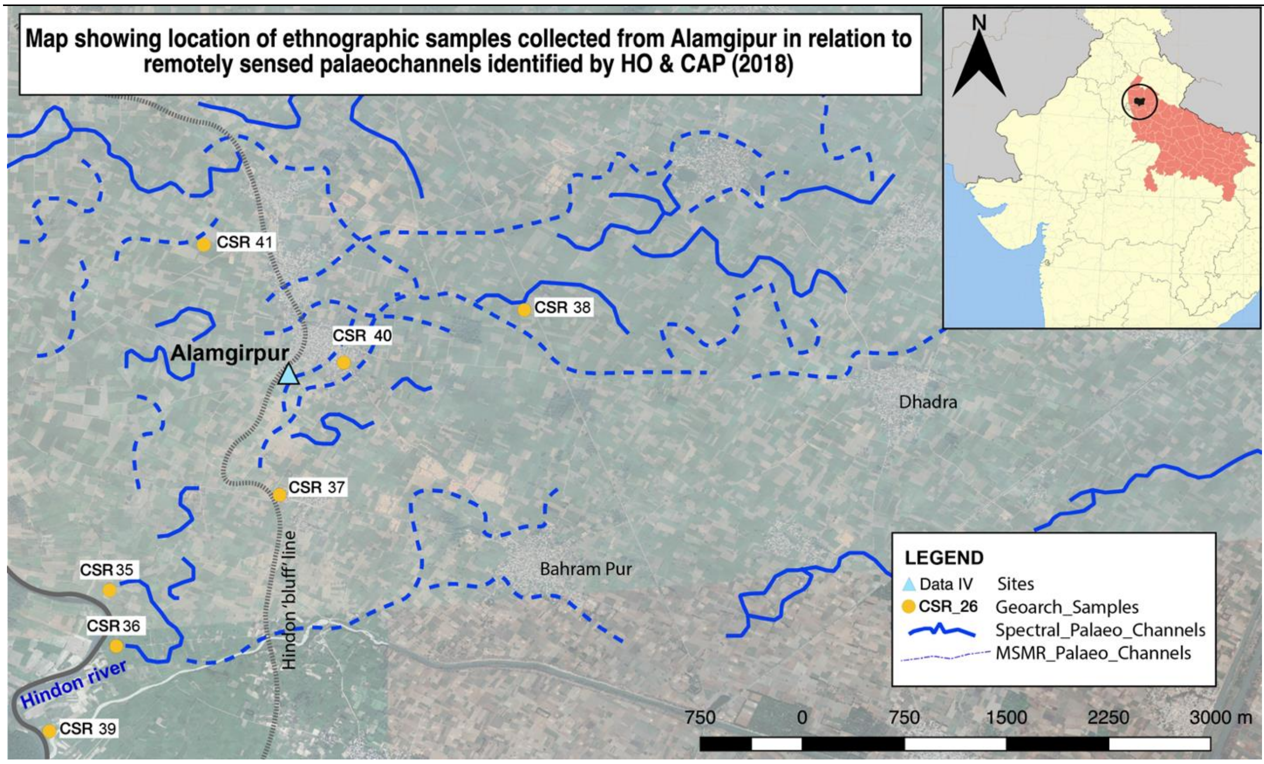


Figure 5.5 Map showing location of soil samples in proximity to Alamgirpur, Uttar Pradesh. . See Appendix A, table A4 for description of CSR samples.



5.4 Geochemical results

The soil samples dataset comprised data on 10 elements for 59 samples. As mentioned, slay-rich soil samples were collected using a combination of methods, including satellite imagery, geoarchaeology and ethnographic study (see above). The method for processing soil samples, producing cuvettes of loose powder for pXRF analysis and more details are available in Chapter 4. A complete list of chemical samples is presented in Appendices A and C, including the GPS coordinates of each location. The statistical analysis of the chemical data was performed considering the most accurate and meaningful elements. The accuracy of each element was assessed across the concentration range it occurs within prehistoric earthenware ceramics, as determined from the INAA datasets of Day et al. (2011) (Bronze Age Greece), Quinn et al. (2010) (Neolithic Greece) and Quinn and Burton (2016) (California). This assessment indicated that the calibration produced results with an accuracy of 20% or lower relative error for 10 elements (Fe, Ga, K, Nb, Rb, Sr, Ti, Y, Zn and Zr). The results for some elements (e.g. Rb, Sr) is <10% relative error. Details concerning the assessment of the performance of pXRF data calibration can be found in Chapter 4 and Appendix E. The statistical method has also been described in Chapter 4.

The chemical variability within the compositional dataset was estimated by determining its total variation. The selected elements and the calculated principal component explain c.61.6% of the proportion of the total variation in the dataset (see Table 5.1). Among the 10 elements, Fe, Ki, Nb and T seem to be the most relevant for determining compositional groups (see Figure 5.6). Principal component analysis (PCA) was then performed on the elemental data in order to produce scatterplot and further investigate clusters and outliers. As shown in Figure 5.6, a few chemical clusters could be distinguished from the principal component analysis (PCA), and each point has been marked by location, or proximity to known settlements. Most of the soil samples seems to describe a broadly similar compositional group. However, some clay rich soil samples appear to be consistently different and show diverging trends. For instance, samples from Alamgipur, Kanoh and Bahola seem to show a diverging chemical fingerprint from other soils samples. Similarly, soils from Masudpur, Lohari Ragho and Rakhigarhi appear to form a broadly similar cluster. However, within this latter group, three trends could be observed (e.g. Lohari Ragho Village vs Lohari Ragho I). The resulting picture seems to suggest a sense of broad homogeneous composition, within which variable subgroups can be successfully identified. The implications of these variability will be discussed in the next chapters (see Figure 5.6).

The dataset will be compared with and integrated to archaeological samples in the next four Chapters. This will be used to better explore compositional variability of clay-rich deposits, and to present remarks concerning use of local raw materials. Geochemical data from archaeological samples collected at Lohari Ragho (Chapter 6), Masudpur (Chapter 7), and Alamgirpur (Chapter 8) will be statistically processed, and the chemical variability of each site with be discussed individually. Eventually, in Chapter 9, all geochemical data from soil samples and archaeological samples will be compared and discussed.

Figure 5.6 Scatter plot of PC1 and PC2 by location. Right corner: load of elements affecting the components.

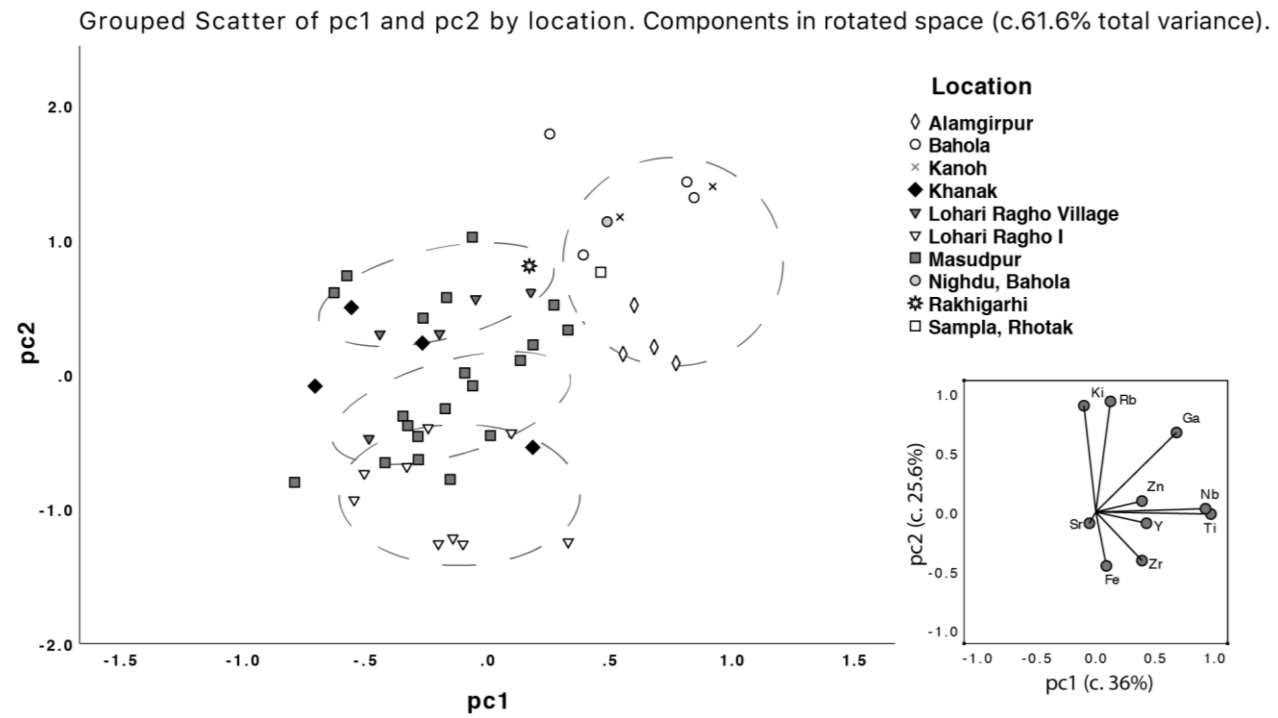


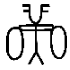
Table 5.1 Variance explained (soil samples) of Principal Components (PC) 1 and 2. Samples and geochemical data in Appendix C.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
PC	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.599	35.994	35.994	3.599	35.994	35.994	2.782	27.816	27.816
2	2.566	25.661	**61.655**	2.566	25.661	61.655	2.534	25.337	53.153

5.5 Summary

This chapter presented the traditional artisanship of the Kumhar potter cast in Haryana and Uttar Pradesh. The study has limited yet meaningful uses for this thesis. First of all, the vernacular knowledge of the traditional potters was pivotal to identify clay-rich deposits, and to gain a better understanding of the physical landscape. This was combined with satellite imagery and geoarchaeology to build up a dataset of geochemical samples to be compared with the composition of archaeological materials. This dataset will be used in the following three chapter and will be further discussed in Chapter 9. Moreover, the work with the Kumhar or Prajapati potters contributed to gain a better understanding of raw materials available in the region, perceptions of the physical landscape, as well as tools and techniques used by rural potters. This was used to reconstruct the sequence of actions and manufacturing techniques employed by modern South Asian rural potters, which have been often directly correlated with ancient Indus ceramic industries (see above Section 3.4). Moreover, the ethnographic study raised awareness among rural communities of the archaeological research projects undertaken by South Asian and western Institutions concerning local heritage. Finally, the interaction with families of potters and network of potters helped to better understand endogamous marital alliances and relationships, which are often believed to explain the resilience and continuity of this long-lasting tradition. This will be further discuss in the final section of this thesis (see below Section 9.7).

Chapter 6. Lohari Ragho I: Early Urban ceramic traditions



6.1 Introduction

This chapter will present data and results concerning the study of the ceramic corpus rediscovered at Lohari Ragho I (LHR I), trench EA, chronologically representative of the transition from the Pre-Urban to the Early Urban Indus productions. The first part of this chapter will be dedicated to the macroscopic assessment of sherds and vessels. Fabrics, manufacturing techniques and surface treatments will be assessed in order to identify the technical actions employed in the production of ceramics. In keeping with the *chaîne opératoire* approach, and by using a visual assessment of sherds, the narrative will begin with observations on clay pastes and recipes, moving to the description of primary and secondary forming techniques, and eventually culminating with finishing techniques, surface treatments and decorations of vessels.

Section 6.7 will combine the above-mentioned technical observations to reconstruct the ceramic traditions evident at LHR I. Techno-groups will be presented in a meaningful and comprehensive fashion, describing in detail their characteristics and cross-referencing the technical actions portrayed in the first part of this chapter. The description of each techno-group will resemble an identity card, discussing its manufacturing techniques, decoration and morphologies, and including references to similar synchronic traditions in the Haryana.

Sections 6.8 to 6.12 will consider the mineralogical and elemental composition. Petrographic classes identified within the LHR I, EA assemblage will be presented and discussed, together with chemical characterisation of ceramic vessels. Petrographic and geochemical analyses will combinate methods to: (a) shape and reinforce the macroscopic technological observations; (b) better characterise paste preparations and recipes of vessels, resulting in a more detailed understanding of ceramic traditions; and (c) present preliminary results concerning local or non-local production of vessels. Even thought it could be beneficial to present the petrographic and geochemical data before the techno-group, the adopted narrative follow the sequence and approach which was successfully employed in other similar studies (see Chapter 2).

These techno-compositional results will make it possible to reconstruct the system of overlapping landscapes of ceramic traditions, the variability in social complexity at the settlement, the functional variability of vessels, and the social identities of communities interacting in both a synchronic and diachronic perspective.

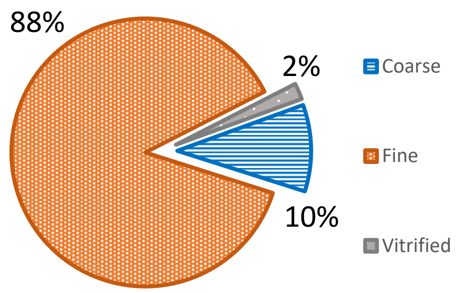
6.2 Macroscopic results

The preliminary analysis of pottery from LHR I was undertaken in two distinctive phases. The first stage took place *in situ* during the excavation of the site in September-October 2017, when all ceramic materials unearthed at the site were carefully assessed and documented. The second stage occurred post-excavation in October-November 2017, at BHU. The first stage involved the identification of preliminary technical-groups, according to fabrics, technical features, surface treatments, decorations and diagnostic parts. It also included the preliminary sorting, counting and weighing of all of the material after it had been sorted. From the 97 distinct stratigraphic contexts exposed in Trench EA at LHR I, a total of 27,502 sherds, weighting 359.82 kilograms, were recovered, sorted and recorded. Once the preliminary assessment and recording was completed, the diagnostic material and a range of representative sherds from context showing well preserved macrobotanical material for radiocarbon dating, which comprised c.10% of the assemblage from each context was selected and stored into labelled bags and boxes for transport to BHU and further processing. The initial techno-groups were defined in the first stage by considering the broad compositions and manufacturing techniques of the ceramics. Both the fabrics and the surface or macro-traces, present on the inner and outer walls of the sherds, were used to identify the techno-groups. Surface treatments were also considered, but neither the morphologies of vessels, their decorative motives nor mineralogical analyses were included at this stage of the analysis.

6.3 Fabrics

Through visual assessment, three main types of fabrics could be identified within the assemblage: a coarse paste, a fine paste, and a vitrified fabric (see Figure 6.1 and Figure 6.3 below). The ODK database of sherds from LHR I, including the fabric characterisation and quantity of sherds, is described in Section 4.2, from which the following presented data and percentages have been extrapolated.

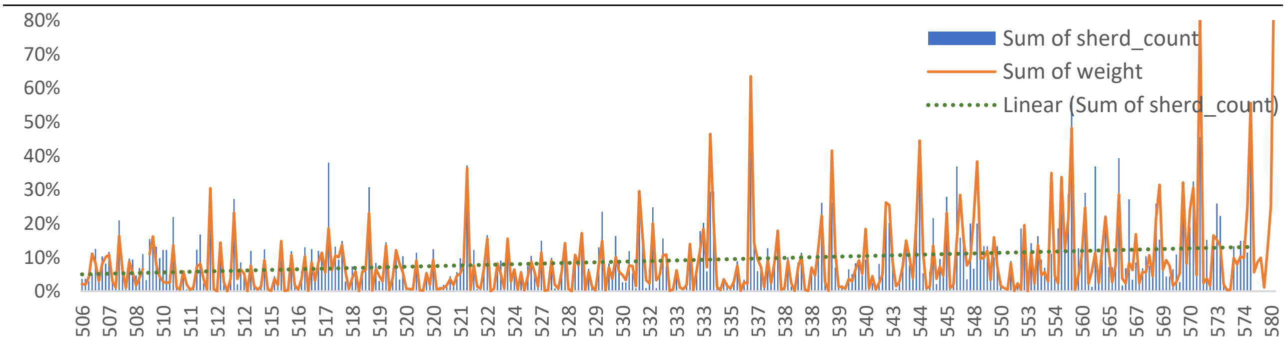
Figure 6.1 Percentage of fabric groups after preliminary visual assessment. See Section 4.2 for database of sherds.



*6.3.1 Coarse (**C-**) paste*

Organic tempered or coarse ceramic paste has been categorised according to the features and composition of the fabric as observed macroscopically. The organic material likely used as temper is no longer visible, and the large pores of voids visible on the surface on in the paste can be attributed to burnt out vegetal material.. Coarse paste ceramics occur in the state of unfired (Figure 6.3:b1, b2) or fired ceramics (Figure 6.3: c1, c2). The voids can measure between 0.2 to 15 mm in length, and show a range of different morphologies, which can be associated to straw, chaff, seeds or and other vegetal temper. Pastes showing these features are quite frequent within the studied assemblage and have been found in almost all deposits. This coarse paste represents c.10% of the whole assemblage, with an average per deposit of c.9-11% (see Figure 6.2). As presented below, vegetal or chaff tempered coarse pastes were mostly used to produce ceramic building materials (CBM), the so-called terracotta cakes, and certain vessels, especially large, shallow trays.

Figure 6.2 Presence of Coarse (C-) paste ceramics in the corpus, per context. Average of c. 9-11% across all deposits.



*6.3.2 Fine (**F-**) paste*

Fine ceramic paste has been categorised according to the features and composition of the fabric as observed macroscopically. Rare, small pores are visible on the surface of ceramics or in the paste, and fine mineral inclusions can be identified to the naked eye, including quartz and mica. The rare voids can measure between 0.2 and 0.5 mm in length, mostly equant and rounded in shape. Fabrics are not always homogeneously mixed, and can show higher or lesser degrees of mixed iron-rich and calcareous clay. Fine ceramic pastes are identified in all deposits at LHR I, Trench EA. The fine paste represents c. 88% of the whole assemblage, with an average per deposit of c.85-92%. As presentred below, fine pastes used to produce a variety of vessels were associated to a vast range of manufacturing techniques, surface treatments, decorations and morphologies. The fragments of ceramics that fall under the fine paste groups are usually red, dull-red or bright red surface and core colours (Figure 6.3:a1, a2), suggesting firing in an oxidizing atmosphere.

*6.3.3 Vitrified (**V-**) fabric*

Ceramics fragments grouped under this category show a foamy, bubbly texture. They tend to be lumps of 2 to 3 cm in length, are remarkably lightweight due to their low density, and show a characteristics 'bubbly' and high porosity structure. The fragments are whitish, light grey, or yellowish brown in colour, have a glassy appearance and are quite fragile. This type of vitrified material can be formed when alkali and silicate compounds (such as ash and burnt wood, sand and clay) react, often due to high temperature within a hearth, a kiln, furnaces or fire episode, such as a burning structure, and are not necessarily indicative of a specific industry. Considering their colour, size and weight, they appear not to be diagnostic of any particular process, such as metallurgy of faience production. In fact, they may be fuel ash slag (e.g. Dungworth 2007, 2009, 2015; Bayley, Dungworth, and Paynter 2009). These fragments will not be further discussed in the present chapter. This type of fragments could be interpreted as vitrified ceramic, vitreous ceramic slag, or possible fuel ash slag. Theserare lumps of vitrified or almost vitrified material represent c.2% of the whole assemblage, and found in a small number of contexts (see Figure 6.3).

Figure 6.3 Examples of most recurrent fabrics: (a..) fine paste; (b.) unfired coarse paste; (c.) fired coarse paste. Below, photo obtained through the use of a Dino-Lite digital microscope (10x).

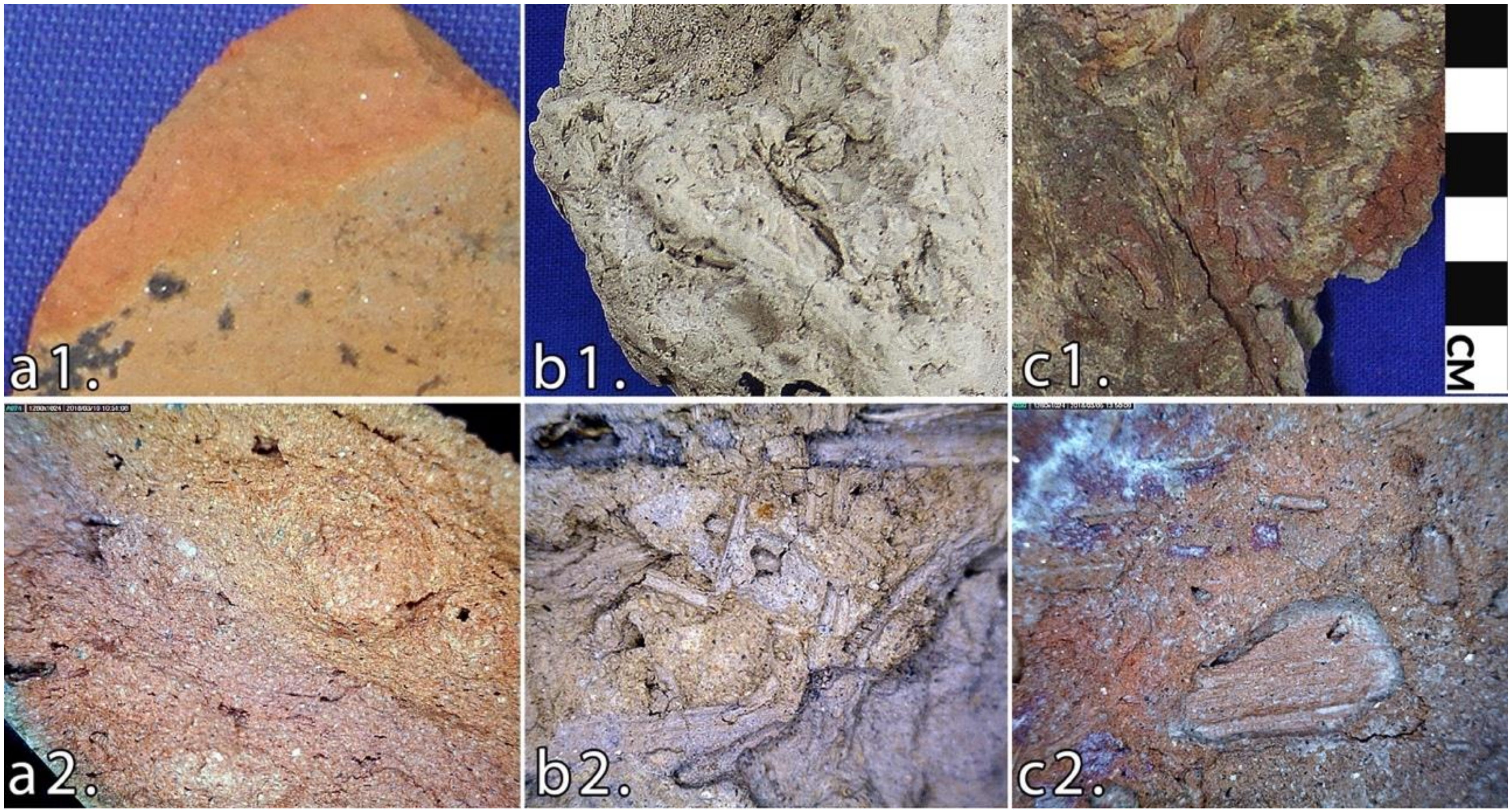
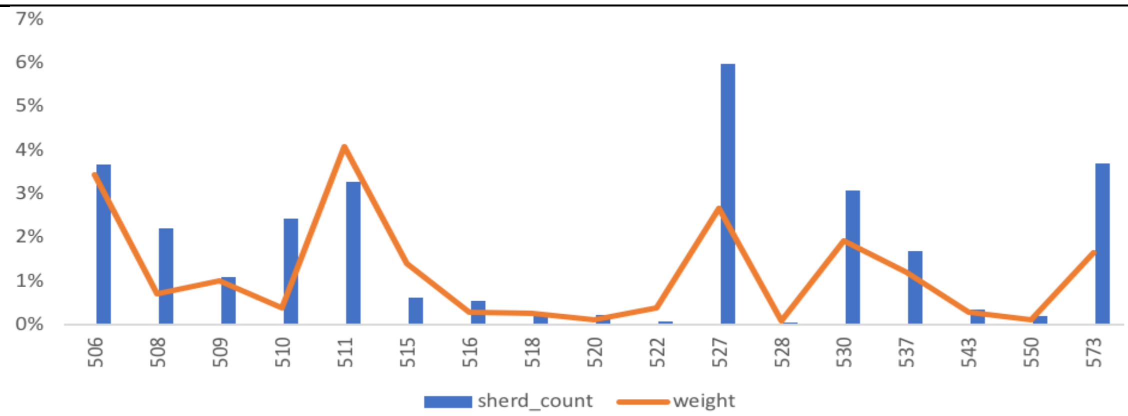


Figure 6.4 Presence of Vitrified (V-) ceramics in the corpus, per context. Linear average of c. 9-11% across all deposits.



6.4 Manufacturing techniques

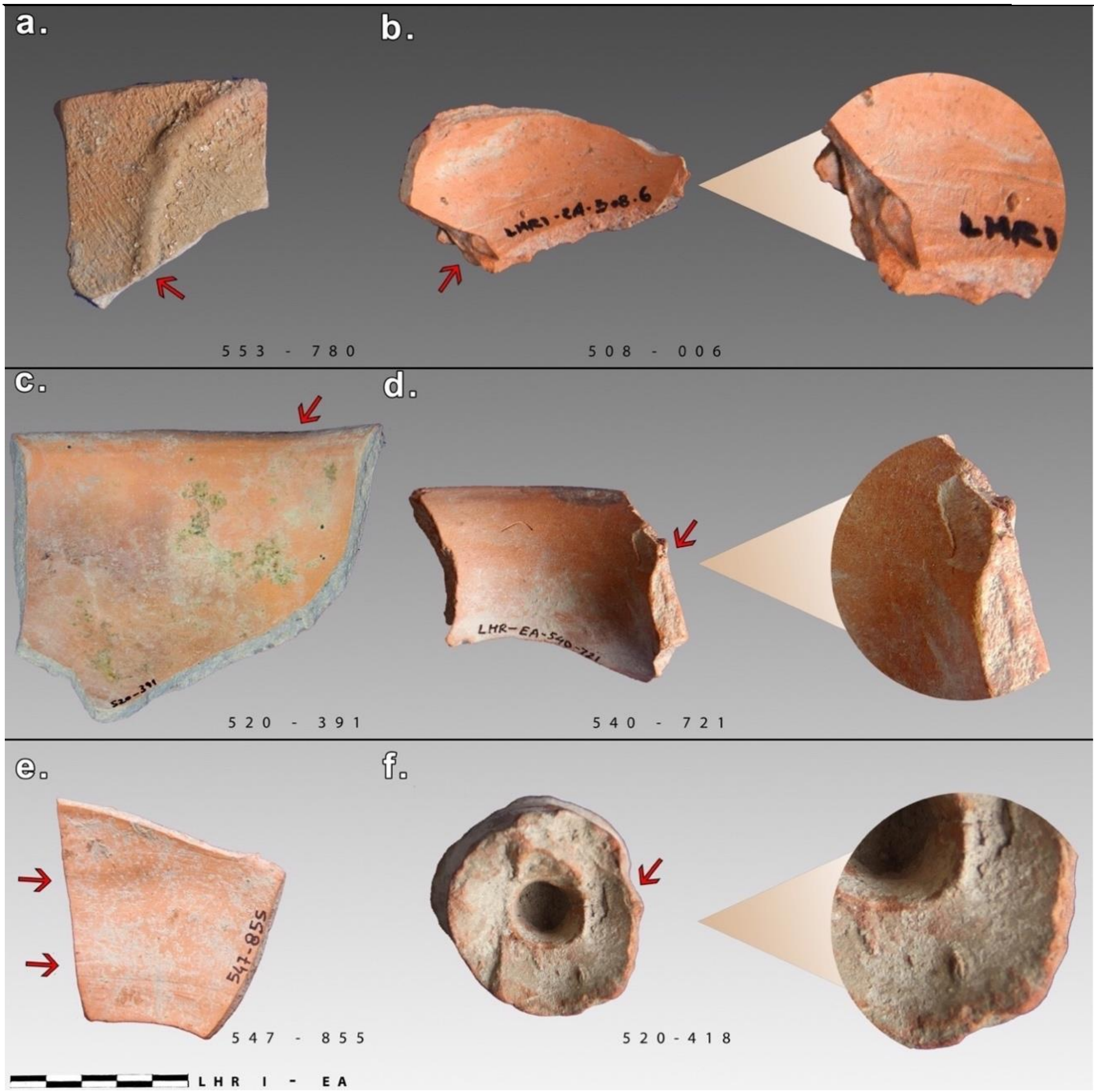
Once ceramics were sorted into broad fabrics groups, evidence for manufacturing techniques were considered to sort the pottery into techno-groups. The evidence used for assessing technical actions and technical-groups will be first described here.

In order to identify manufacturing techniques, the first macro-traces considered were evidence for the use, whether abundant, limited or completely absent, of rotational devices, i.e. *Rotative Kinetic Energy* or RKE (also see Chapter 3.11, 3.12). As summarised by Roux (2009: 199), vessels produced using RKE often show clear diagnostic marco-trace attributes, such as concentric parallel striations on the inner walls, stretched walls, and string cut marks on the bases (see Figure 6.5). Microscopically, RKE is indicated by parallel to moderately parallel organization of voids and inclusions to the walls, as well as elongation of voids and fractures. Concentric parallel striations on the outer surface of walls cannot be used as clear evidence for RKE, however, since they could have been produced by smoothing the walls while revolving the pot by a simple movement of the hand (e.g. when applying a slip on a globular jar).

6.4.1 Fine (F-) fabrics associated technical actions

Fine ceramics were first divided into sherds that show evidence for the use of RKE, and those which do not. Sherds that do not show any evidence for rotational gestures were further sorted according to other visible macro-traces or evidence of manufacturing techniques. Those sherds who show clear use of RKE were observed according to patterns of fractures, morphology of the walls, and other features to further study preliminary forming techniques.

Figure 6.5 Evidence for the use of coils at various stages of ceramic production on sherds from Lohari Ragho I Trench EA. Arrows point to macroscopic features that could be used to determine the use of forming methods, including the possible use of coils (e.g. brekage patterns, surface topography, and coil joints).



6.4.2 Coiling (with or without RKE)

On LHR-I sherds, a number of distinctive traces were identified which suggest the use of coiling techniques during the initial phases of forming. Figures 6.5 and 6.7 show the range of morphological features that have been considered when assessing the forming techniques of vessels, especially in relation with coiling. Traces are not enough, however, to make a clear statement concerning possible wheel-coiling techniques. Overall, 10,368 ceramic sherds (c.105.17 kg), seem to show evidence for a combination of forming techniques, including possible preliminary forming techniques such as coiling for forming the rough-out of vessels. The percentage of sherds showing this technical action is relatively high, c.38% of the whole corpus, which also includes ceramics that show moulding or unclear sets of manufacturing techniques. Given the above, it could be hypothesised that a substantial proportion of ceramics could have been produced using this preliminary forming method. Coils are also used to produce the ring-base of certain globular vessels (see Figure 6.5:a).

6.4.3 Scraping (with or without RKE).

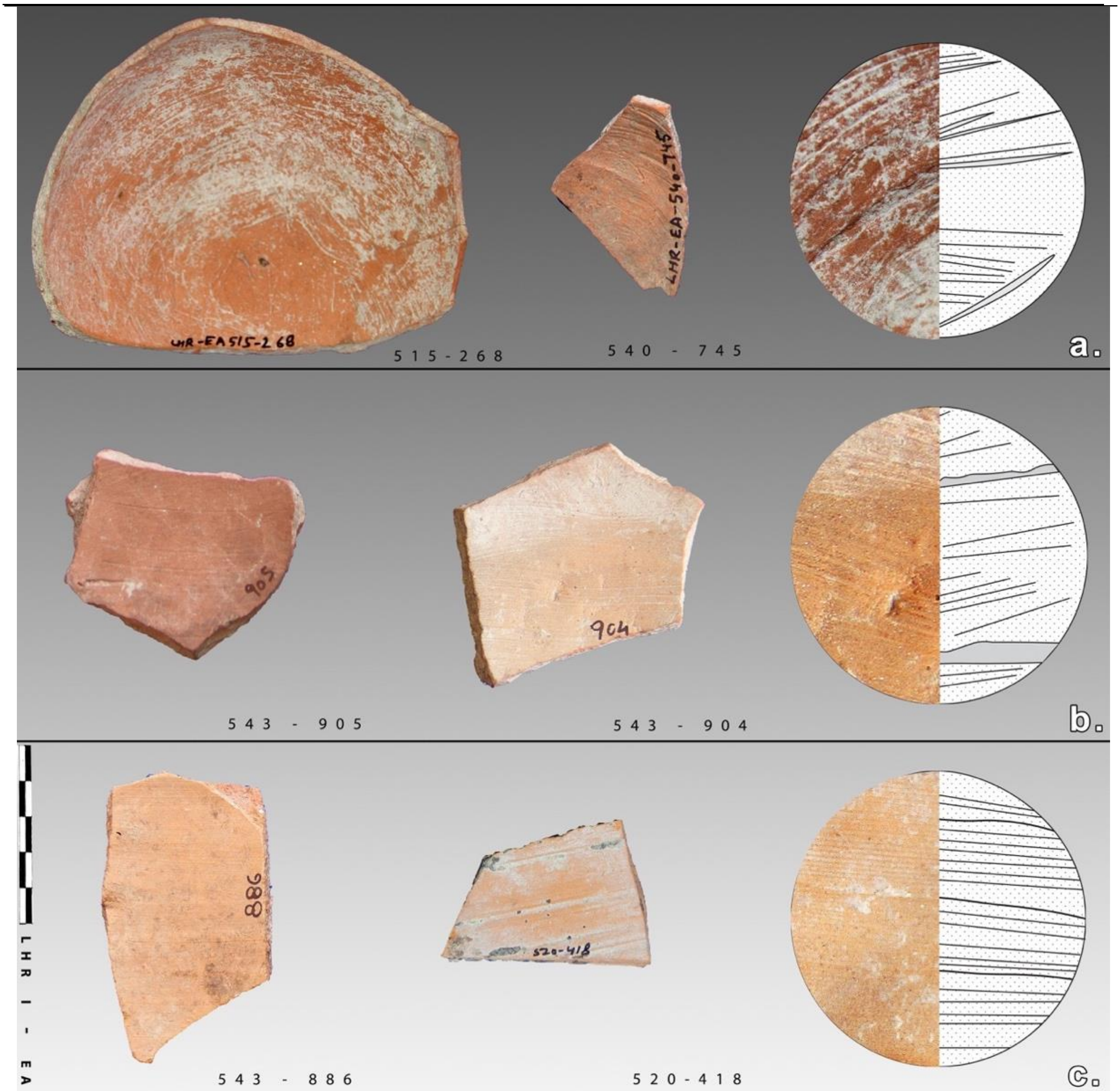
According to macro-traces identified on LHR I sherds, scraping was widely used and performed in a variety of ways: for instance, with or without the partial use rotational motion or devices, such as *tournettes* or turntables. The type of evidence that may suggest partial use of rotational devices is presented in Figure 6.6:b-c; while the lack of RKE could be inferred from sherds such as Figure 6.6:a, which shows little to no parallel sets of grooves or striations. Overall, the percentage of sherds showing this technical action is relatively high: c.7,881 sherds (c.83.72 kg), or c.28% of the whole assemblage.

6.4.4 Non- or limited RKE

Given the above, it appears that the vast majority of ceramic vessels were produced using a combination of forming methods. After forming the roughout, possibly using coiling, vessels were often shaped using scraping. Fine (F-) paste ceramics, formed without using RKE, rotational gestures, a wheel or rotational devices (NW), often show evidence for different degrees of scraping and smoothing (see summary of combined techniques below in Table 6.1):

F-NW-A: rare striations, with quasi-parallel to non-parallel orientation. The marks can be very shallow or slightly deep. Often coils and coil-joins are visible (see Figure 6.5 and Figure 6.7); ***F-NW- B***: abundant striation, from nonparallel to moderately-parallel. Shallow as well as deep marks on the inner walls can be seen. Often coils and coil-joins are visible (see Figure 6.5, and Figure 6.7); and ***F-NW-C***: very abundant striations. This can be confused with wheel marks due to the presence of marks on the interior surface, mostly found in proximity of the neck and on rims of vessels, can be misunderstood as evidence for the use of the wheel in the forming phase. The non-consistent nature of these marks seems to suggest rotational movements of tools and scrapers, rather than the use of a rotational device. If a rotational device was used, the use of rotational gestures was minimal (see Figure 6.5 and 6.6:c).

Figure 6.6 Evidence for secondary forming techniques, such as scraping on sherds from LHR-EA. The uneven surface topography and the macrotraces on internal and external surfaces suggest different secondary forming and finishing technique, likely without the use of RKE or rotational devices.



6.4.5 *Wheel finishing and wheel forming*

Similar to the scraping technique, wheel-finishing is often found associated with coiling, or possibly wheel-coiling techniques. The sherd shows perfectly parallel grooves, indicative of the use of rotational devices and RKE during the secondary or finishing forming phases. Clear evidence for the use of this combination of technical actions are often difficult to identify. However, as presented in Figure 6.5 and Figure 6.7 preliminary forming techniques, such as coiling, can be seen on sherds associated with clear parallel grooves, which are often indicative of wheel finishing technique. The wheel-finishing technique could have been associated with both coiling and scraping (see Table 6.1). In fact, as shown in Figure 6.7; parallel grooves are often only identifiable in close proximity to the rim, while sherds from lower portions of vessels seem to suggest the use of scraping technique for thinning and shaping the roughout. This means that different combinations of techniques were likely used in different locations on the same vessel.

There are, however, rare vessels were parallel grooves are observed across the whole body, neck and rims of vessels (Figure 6.7). Even though certain bases show string cuts, these cannot be used to inferred the whole sequence of actions for producing vessels. In fact, ceramics can exhibit string cut marks on the outer surface of the vessel's base; yet, there may have been only limited transformation of the roughout with the help of RKE via a *tournette*, turntable or wheel (e.g. ceramics from Fâr'ah; see Roux 2009). Evidence for the use of rotational motions or devices have been found on c.9,404 sherds (c.105.33 kg), or c.34% of the whole assemblage.

Given the above, it was possible to tentatively group wheel-finished (-**W**), and possible wheel-formed, fine (**F-**) paste ceramics into the following two groups:

F-W1: wheel-marks associated with scarping marks. These horizontal striations are mostly, but not only, confined to the upper portion of vessels, mostly on the interior surfaces of rims and necks. This seems to suggest that rims showing this configuration were possibly moulded separately and attached to the vessel using a rotational motion in a subsequent phase of manufacture. Alternatively, rotational devices could have been used only in the final stage of fashioning. The lower portion of vessels tend to show evidence for the combination of coiling and scraping techniques, along with clear joint zones with the upper wheel-finished neck and rim (see Figure 6.7).

F-W2: perfectly parallel striations and grooves, which are often found across the whole wall of vessels – from rim to base, on both thick or thin walls (see Table 6.1: method 4).

Figure 6.7 *Top left*: Schematic representation of preliminary forming techniques, e.g. coiling, applied neck, assembled necks and rims, and smoothing via RKE. *Top right*: Most recurrent types of bases: disc, ring, and rounded or flat. A complete description of types of bases is presented in Appendix D, Plate I. *Below*: Evidence for rotational motion and use of RKE. Possible evidence for the partial use of rotational devices. The presence of grooves is mostly found on the neck and rim, suggesting a specific use of RKE in certain phases of the manufacturing process.

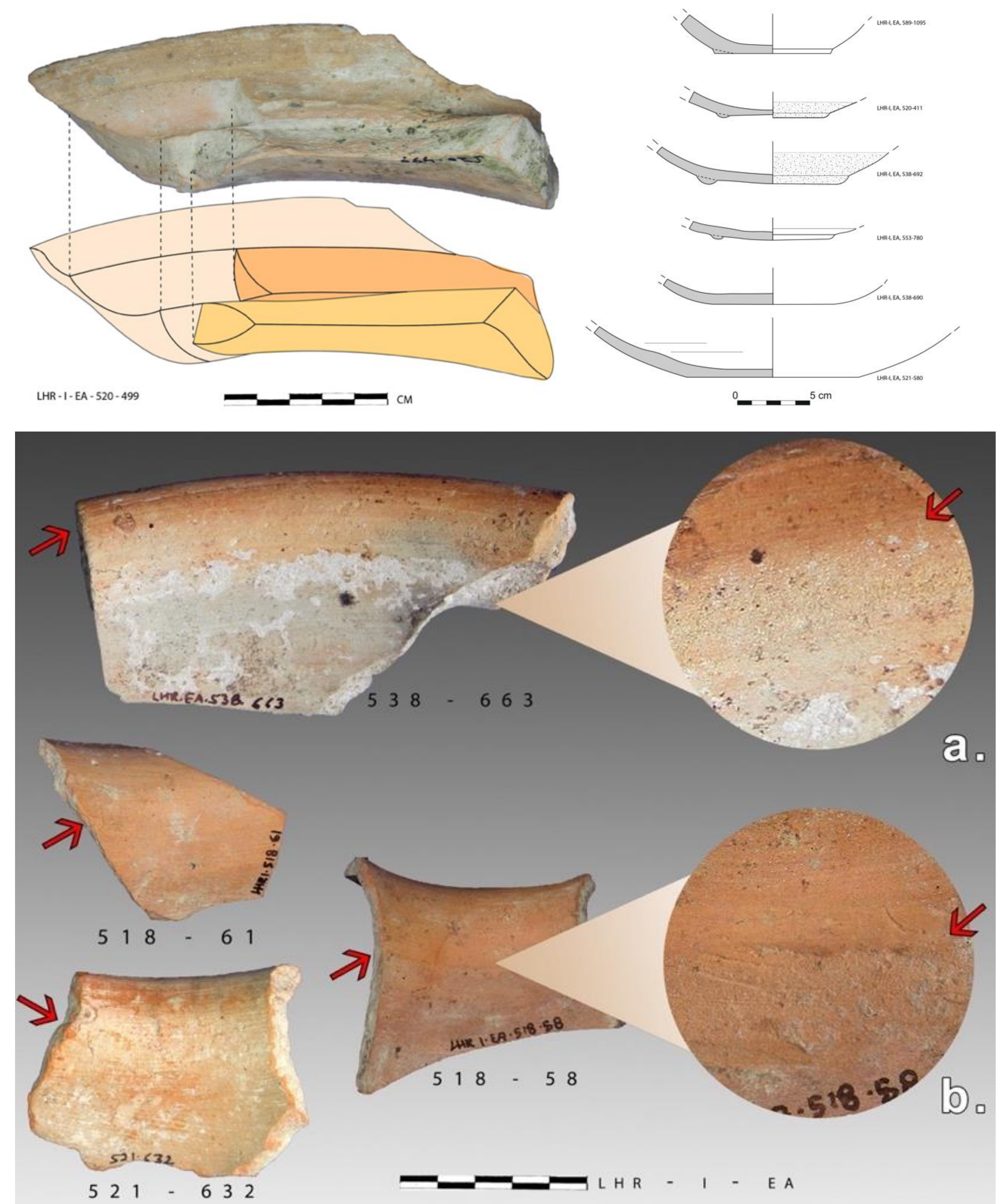


Table 6.1 Combinations of preforming, forming and finishing techniques, associated with use of RKE, e.g. use of rotational gestures or devices, and groups.

METHOD	FORMING THE ROUGHOUT	JOINING THE COILS	THINNING THE COILS	SHAPING THE ROUGHOUT	GROUP
Method 0	NON-RKE	NON-RKE	NON-RKE	NON-RKE	F-NWA; F-NWB
Method 1	NON-RKE	NON-RKE	NON-RKE	RKE	F-NWC
Method 2	NON-RKE	NON-RKE	RKE	RKE	F-W1
Method 3	NON-RKE	RKE	RKE	RKE	N/A or F-W2
Method 4	RKE?	RKE	RKE	RKE	

Traces on the interior surfaces of vessels, as well as breakage patterns, seem to suggest that necks and/or rims of certain vessels were formed in a subsequent phase of the manufacturing process, independently from the rest of the vessel's body. Figure 6.7 shows changes in terms of striation's patterns in close proximity to the neck and rim of certain vessels, suggesting a specific set of actions for obtaining the desired morphologies. The presence of visible coils in close proximity to the neck (e.g. Figure 6.7), associated with changes in striation patterns (e.g. Figure 6.7:a,b) seem to suggest that the rims where often finished using abundant rotational gestures and possibly rotational devices. It is not clear whether the rims or necks where formed separately, and subsequently attached to the body of vessels; however, this hypothesis should not be discounted.

6.4.6 Bases and pedestals

The most recurrent types of bases are flat to slightly concave. However, a ring type and a disk type are also observed and seems to be distinctive of vessels produced with no or little use of rotational gestures or devices. Both disc and ring types of bases seem to have been crafted by adding clay to a rounded, globular base (see Figures 6.5, 6.7 and 6.8:a,b) The concave base of vessels with an attached ring can, at times, project downwards beyond the ring (see Appendix D: Plate I; see sherd LHR I, Trench EA, 515-268). Flat bases or pointed bases with string-cut marks are rare. Where parallel striations or marks of rotational gestures are visible, bases are mostly flat and may show string-cuts, or are assembled on a pedestal. The pedestal, or stand, of 'dish-on-stands' or 'bowl-on-stands' morphologies appears to have been made separately and attached to the base of bowls and dishes. The base of the dish or bowl appears to have been attached horizontally to the foot or stand (see Appendix D: Plate I). The joints are usually easy to identify between the dish or bowl and the pedestal, and coils and coil-joints are usually visible on the fractured pedestals (see Figure 6.5:f).

6.4.7 Attached handles

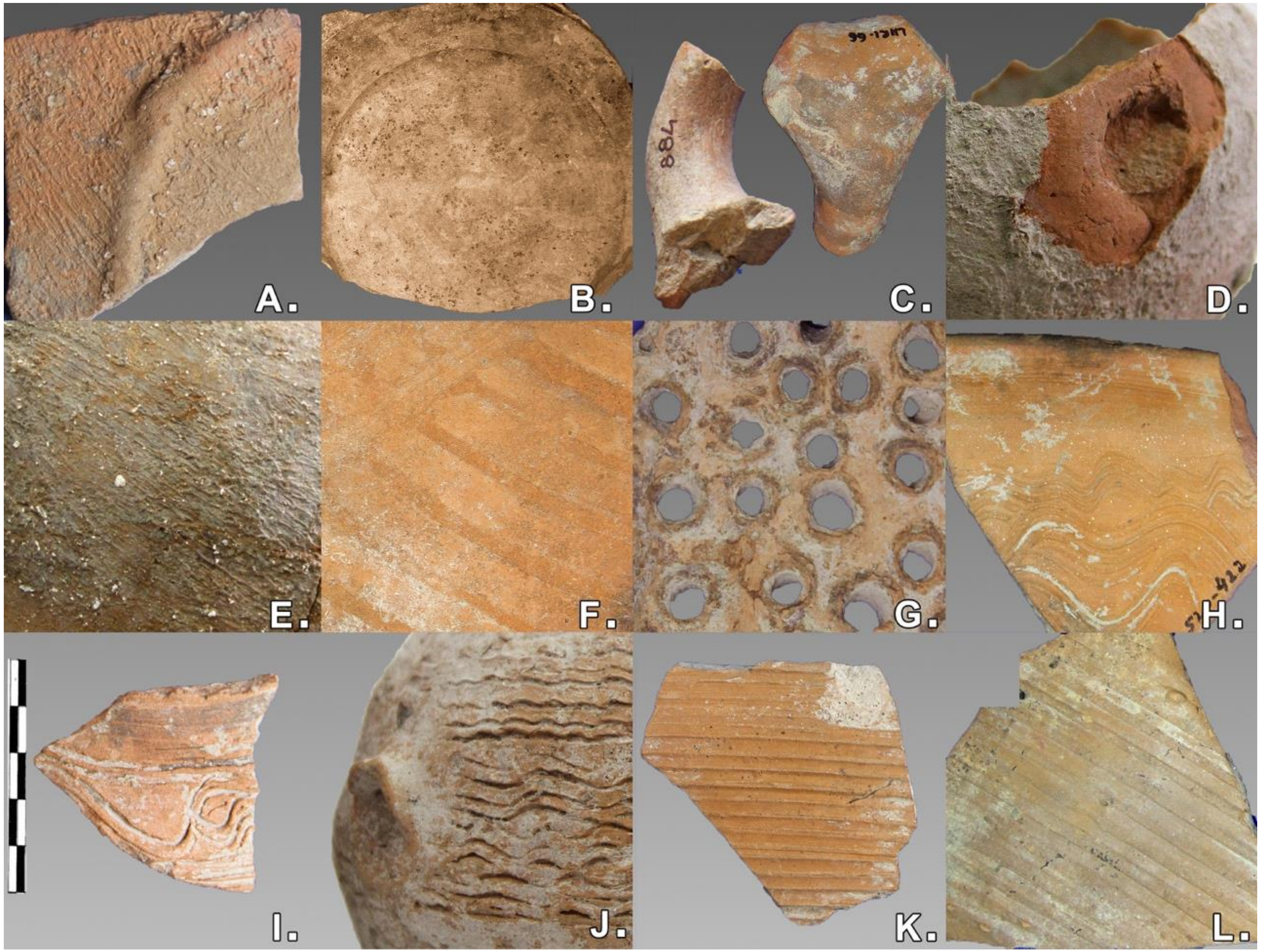
Several handles, or fragments of handles, have been identified in the corpus. They all show minimal morphological and compositional variations, being mostly produced using a fine to medium fine paste, and being circular, ovoid or semi-rectangular in section. They are likely to have been attached to the body, neck and rims of vessels, but only few of them are still attached (see Figure 6.8:D and H). However, one vessel, sample (511-203), shows a mostly intact jar with parts of a handle still attached to the body (see below Section 6.7.1). This vessel is globular to elliptical in shape, with a short neck and everted rim with distinctive parallel lines and wavy grooves incised on the outer walls, and the handle is attached to the rim and to the body (see Appendix D: Plate IV).

6.5 Surface treatments

6.5.1 Slip

Red slip: Three types of red slips have been identified at LHR I. The first and most common is pale reddish-brown to red in colour, and is visible on both the outer and inner surfaces of vessels (see Figure 6.9:C, J, and L). When assessing this kind of red slip, it is difficult to distinguish and clearly document an actual applied iron-rich clay slurry to the surface of vessels, as opposed to a sort of 'self-slip'. The latter may have been produced during a finishing stage, such as smoothing with abundant water. 'True slips' are relatively easier to classify (see Fig 6.9: E, F and M) as they usually appear bright red or dark red, depending on the thickness and composition of the slip, as well as firing techniques (Dales and Kenoyer 1986: 64). Superimposed layers of slip can also be found. The third type of slip is vibrant-red to deep red in colour, and it is usually associated with profuse polishing and even burnishing of the outer surface of vessels.

Figure 6.8 Finishing technique, or techniques employed in the last phases of production. A: applied ring base; B: string cut marks; C: attached handles; D: negative impression of attached handles; E: applied rustication with visible fragments of limestone or *kankar*; F: applied ‘ fingers’ rustication; G: perforations; H: wavy line incisions, inner surface; I: wavy line incisions, outer surface; K: parallel incisions; L: large parallel incisions.



Light brown or 'chai' slip. Perhaps a variety of red slip, this is pale, light red to light brown in colour (Figure 6.9:D). No particular pattern has been observed for the presence of this particular slip, which seems to be mostly abundant on jars and globular jars. However, whether this is a distinctive technical choice, or just the result of non-homogeneous firing techniques or post-depositional process, it is still to be clarified.

Dark brown or 'chocolate' slip. A dark-brown to brownish-black slip was identified on the outer surfaces of small jars or bottles (Figure 6.9:B and O). The majority of vessels with this slip show a combination of manufacturing techniques, including the use of rotational kinetic energy and possible rotational devices for finishing the small jars. The rims of these bottle-like ceramics are always out-curved, with a short neck (see Appendix D: Plate VI; and see Section 6.7.4). Some black-slipped red vessels can be found slipped on both the inner and outer surfaces.

It is worth noting that the use of a dark brown or brownish black slip as a type of surface treatment, applied on red vessels, could be observed in the third millennium BC on a variety of ceramics in the Indus zone. For example, an iconic example of Indus dark-slipped jars are, for instance, the large black-slipped jars found at several sites within and beyond the Indus zone, including in modern Oman (Wright 1991: 82; Mery and Blackman 1996). In terms of technical actions, Mery (1994: 479) argues that application of a black slip at the Indus pottery workshop at Nausharo was performed using large fiat brushes, but pieces of cloth may have been also used.

Black slip (burnished). A dark-grey to black slip has been observed on bowl, dishes, and bowl-on-stands (Figure 6.9:A). This black slip is found on vessels which show a homogeneous grey core, likely indicative of thorough firing in a reduced atmosphere. Besides the distinctive firing techniques, colours and morphologies, vessels with an applied black slip tend to show burnishing on both the inner and outer surfaces. This surface treatment is quite rare at LHR I, and it was found on a very limited number of fragments; yet, it is consistently found in most deposits (see Section 6.7.3 below, Vessels LHR-γ)

6.5.2 Application of slurry or rustication

As mentioned in Chapter 3, the application of a rustication - a thin or thick coarse slurry - on the surface of vessels is found across the Indus zone and beyond, e.g. on Hakra ceramics, and Sothi-Siswal, Ravi, Kot Diji, Tochi-Gomal, Sheri Khan Tarakai, Jalipur I, and

Harappan pottery assemblages (Uesugi 2011: 99; Khan et al. 1991: 39). However, the stylistic and functional aspects of such applied rustication, whether it was the result of manufacturing process or a mindful stylistic/functional choice, is still under investigation (Rye and Evans 1976: 53; Dales and Kenoyer 1986: 42; Rice 1987: 138, 232; Petrie 2010: 82-83). Vidale (2000: 84) ascribed this surface treatment to the category of 'positive treatments', when Indus vessels show partial coating of the outer surface with coarse clay-rich slurry, mixed with sand and other sediments. He has suggested that, on water jars, such coatings may have improved the cooling function; alternatively, on cooking vessels, the coarse slurry may have protected the lower portion of vessels from thermal shocks (Vidale 2000: 84). The applied rustication may have served a protective function against friction from the ground during movement and transport of storage jars, as well as improving grip and manageability of globular jars. A combination of all the above could also be proposed. Sandy coatings, or kankar/calcrete-rich slurries were applied in horizontal bands on the lower portions of large globular vessels often combined with painted black designs, combing and incisions. Some of these bands appear to have been created by a broad slurry that has then been scrapped. They might be also found on small and medium sized vessels. Slurries were usually applied without rotational gestures , and they might vary in terms of grain-size, texture, composition, and thickness.

Sherds at LHR I Trench EA show a few varieties of applied rustication, also known as '*mud applique*' by archaeologists working in Rajasthan, Haryana and Uttar Pradesh. Usually, the rustication is applied on the outer surface of the lower portion of vessels, starting from the jar's shoulders or mid-body downwards. Most shapes are globular vessels with concave base, ring base or flat base (e.g. sherds 201, 200, 202). The neck is very short and the rim is usually everted, showing painted motifs on the edge of the rim. The upper edge of the rustication can be found associated with a black painted line decoration. Four main different types of rustications could be identified:

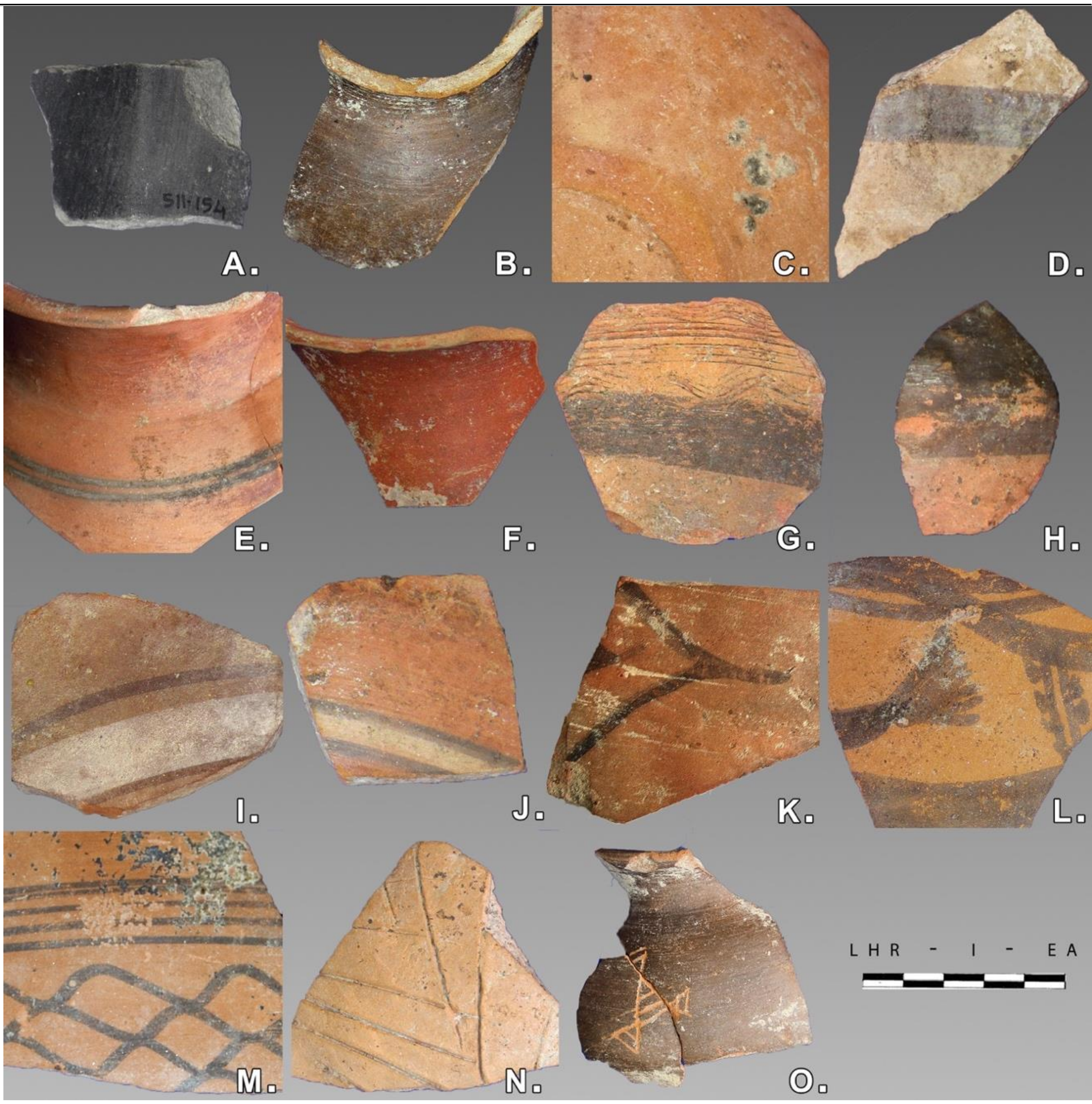
F-NW-KR: applied fine paste kankar-rich rustication (**-KR**, or *mud appliqué* 1), it is applied to the external surface of ceramics, often associated with scraping marks on the inner surfaces of the sherds (see 6.9: A, D, and E). It can be sub-dived into:

F-NW-LR: a thinner layer is applied, Light Rustication (or *mud appliqué* 2);

F-NW-CR: a thicker layer is applied, Coarse Rustication (or *mud appliqué* 3). This type is the only one which is also rarely found on both the inner and outer surface of certain types of bowls (see Appendix D: Plate II, Bowl Type 3C);

F-W-FR: a finer recipe, with a smaller-grain size paste. No temper or inclusions are visible in the slurry (see 6.9: F). This seems to have been applied by the producers using their fingers, thus named applied Finger Rustication (-**FR**, *mud appliqué* 4) mostly on wheel-finished vessels.

Figure 6.9 Surface treatments. A: black burnished surface; B: chocolate slip, polished; C: possible 'self-slip', red; D: chai slip, black painting; E: thin black painted lines and red slip, polished; F: deep red slip; G: black painted thick band and incisions; H: black painted decorations; I: bichrome, black and white painting; J: bichrome, black and white painting; K: pipal leaf painted decoration; K: peacock painted decorations and lines; M: fish-scale and wavy painted decorations; N: surface cuts or incisions; O: post-firing graffiti.



*6.5.3 Perforations and incisions (**F-NW-P**)*

A distinctive set of manufacturing techniques was observed on fragments of perforated vessels. Perforations (**-P**), or small holes, are pierced from the outer surface towards the interior trough the walls of cylindrical vessels (Figure 6.8:G; also see Appendix D: Plate IX). After the holes where made through the walls of vessels from outside inwards, the inner surface was scraped to remove the resulting surplus of clay and flatten the edge of holes. Such perforated vessels are made out of a fine clay paste (**F-**), sometimes showing small calcareous inclusions; they seem to have been formed without the use of any rotational gestures (**-NW**), or very limited use of rotational motions or devices. A larger hole is often found in the middle of the bases of such vessels. This form is often found at Indus sites, as mentioned in Chapter 3, and they are usually referred to as *Perforated Jars* or *Cut Ware* (e.g. Marshal 1931: 465; Mackay 1938: 181; Dales and Kenoyer 1986: 57, 423; Madhu Bala 2015: 405-407; also Rice 1987: 147;).

Two styles of decorative incisions have been identified at LHR I, Trench EA. They are either performed on the exterior surface of jars and bowls, or on the interior surface of bowls.

Exterior: four distinctive sub-classes of exterior incision could be identified according to their most frequent patterns. These include can be wavy lines (-EXT-WL), parallel combed incisions (-EXT-C), deep combed incisions (EXT- DC), and shallow cuts (-EXT-CUT). These are different from incised lines and deep combed decoration. It is often difficult to understand the shape and location of combed decoration. Rare black painted lines (e.g. sherd LHR-I-EA-613; Figure 6.9:G) are also found on combed decorations.

F-EXT-WL: wavy lines are mostly associated with vessels that were manufactured with little to no use of rotational gestures or devices. Wavy lines are often associated with parallel combed incisions, as well as black painting, mostly in the form of bands or parallel black lines (Figure 6.8:I, J; and Figure 6.9: G). Similar decoration has been found at Girawad, Sothi, Hanumangarh, Rajasthan, and Siswal, Hisar, Haryana (see above Section 3.8).

F-EXT-C and **F-EXT-DC**: parallel combed incisions can be shallow and are not necessarily symmetric or straight (-C); or perfectly parallel and quite deep (-DC). The latter type is often associated with the use of abundant rotational gestures and possible use of rotational devices. The former type seems to have been performed using a sharp or semi-sharp object; while the latter type seems to have been incised using a comb with rounded or flat points (Figure 6.8: I, K, L; and Figure 6.9: G).

F-EXT-CUT: these incisions seem to be rare and are quite different from the most abundant incisions at the site. The incisions are quite shallow and seem to have been performed with a sharp object. They are usually found on the body of vessels (Figure 6.8: I, J; and Figure 6.9: N). This type of incision resembles decoration identified at Sothi, Hanumangarh, and Ganeshwar in Rajasthan (see above Section 3.8 and 3.13).

Interior (**F- INT-WL**): a few fragments of red bowls with black paintings show incised patterns on the inner surface. The practice of performing incisions on the interior of bowls was also observed at other sites in the region, such as Kalibangān and Shyamlo Kalan, Jind (Garge 2010). The incised motifs are generally simple, restricted to parallel grooves or wavy parallel lines (Figure 6.8: H).

6.5.4 Polishing and burnishing

It is not always easy to distinguish between polishing and burnishing techniques in the studied corpus of vessels. These techniques produce similar effects on pottery, a smooth, glossy surface, and they can be used in combination. Smoothing and polishing techniques seem to be quite widespread, and are found on most red slipped (Figure 6.9: G, D, M) and chocolate slipped (Figure 6.9: B, O) vessels. However, burnishing techniques seem to be more limited, and can be inferred from certain traces on vessel surfaces that are indicative of the use of a hard or semi-hard object for performing the burnishing on leather-dry vessels. In particular, two groups of vessels show the clear use of burnishing techniques: burnished black bowls and dishes (Figure 6.9: A); and burnished black-on-red jars (Figure 6.9: E). The former tend to show burnishing marks on both inner and outer surfaces, and the latter show careful burnishing on the outer surface.

6.5.5 Painting

Painted ceramics at LHR I, trench EA have been identified and classified into two macro categories: a black-on-red type; and a bichrome (black and white on red) variety. Even though this study will not rely on painted decoration for assessing technological traditions, painting patterns and motifs have been observed and partially considered (see Figure 6.10). Black painted decorations of the Early Indus phases are generally limited to simple patterns, such as multiple horizontal or wavy lines. Painting usually starts at the rim and moves down to the neck, shoulder and body of vessels. Right before and during the urban phenomenon of the Indus Civilisation, the inventory of painted motifs is said to become richer, with designs such as fish-scale patterns, pipal leaves, circles and geometric shapes, festoons with applied round dots (Kenoyer 1998: 153). painted decoration is often believed to give a distinctive Harappan taste to ceramic products. Sherds showing certain painted motifs originally intended to be black lines, appear purple rather than black on misfired ceramics (see Figure 6.9: I). This might suggest that the composition of the slurry used for painting may have been particularly manganese rich. For instance, at Lohari Ragho I, Trench EA, black-on-red painted motifs can be described as follow:

a. A single thick band on the rim and neck, not to be confused with chocolate slip;
b. A single narrow band, in close proximity to or on the rim (inner and outer portion). For instance, on bowls with upright rims, painted with a straight line on the rim (e.g. sherds 637, 638);
c. Multiple thick bands on the rim, neck and upper body;
d. Multiple narrow bands on the body of vessels;
e. Parallel bands and wavy bands, which are arranged to show a fish scale-like pattern (Figure 6.9: M, also see Girawad sherds 1344 and 174); and
f. Figurative motifs, e.g. vegetal, peacock, horn or *pipal*-leaf motifs (Figure 6.9: K, L).

A distinctive type of bichrome painted decoration was also identified. This black and white on red painting resembled motifs and techniques identified at sites such as Girawad, Kunal, Sothi, and Siswal (see Section 6.7.1, LHR- α3**)**.

6.5.6 Post-firing graffiti

A distinctive feature of the ceramic corpus is the presence of graffiti, carved on fired chocolate slipped vessels, and post-fired vessels that show limited use of rotational gestures. Star patterns, triangles, zig-zag lines, tree-like motifs, intersecting triangles, V-shape and Y-shape motifs, as well as parallel lines are found. They seem to have been carved mostly on sherds of small and medium jars, rarely on bowls (see Figure 6.9:O) . Similar geometric graffiti have also been identified at Pre-Urban and Early Urban sites such as Girawad, and also Masupur VII and Burj (Parikh and Petrie 2016).

Figure 6.10 Examples of painted decorations (colour code: dark grey) on red slipped (colour code: light grey) vessels from LHR I, Trench EA.

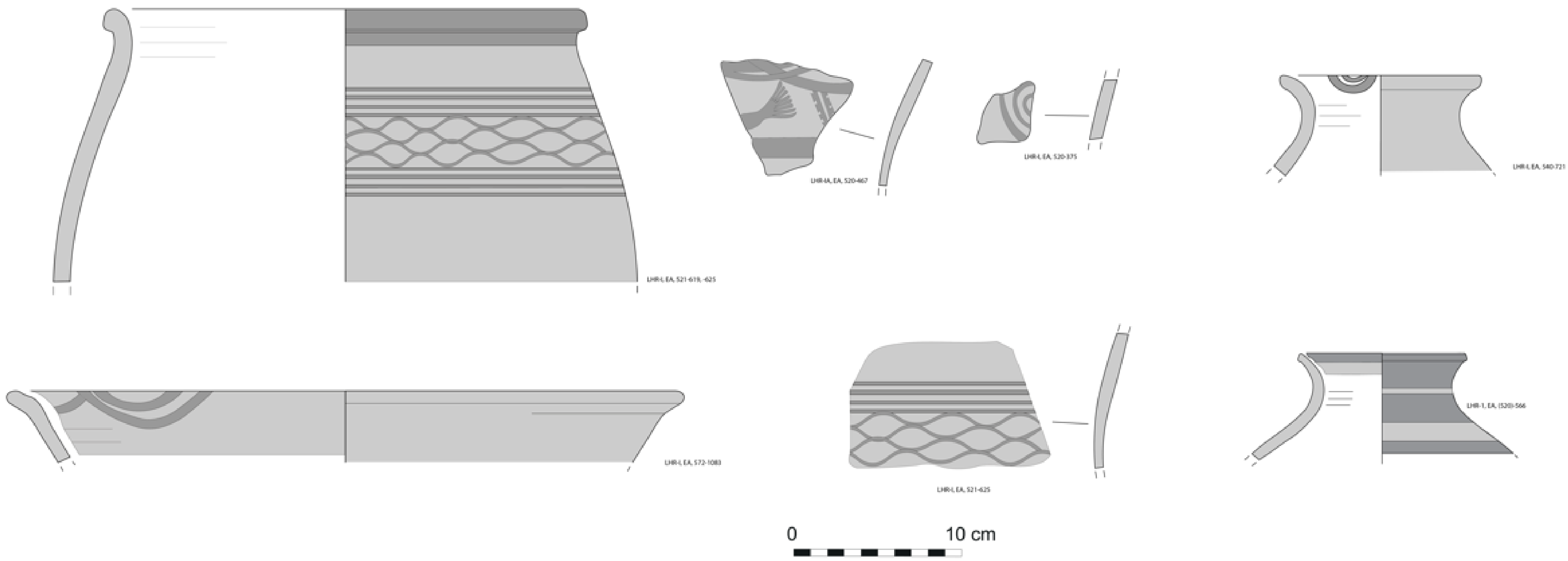
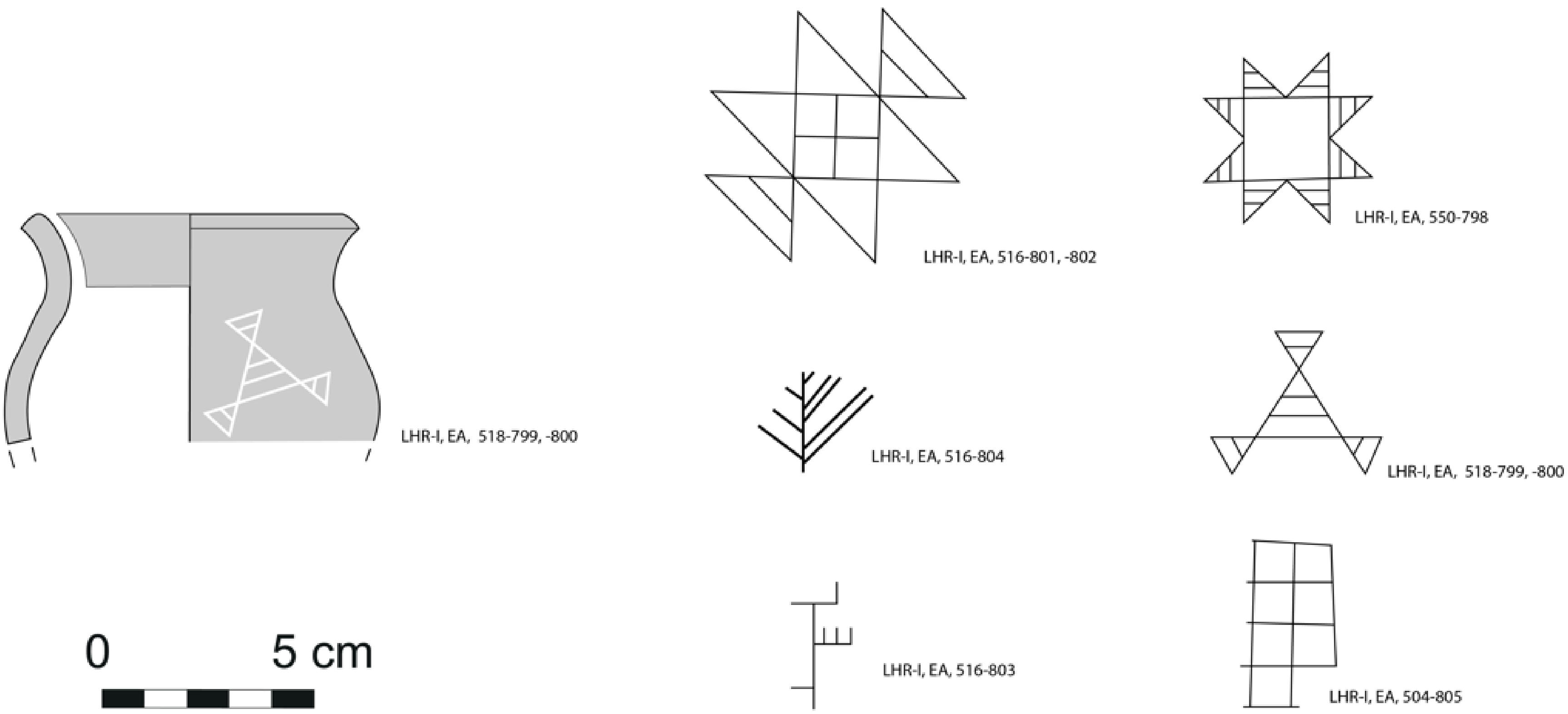


Figure 6.11 Post-firing graffiti from LHR I, Trench EA.



6.6 Coarse (C-) fabrics associated techniques

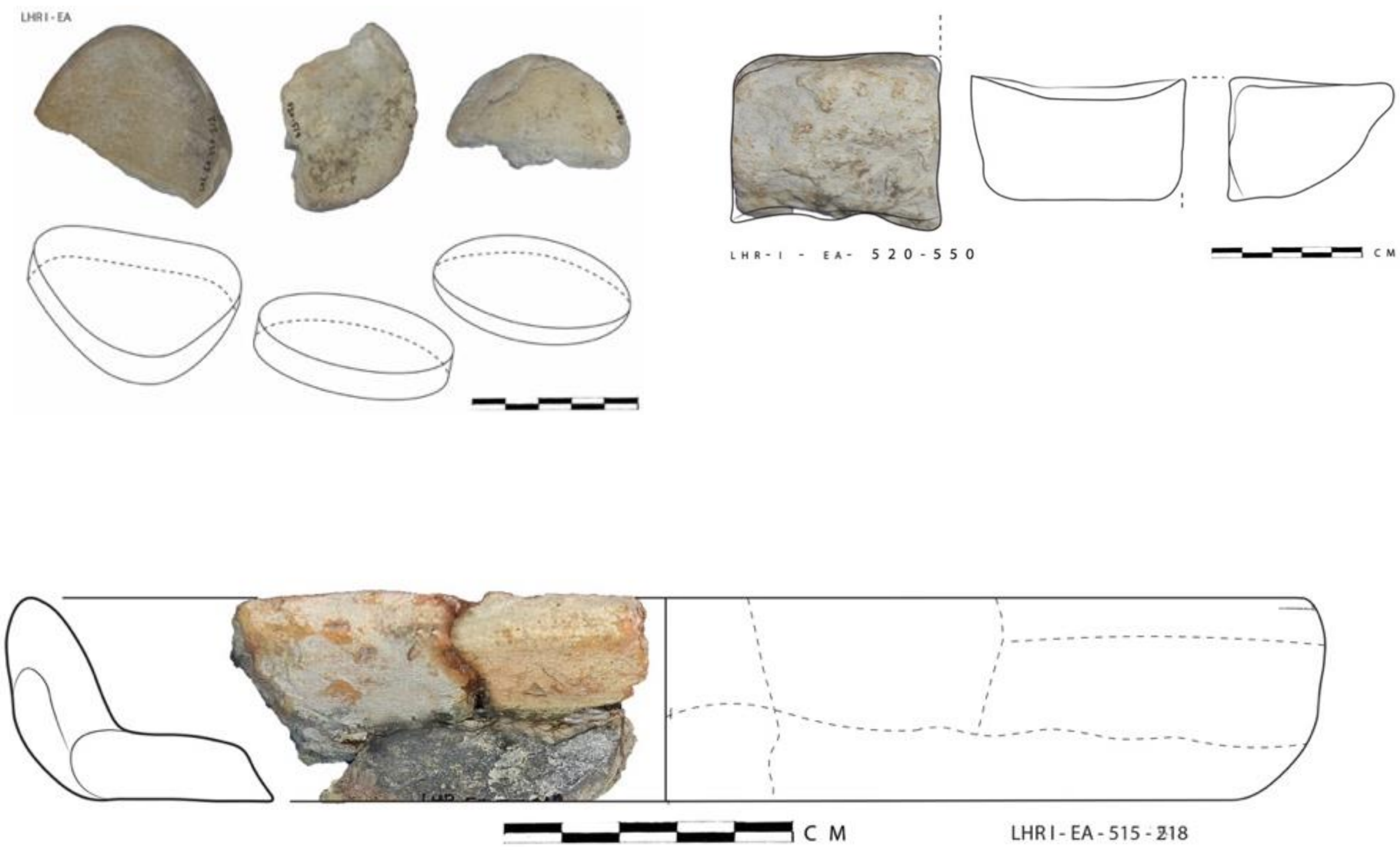
*6.6.1 Moulding (**C-M**)*

Fragments of ceramics that seem to show evidence of moulding as the main forming technique were sorted as a separate group (see Figure 6.12). The majority of these ceramics were produced using a medium coarse to very coarse clay paste, often mixed with vegetal or chaff temper. Moulded coarse ceramics include fragments of bricks, either fired (**C-M-CBM**) or unfired mud-bricks (**C-M-UM**), and the 'terracotta cakes' (**C-M-TC)**.

*A1. Terracotta cakes (***C-M-TC***)*: terracotta (**-TC**) cakes are well known among archaeologists operating in South Asia, and have been largely considered as one of the most iconic ceramic objects of the Indus Civilisation. They appear in a number of shapes, and can be triangular, disk shape, oblong, or '*idly*-shaped' ceramic objects (see Figure 6.12) that are not particularly large, and can be held in one hand (Pradhan 1999). Hundreds of thousands of terracotta cakes have been recovered from Indus sites (Jarrige et al. 2011), and they have been sometimes found associated to firing structures, such as kilns and hearths. This association has lead to the suggestion that terracotta cakes were possibly used for retaining heat during firing and cooking, or placed near the base of globular cooking pots to keep them steady in position during the cooking process (Ceccarelli, forthcoming). Indirect heating techniques have been observed as early as Mehrgarh Neolithic, where circular hearths filled with burnt pebbles or with terracotta nodules (Jarrige et al., 1995: 455). Currently, the generally accepted interpretation is that with the emergence of the Indus civilization, terracotta cakes replaced pebbles in the hearth zones. However, some cakes have shown graffiti or seal impressions, suggesting that they might have had an administrative role, e.g. stamped TC cakes at Jhandi Babar A (Khan et al. 2000). Teracotta cakes have also been found beyond the Indus zone, in the Iranian plateau (e.g. Shahr-I Sokhta; see Cortesi et al., 2008: 17). The earliest examples of terracotta cakes are believed to have been found at Mehrgarh Period VII (Jarrige et al., 1995: 237) and at Nausharo I (Jarrige et al. 2011), preceding the Indus Civilisation. However, it is still difficult to explain the relation between the terracotta cakes of the first half of the third millennium BC and their mass production during the Indus civilization across the vast Indus zone.

A2. Ceramic Building Material and unfired mud-bricks (**C-M-CBM**; and **C-M-UM**): Indus ceramic building material (-**CBM**) is here defined as a clay body that has been deliberately

Figure 6.12 Schematic representation of ceramics manufactured using coarse clay paste (i.e. *top*: moulding techniques, e.g. Terracotta cakes and bricks; *below*: SSC technique, e.g. tray).



fired for use as part of a structure. Within the context of Indus sites, this category includes bricks, floor tiles, kiln firebars, and kiln lining. They have been likely produced using local easily obtained clays, which is mixed together with sand and vegetal or chaff temper, and rarely with grog and ash. CBM is found at most Indus sites. As they tend to be durable and form a major constituent of many structures, CBM fragments are often a significant percentage of a ceramic corpus found at Indus sites. Although there is neither high variability of morphology, nor extensive available studies on Indus CBM, fragments can be used to observe variation in fabrics, and identify local clay sources.

*6.6.2 Slab construction (**C-S**)*

A distinctive type of shallow, large trays or basins is produced using coarse (**C-**) ceramic paste, abundantly mixed with vegetal or chaff temper (see Figure 6.12). The rims are usually thick and heavy, and upright. Given the friability of these ceramic vessels, and the highly fragmentary conditions of the sherds recovered, it is not possible to provide a comprehensive analysis of coarse trays. Nevertheless, the likely use of thick coils or slabs **(-S**) during the manufacturing process could be inferred from the distinctive fractures between the base and the walls, and along the walls. To an extent, the combination of vegetal temper and tray-like morphology resembles the contemporary ceramic industries of Iran, (e.g. Iranian husking trays), and South Asian SSC chaff tempered vessels of the fourth to third millennium B.C. (Rice 1999; Smith and Bagherzadeh 1976; Vandiver 1985, 1987). However, using these similarities for tracing a connection would be premature.

6.7 Techno-groups

Depending on the method and scale of observations, the ceramic assemblage discovered at LHR I, trench EA, can be considered both highly variable and somewhat homogeneous. The diversity is expressed on two levels: forming techniques, and finishing operations. Homogeneity is expressed at the level of the clay pastes, including macroscopic variations of colours and composition, and partially at the level of the morphologies. The vast majority of vessels (large or small, open or closed) seem to show preliminary forming techniques, such as coiling, or possibly wheel-coiling. The coils were likely joined and thinned using scraping technique, with or without the use of RKE or rotational devices. Finishing techniques include those operations which aimed to transform the walls, and decoration.

Table 6.2 Summary and significant features of LHR techno-groups.

Group	Sub	Code	Paste	Forming Method	Finishing	Rustication	Slip	Polishing or Burnishing	Cutting or Incisions	Painting	Most common Shape
	LHR- α1	F-NW-A		Method 0	Scraped		Red		None or Incisions	Black	Bowl
LHR-α	LHR- α2	F-NW-B		Method 0	Scraped	F-NW-KR F-NW-CR F-NW-LR	Red, or Chai		-	Black	Bowl or Globular Jars
	LHR- α3	F-NW-C		Method 1	Scraped		Red, or Chai		-	Black	Globular Jars
LHR-β		F-NW-		Method 1/3	Scraped	-	Red	-	Perforation	No	Tall, cylindrical Jar
LHR-γ		F-NW-?	Fine (F-)	Method 1/3	Assembled (Stand)	-	Dark Grey or Black	Burnished		No	Bowl or Dishes; on-Stand.
LHR-δ		F-NW-C, or F-W1		Method 3/1			Chocolate	Polished		No	Small water Jar or Bottle
LHR-ε	LHR- ε1	F-W1		Method 3	RKE or Scraped	-	Red	Polished		Black; Black and White	Small or Medium Jar
	LHR- ε2	F-W1		Method 3	RKE or Scraped	None, or F-W-FR	Red	Polished		Black	Medium or Large Jars
LHR- ζ		F-W2		Method 4	RKE	-	-	Polished	-	Black	Small Jars
LHR- η		C-S	Coarse (C-)	SSC	-	-	-	-		No	Shallow, large bowl
L HR-θ		C-M		Moulding	-	--	-	-		No	Cakes or Bricks

The analysis of technical actions has resulted in the identification of eight main technological groups of vessels (see Appendix H: Table H.5). The groups have been organised using letters of the Greek alphabet, from *α* to *θ*. The technical actions and macroscopic technical features identified and described above will now be combined to present a comprehensive understanding of each ceramic tradition and the production of specific groups of vessels. Preliminary forming techniques and the use (or not) of rotational gestures and devices are both still central in this part of the Chapter, as well as certain finishing techniques and surface treatments previously described. Chapter 3 can be used as reference and offers a list of technical concepts and nomenclature used in the following section.

6.7.1 Vessels LHR-α

Red vessels produced with limited use of rotational gestures (Figure 6.13) have been identified in all deposits in trench EA at LHR I. These vessels seem to have been formed using a combination of techniques, including coiling, scraping and smoothing (***F-NW-A, -B,*** and ***-C*** see above). This mostly corresponds to *method 0* or *method 1* (see above Table 6.1). The quality of vessels ranges from approximate or low, to high (see below). Rims and walls are often irregular, reflecting a certain degree of variability in the forming process. The outer surfaces tend to be smooth and red slipped and/or painted; while the inner surfaces tend to show scraping marks and incisions. The core of the walls tends to be red, thus indicative of a thorough oxidising firing process. Bowls, small jars, medium globular jars, and jugs seems to be the most frequent morphological categories. The most common forms are bowl with upright rims or jars with out-curved rims, hemispherical body and out-curved necks. Bases are usually concave or flat, and applied rings can also be found on the external surfaces of the bases. Some jars show a handle, attached directly on rim and body.

In terms of surface treatments, the lower portion of certain vessels, especially globular jars and bowls, show an applied rustication (**-KR**, or *mud appliqué* 1). The rustication is applied on the external surface, and is often associated with scraping marks on the inner surfaces (see Figure 6.8: A, D, and E). Incised wavy lines and parallel combed incisions on vessel surfaces, as well as black painting, mostly bands or parallel black lines, also occur (Figure 6.8: I, J; and Figure 6.9: G).

Figure 6.13 Above: some rusticated vessels of the LHR- α tradition, globular and elliptical jars. Below: examples of fragments of LHR- α (1-2) vessels.

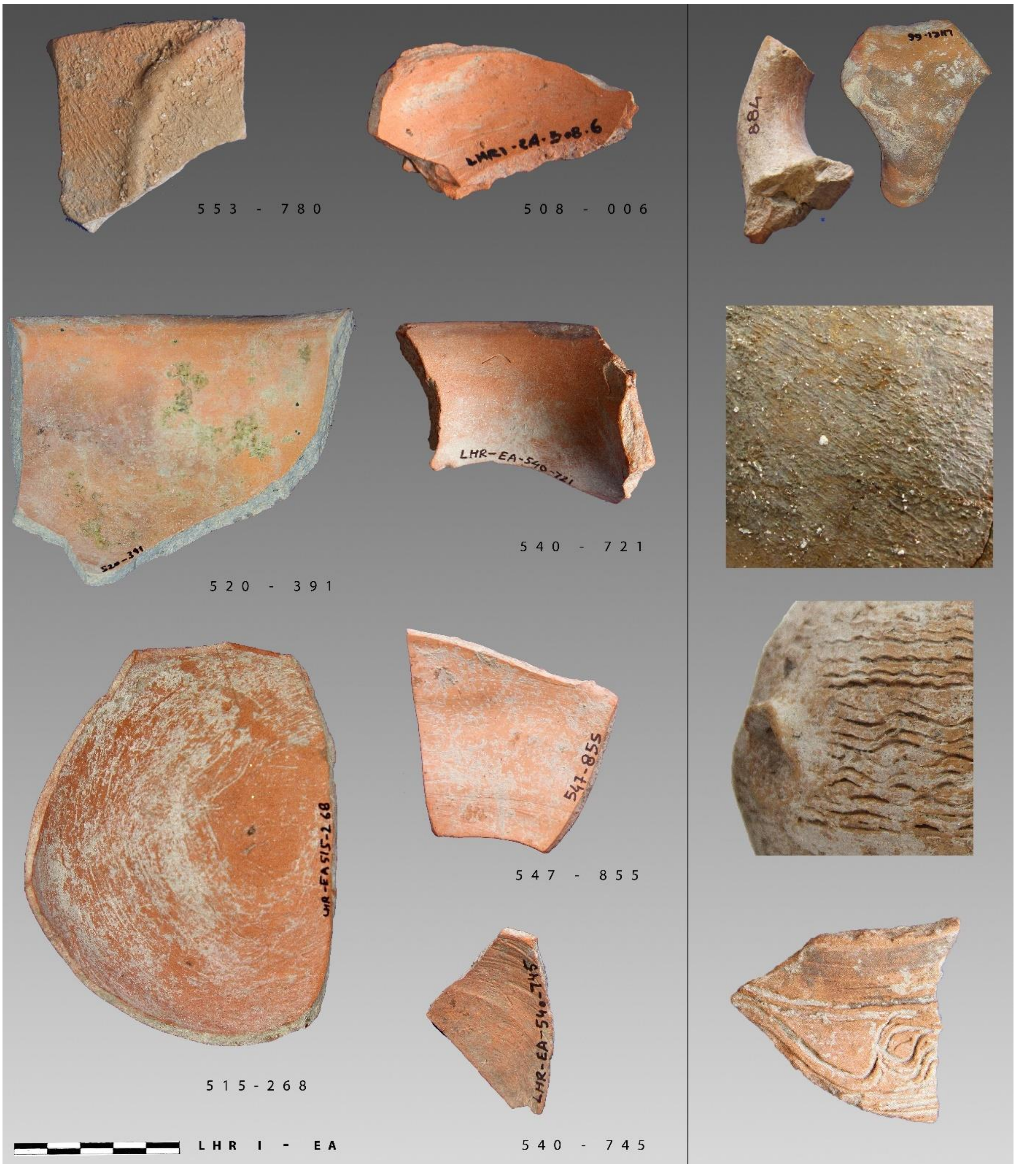
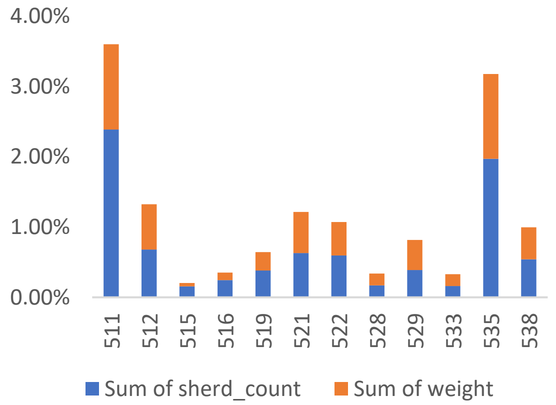


Figure 6.14 Presence of Bichrome painted pottery in the corpus (% per context and total assemblage).

context_id	Sum of sherd_count	Sum of weight
511	2.39%	1.21%
512	0.68%	0.64%
515	0.15%	0.05%
516	0.24%	0.11%
519	0.38%	0.26%
521	0.63%	0.59%
522	0.59%	0.48%
528	0.17%	0.17%
529	0.39%	0.43%
533	0.16%	0.17%
535	1.97%	1.21%
538	0.54%	0.46%



Rare fragments of red bowls with black painting show incised patterns on the inner surface, which resembles *Fabric D* bowls from Kalibangān (Madhu Bala 1997; 2003). Red slip and *chai* slip, including pale reddish-brown to red in colour, visible on both the outer and inner surfaces. It can be sub-dived into three sub-groups, the descriptions of which will follow.

"Low" and "Medium Quality" Vessels – **LHR- α1**: from a technical perspective, this sub-group includes bowls and jars that have been shaped using little to no use of rotational gestures and devices (NW-A and NW-B). This group tends to not show the use of applied rustication.

"High Quality" – **LHR- α2**: from a technical perspective, this sub-group includes bowls and jars that have been shaped using rotational gestures and devices during the finishing stage. Parallel striations are particularly visible in close proximity of rims and are associated to certain surface treatments (**NW-A** and **NW-B**). This group also includes vessels with applied rustication and bichrome painting. Bichrome painted white and black on red ware have been identified at Kalibangān (Fabrics A and B; see Madhu Bala 2003) and Sothi (see above Section 3.8) and other sites (e.g. Kunal and MSD VII), and are believed to be part of the broad genre of Early Harappan pottery. Here in Trench EA at LHR I, fragments of bichrome painted vessels are rare and have been recovered from limited contexts (less than 1% within each context; see Figure 6.14). Moreover, given the fragmentary and particularly small-size of these sherds, they could be as considered extrusive contamination, thus are not reliable chronological markers.

"Hyper-micaceous Vessels" – **LHR-α3**: these vessels show a clay paste that seems to be particularly mica-rich. The manufacturing process likely involved limited to no use of rotational motions, and the outer surfaces show a distinctive bright red paint applied to the upper portion of vessels. The body of vessels shows distinctive incisions, such as lines and criss-crossed lines, on the lower portion of vessels (**F-EXT-CUT**). This combination of decoration resembles vessels identified at Sothi, Ganeshwar, Bagor, and Gilund in Rajasthan (see above Section 3.8). In particular, these vessels show similarities with the incised pottery from Bagor phase 2 (Misra 1973b) and incised pottery from Chalcolithic Gilund (IAR 1959-60, plate: XLIV). Given the low frequency of these sherds in the assemblage, they are considered as exceptional, and are representative of a separate group within the LHR I corpus.

Figure 6.15 Some fragments of “Hyper-micaceous” Vessels – *LHR- α3.*

Figure 6.16 Some fragments of Vessels LHR-β, perforated, cylindrical jars.

6.7.2 *Vessels LHR-β*

Perforations are primarily applied to distinctive tall, cylindrical jars, whose body was entirely pierced with a small tubular object. These vessels represent 1.34% of all ceramic fragments, and 1.55% of the total weight (see Figure 6.17). They seem to have been firstly formed using a fine clay paste, and formed with little to no use of rotational gestures or devices. Coils, possibly large coils or slabs, along with scraping technique appear to be the primary manufacturing techniques (Method 1 or 2, see Table 6.1). Perforations were likely undertaken at a semi-dry or leather-dry stage, piercing the walls of vessels from the outer surface towards the interior of vessels. The resulting excess of clay material was typically then scrapped out and levelled from the inner surface, resulting in distinctive rings around the holes on the inner walls. The core of the walls tends to be red, thus indicative of a thorough oxidising firing process. Tall, cylindrical jars are the dominant morphological category. Bases are usually flat, frequently showing a large circular hole in the middle of the base (e.g. Figure 16, sherd 520-433; also see Appendix D: Plate IX).

Figure 6.17 Presence of Perforated Jars in the corpus (% per context and total assemblage).

context_id	Sum of sherd_count	Sum of weight
515	0.15%	0.10%
518	0.26%	0.06%
520	0.34%	0.23%
522	0.07%	0.74%
528	0.04%	0.02%
529	0.19%	0.29%
538	0.27%	0.11%
Total Assemblage	1.34%	1.55%

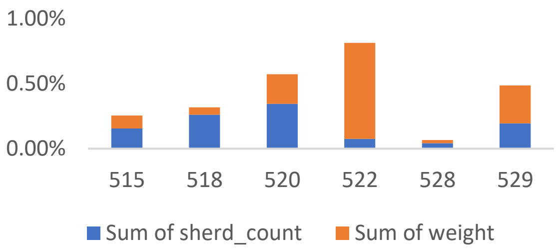


Figure 6.18 Quantity of fragments of Black Burnished vessels from LHR-I, EA.

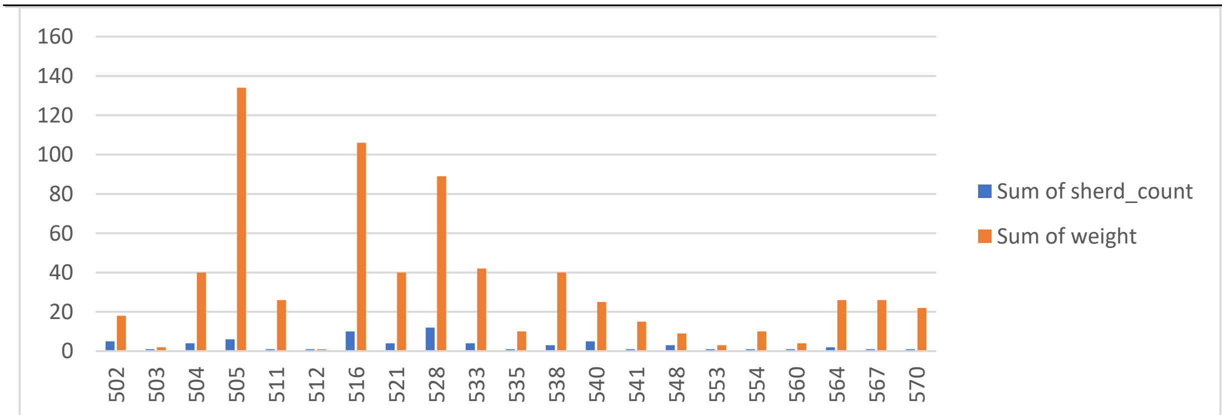


Figure 6.19 Some fragments of Vessels LHR-γ, black or dark grey burnished vessels.

6.7.3 Vessels LHR-γ

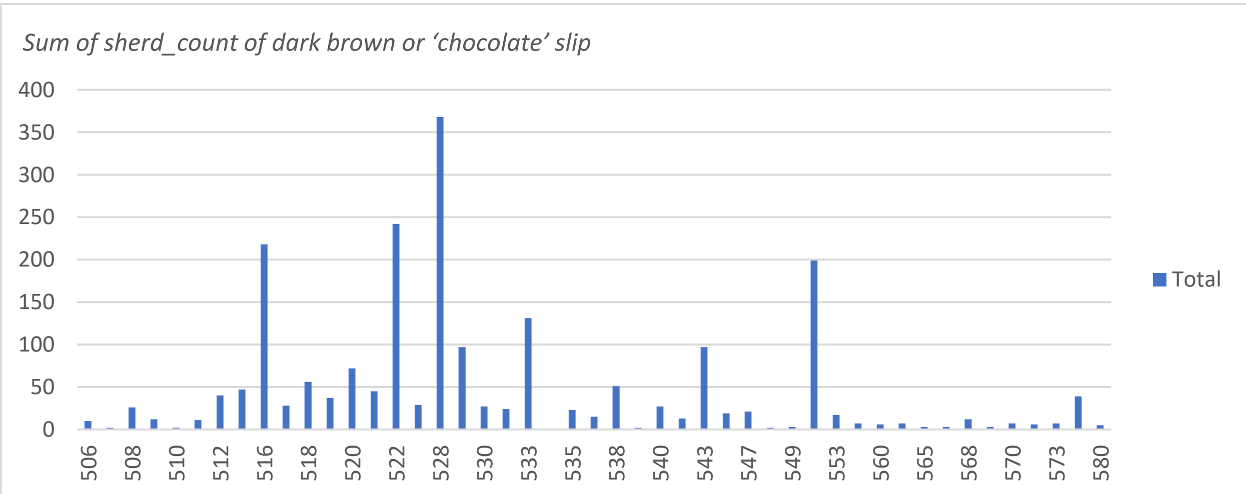
Burnished black or dark grey vessels (Figure 6.18) have been identified in twenty-one deposits and represent 0.25% (68 sherds) of all ceramic fragments, or 0.60% (688 grams) of the grand total weight (Figure 6.19). The finishing stage of these black or dark grey vessels are extremely sophisticated, compared to most of the contemporary red wares. The burnished, dark surfaces suggest advanced coating and smoothing operations. However, rims and walls are not always regular, reflecting a certain degree of variability in the forming process. Both the inner and outer surfaces are burnished using a hard tool, possibly wood or a pebble, and present a black to dark grey slip. The core of the walls is also grey, thus indicative of a thorough reducing firing process. The most frequent morphological categories include bowls or bowls-on-stand. They mostly show out-curved neck, an hemispherical or carinated body, and out-flaring, thick rims. Dishes, bowls, and less common dish-on-stands or bowl-on-stands are found n the corpus of ceramics in trench EA at LHR I.

6.7.4 Vessels LHR-δ

Chocolate slipped jars are the some of the most sophisticated ceramic vessels at LHR I. They appear to fully oxidised jars, showing a red core and red inner walls, which are partially covered with a dark brown, brownish black or purplish black slip on the outer walls. The slip can be a thin (see Figure 6.9:H) or thick layer, which in some cases tends to fade out or peel off. The dark slip is mostly applied from the rim to the lower portion of the vessels, often leaving the lower portion of the outer walls uncovered. In most cases, the lower portion can show a red slip or a light applied rustication. The slip can also be found on the inner walls of the vessels, limitedly in proximity of the rim, in the form of a narrow band. The presence of abundant mica in the clay slurry, as well as polishing or burnishing finish, tends to give a glossy, deluxe appearance to these vessels.

In terms of manufacturing techniques, these vessels show the limited use of rotational gestures in the final forming stage (see Method 1 and 3). The bases and rims in particular show regular parallel striation marks, which suggest the extensive use of rotational gestures and likely rotational devices. Similarly, the applied slip seems to show parallel grooves on the outer slip, suggesting a rotational motion for applying the clay-rich slurry. They represent 12.8% of all LHR I ceramic fragments, or 7.95% of the total weight (Figure 6.19).

Figure 6.20 Top: fragmetns of Vessels LHR- δ: Chocolate slipped small jars. Below: quantity of fragments showing the characteristic slip: they represent 12.8% of all LHR fragments, or 7.95% of the total weight (Figure 6.19), with 62.3% of these fragments showing marks on the internal surfaces suggesting rotational gestures or motions.



However, the morphology of the body of vessels seem to be slightly irregular, undulating and mostly asymmetrical, with inner walls showing coil-joints, scraping marks, and finger impressions. Morphologically, chocolate slipped vessels include medium to small vessels including globular jars with a short neck and out-turned rims, or globular jars with high neck and narrow neck (see Appendix D: Plate VI). These vessels could be considered deluxe water jars or bottles, a sort of tableware comprised of small and medium size vessels. Ring bases are a common feature of these vessels.

Across archaeological sites in the Indus zone, the description of black, brown and dark slips in general often depends on subjective perceptions of the archaeologists studying the ceramics. A variety of ceramics broadly similar to the **vessels LHR-δ**, or chocolate slipped vessels, have been identified as Hakra Black Burnished ware from the surface of sites in Cholistan (Mughal 1997: 66; Rao et al. 2005), as well as within assemblages excavated at Baror, Bhirrana (Dalal 1980), and Rakhigarhi (Amarendra Nath 2014). Also, some early Amri sites and the Sothi black slipped assemblage (Dikshit 1984) seem to show similar morphologies and surface treatment as **vessels LHR-δ**.

A number of features can help to distinguish **vessels LHR- δ**, or chocolate slipped vessels, from the **vessels LHR-γ**, or burnished black or dark grey vessels. The most obvious distinction is that the former are fully oxidised vessels, showing red walls and red cores, covered with a dark brown to purplish black slip on the outer surface; while the latter are fully reduced vessels, showing dark grey to black cores and walls, covered with a dark slip on both inner and outer surfaces.

6.7.5 Vessels LHR-ε

The second most abundant group of ceramics is the **Vessels LHR-ε** techno-group. This group is defined by a combination of sophisticated forming techniques and high control during the manufacturing process, including preliminary coiling and marks associated to abundant use of rotational gestures. Parallel horizontal striations are not only confined to the upper portion of vessels, mostly on the interior surfaces of rims and necks, but they can also be found throughout the whole length of vessels – from rim to base, on both thick or thin walls (see above, technical actions **F-W1** and **F-W2**). Most diagnostic fragments of rims show clear parallel striations. This is still indicative of vessel rims being possibly crafted separately and attached to the vessel using a rotational motion in a subsequent phase of manufacture; or that the rotational devices were used more abundantly mostly in the final stage of fashioning. These type of vessels tend to show a red slip, and black-on-red painted decorations. Some jars, mostly medium or large jars, show a particular type of surface treatment: (**F-W-FR**) a fine applied rustication, using small-grain size clay slurry. No temper or inclusions are visible in the slurry (see Figure 6.8: F), which seems to have been applied by the producers using their fingers, thus named applied Fingers Rustication (-**FR**, or *mud appliqué* 4):

In terms of morphology, this group is possibly one of the evocative of a regional Indus or regional Harappan flavour (see Appendix D: Plate IX). Distinctive forms, such as dishes, bowl, jars with tall and narrow necks, jars with wide mouths, and goblets are the most common shapes. These have also been identified at other sites in the macro-region, including Rakhigarhi (Amarendra Nath 2014), Girawad (Uesugi 2011), Masudpur (see below Chapter 7), and Mitathal (e.g. from Trench A4, MTL-1; see Manmohan Kumar et al. 2012), but they also resemble assemblage from Farmana, including Harappan jars (Uesugi 2014: Fig 6.30), Harappan bowl types (e.g. Farmana Burial no. 10; see Uesugi 2014: Fig 9.7)

Figure 6.21 Fragments of Vessels LHR-ε: Wheel-finished storage Jars, dishes and medium jars.

and non-harappan bowl types 2 and 3 (Uesugi 2014: Fig 9.19). However, a number of shared morphologies with Vessels LHR-α are also produce within this technical groups (see Appendix D: Plate V), which appear to differ mostly in terms of technical actions, skills and mastery of techniques. These aspects will be further discussed Chapter 8.

6.7.6 Vessels LHR-ζ

These vessels, mostly small jars, show perfectly parallel striations and grooves, which are often found throughout the whole wall of vessels – from rim to base, on thin walls. Most diagnostic rims show clear parallel striations (**F-W2)**. This type of vessels includes the rarer type of slip, vibrant-red to deep red in colour. It is usually associated with profuse polishing and even burnishing of the outer surface of vessels. Only a few, rare specimens have been identified at LHR I (see Figure 6.9:E; also see Appendix D: Plate IV) and considered for this study.

6.7.7 Vessels LHR- η

These distinctive shallow, large trays or basins are produced using coarse (**C-**) ceramic paste, abundantly mixed with vegetal or chaff temper (Figure 6.12). The rims are usually thick, heavy, and upright. Given the friability of these vessels, and the highly fragmentary conditions of the sherds recovered, it is not possible to provide a comprehensive analysis. Nevertheless, the likely use of thick coils or slabs **(-S**) during the manufacturing process could be inferred from the distinctive fractures between the base and the walls, and along the walls. To an extent, the combination of vegetal temper combined with the use of coils and slabs (**C-S**), and tray-like morphology resembles other contemporary ceramic industries from neighboring areas or earlier periods (see above Section 6.6). However, using these macroscopic similarities for tracing a direct connection or parallel histories of these ceramic industries would be premature, and shall not be here discussed. Given the very limited presence of these vessels in the studied corpus, these will not be considered in subsequent stages of analysis and will not be included in the following section.

6.7.8 Ceramics LHR-θ

Terracotta (**C-M-TC**) cakes, *Ceramic Building Material* and *unfired mud-bricks* (**C-M-CBM**; and **C-M-UM**) have already been discussed above (Section 6.6) Given their unique recipe and manufacturing technique, they can be grouped into one local tradition of ceramic production. Assuming that the recipes of ceramic building material (CBM) and terracotta cakes, overly abundant in the studied corpus, have been prepared using locally available raw material in proximity to the site, this will be considered in the following section and used in further stages of the ceramic analyses, including petrographic and chemical characterization.

6.8 Petrographic results

The second sorting stage of the analysis is the identification of *techno-petrographic groups* or *classes*. After considering the technical groups and diagnostic sherds, samples were selected to produce ceramic thin-sections. As mentioned in Chapter 4, from trench EA at LHR I, 100 thin-sections has been produced and studied, which provided information about raw materials, clay paste preparation, forming and firing techniques. Five main petrographic groups (LHR-A to LHR-E; see Table 6.2) have been identified according to fabric components, including: particulate inclusions; size and shape of voids; clay matrix; and the nature, size and orientation of mineral and rock fragments. Details about the samples and petrographic group descriptions are available in Appendix A and Appendix B, and the correlations between petro-groups and the above described techno-groups are presented in the following sections. A summary of the petro-groups or petro-classes is first provided below (see Figure 6.22).

6.8.1 Petro-technological classification

a. Petro-class LHR-A: Mica and Quartz Fabric

This homogeneous fabric group is characterised by the presence of mica and quartz inclusions in a non-calcareous red-brown clay with a very low abundance of voids. There is a low abundance of small sub-angular to sub-rounded limestone and *polycrystalline* inclusions and dark iron-rich fragments. The shape/size/density of these homogeneous inclusions suggests that they were naturally present in an alluvial fine clay that was used to produce the samples. Weak alignment of the inclusions with the samples' margins, and possible relic coils can be seen in pottery sherds n. 521-619, 520-814, 508-7 (see Appendix A and B)) suggesting that the vessels from which the sample came may have been coil built.

This fabric group could be a slightly coarser version of LHR-B group due to the abundance of fine mica and the presence of polycrystalline quartz and Clinopyroxene.

b. Petro-class LHR-B: Fine Mica and Quartz Fabric

This homogeneous fabric group is characterised by the presence of very fine mica and quartz inclusions in a non-calcareous red-brown clay with a very low abundance of voids. There is a low abundance of small-sized sub-angular to sub-rounded *polycrystalline* inclusions and dark iron-rich fragments. The shape, size, and density of homogeneous small inclusions suggests that they are naturally present in the fine clay that was used to produce the samples. Weak alignment of the inclusions with the margins of the samples, and possible relic coils can be seen in sherd 508-5, 520-565, 518-87, 520-401, 521-620 (see Appendix A and B), suggesting that the vessels from which the sample came may have been coil built.

However, the crude alignment of elongate inclusions and voids in proximity to the margins in samples 508-5, 521-629 and 518-87, may also suggest that they were wheel finished. Samples 518-87 and 520-400 exhibit a thin external layer of dark clay, which represents a slip. Given the colour of the matrix and low to none optical activity, the samples were well-fired in an oxidising atmosphere. This fabric group could be a very fine version of LHR-A group due to the abundance of fine mica and the presence of polycrystalline quartz and clinopyroxene.

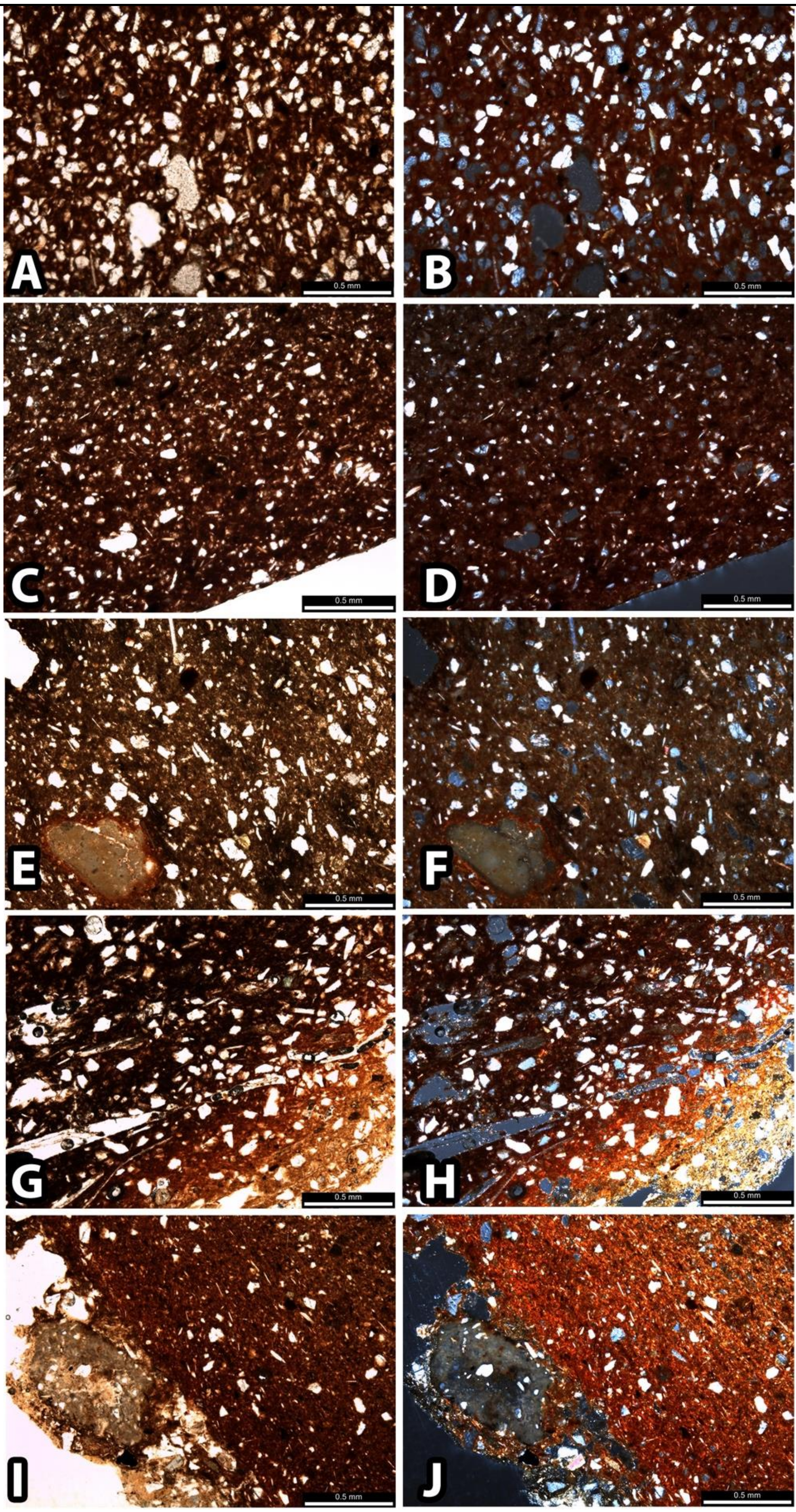
c. Petro-class LHR-C: Lime-kankar Fabric

This fabric group is characterised by a combination of two distinctive recipes, both showing a non-calcareous clay with single- to double-spaced or sparse inclusions. There is a clear distinction in terms of the grain distribution and spacing of the inclusions within each thin-section, depending on the area examined. In particular, the area of the thin-section closer to the outer surface of the vessel shows remarkable difference from the rest of each thin-section. In fact, the outer layer seems to show coarser inclusions that are remarkably different from the rest of each sample. These thin-sections can be described as follows: (1) the coarse fraction characterise the outer layer of each thin-section. It shows large fragments of calcrete or limestone, which are remarkably larger than the fine fraction. The nature of the calcrete, composed of micritic calcite, might be related to nodules of kankar in the region. This have been likely added as temper in a non-calcareous red clay paste containing quartz, mica, and rare plagioclase feldspar, polycrystalline quartz and pyroxene; (2) the finer fraction characterises the rest of each samples, core and inner areas. This is dominated by small quartz and mica, and by the presence of polycrystalline quartz, often found associated with iron-rich fragments and clinopyroxen. The two clay paste recipes show similarities with other fabric classes: the coarse recipe (1) shows similarities with Class LHR-D, while the finer recipe (2) shows similarities with class LHR-B. The combined use of two distinctive clay paste recipes for manufacturing one vessels has also been observed in other thin-sections from neighbouring regions (see Alamgirpur site below; Section 8.12). The source of clay for both recipe's was probably an alluvial or fluvial deposit.

d. Petro-class LHR-D: Limestone Fabric

This fine fabric group is characterised by a non-homogeneous, non-calcareous clay with double spaced or sparse inclusions. There is a good degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions. The coarse fraction shows large fragments of limestone, which are notably larger than the fine fraction. The nature of the limestone fragments, composed of micritic calcite, might be related to nodules of calcrete or kankar in the region.

Figure 6.22 Petro-Classes (see Appendix B). *A-B*: Petro-class LHR-A; *C-D*: Petro-class LHR-B; *E-F:* Petro-class LHR-C; *G-H*: Petro-class LHR-D; *I-J*: Petro-class LHR-E. Left colum PPL, and right column XP. Scale bar is 0.5mm.



This coarse fraction might have been either added as temper, or naturally occurring in a non-calcareous red clay paste containing quartz, mica, and rare plagioclase feldspar, polycrystalline quartz and pyroxene (clarify the two interpretations). The source of clay was probably an alluvial or fluvial deposit. No samples show evidence for the use of coils, wheel-coiling, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding can be considered.

e. Petro-class LHR-E: Coarse Phantom Chaff Fabric

This coarse fabric group is characterised by the dominant presence of elongate voids in a non-homogeneous clay matrix, which is generally non-calcareous. There is a certain degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions. However, the samples do not subdivide easily into different textural subgroups. Given the presence of impressions of coarse vegetal inclusions, all of the samples appear to have been produced by the addition of a quantity of organic material, possibly chaff, to a non-calcareous red clay containing quartz, mica, plagioclase feldspar, polycrystalline quartz and rare clinopyroxene. The source of the clay was probably an alluvial deposit. No samples show evidence for the use of coils, wheel-coiling, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding should be considered. Some samples show frequent clay pellets in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage

Table 6.3 Petrographic classes and sub-groups, and related thin-section samples.

Class	Sub-Group	Thin-section no. (TS-L-)
LHR-A	LHR-A1	8, 14, 17, 27, 28, 29, 32, 37, 38, 40, 42, 45, 54, 56, 58, 59, 60, 62, 64, 65, 66, 76, 77, 78, 81, 83, 85, 86, 91, 93, 94, 96, 97
	LHR-A2	2, 9, 12, 13, 16, 19, 22, 30, 31, 44, 51, 52, 53, 55, 63, 67, 82
	LHR-A3	4, 15, 20, 21, 23, 35, 39, 43, 46, 61, 87, 90, 98
LHR-B	LHR-B	1, 10, 11, 33, 41, 47, 57, 72, 74, 75, 84, 89
LHR-C	LHR-C	6, 24, 25, 26, 34, 79, 80, 88, 99, 100
LHR-D	LHR-D	48, 49, 92
LHR-E	LHR-E1	5, 7, 18, 36, 50, 68, 70
	LHR-E2	3, 69, 71, 73, 95

6.9 Correlations between Petro-groups and Techno-groups

The petrographic data suggests the widespread use of fine grain raw materials across most samples, which reflects the dominance of locally available clay-rich fluvial or alluvial deposits, or depositional basins in close proximity to active and palaeo water channels (see Chapter 3.16). However, a careful analysis of petrographic classes suggest the use of a variety of recipes and raw materials. For instance, petro-class LHR-B appears remarkably different from the other fabrics, given its textural aspect, and could be related to a different clay source or to a different tradition of clay processing and paste preparation. Similarly, certain portion of vessels and certain clay slurries seem to be tempered in very specific ways. Such is the case of petro-classes LHR-C and LHR-D, which show the use of Limestone or calcrete-Kankar nodules in paste preparation. Finally, petro-class E suggest the abundant use of vegetal or temper for the production of certain ceramics. This picture reveals a certain level of heterogeneity within the third millennium BCE assemblage in terms technologies and provenance. Given the macroscopic and petrographic observation, the sites seem to corroborate the widely accepted assumption that, at a prehistoric or protohistoric settlement, the ceramic corpus includes a majority of locally made ceramics. In other words, clay sources could have been located in close proximity to the site, within a 10-km radius (e.g. Arnold 1985). To some extent, majority of raw materials and assemblage at Lohari Ragho-I, EA could to fall within this category. As we shall see in the following sections, this hypothesis will be further tested using chemical data.

The vessels that comprise groups Vessels-α to Vessels-θ have been identified according to their distinctive technologies, including the set of recipes, forming techniques, finishing techniques and surface treatments (Section 6.7). Their similarities and differences in terms of petrographic fabrics are particularly interesting (see Figure 6.22; Figure 6.23; Table 6.3; Table 6.4).

Vessels-α are dominated by the petro-class LHR-A, the *Mica and Quartz Fabric* (A1: ~44%; A2: ~37%; A3: ~7%) and by a minor percentage of Petro-Class LHR-C, the *Lime-kankar Fabric* (~11%). Within this group, sub-groups Vessels-α2 and Vessels-α4 tend to show a strong correlation respectively with the LHR-C and LHR-A3. In particular, Vessels-α2 show the dominant presence of *Lime-kankar Fabric* (100%).

Figure 6.23 Correlations between Techno-groups and Petro-classes (axe X), number of thin-sections (axe Y), and petro-fabric sub-groups (legend).

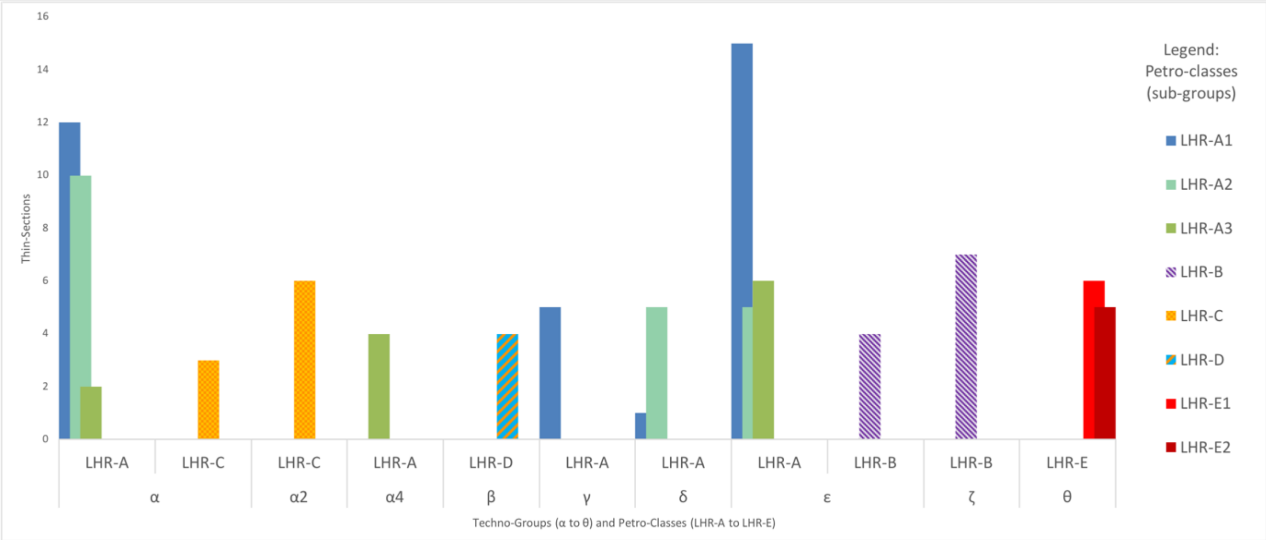


Table 6.4 Correlations (%) of Techno-groups and Petro-classes.

Techno-Groups (Vessels)	Petro-Classes	Percentage (%) of TG/PG
Vessels-α	LHR-A1	44.44%
	LHR-A2	37.04%
	LHR-A3	7.41%
	LHR-C	11.11%
Vessels-α2	LHR-C	100.00%
Vessels-α4	LHR-A3	100.00%
Vessels-β	LHR-D	100.00%
Vessels-γ	LHR-A1	100.00%
Vessels-δ	LHR-A1	16.67%
	LHR-A2	83.33%
Vessels-ε	LHR-A1	50.00%
	LHR-A2	16.67%
	LHR-A3	20.00%
	LHR-B	13.33%
Vessels-ζ	LHR-B	100.00%
Vessels-θ	LHR-E1	54.55%
	LHR-E2	45.45%

Both Vessels-γ and Vessels-δ show a strong correlation with petro-class LHR-A (respectively A1: 100%; and A1: ~16%, A2: ~83%). All Vessels-β vessels belong to the petro-class LHR-D, the Limestone Fabric (100%). The majority of vessels Vessels-ε (~86%) belong to LHR-A, even though a small portion (~13%) seems to belong to LHR-B, a finer quartz and mica rich fabric. Finally, Vessels-ζ and Vessels-θ show a perfect match respectively with LHR-B and with LHR-E.

From a technological perspective, Vessels-α, which are manufactured with no to limited use of rotational gestures, seem to be produced using a consistent fabric that corresponds to petrographic class (LHR-A). However, Vessels-α with an applied rustication

(Vessels-α2) show the consistent use of a specific clay recipe that corresponds to petrographic class LHR-C, the *Lime-kankar Fabric.* These correlations suggests the use of a combination of recipes for the manufacture of Vessels-α, especially globular vessels with applied rustication. Vessels-β, the perforated jars, show the consistent use of a unique recipe and consistently form a separate petrographic class (LHR-D, *Limestone Fabric*).

This fabric is characterised by the presence of fragments of limestone within the clay paste. Vessels-γ (black burnished vessels) and Vessels-δ (chocolate slip vessels), show the consistent presence of a *Mica and Quartz Fabric* (LHR-A1 and LHR-A2), which resembles the composition of majority of Vessels-α and Vessels-ε. Vessels-ε also show the prominent use of rotational gestures and possibly rotational devices, and they are particularly interesting due to the use of a finer ceramic paste (LHR-B, ~13%). Vessels-ζ, possibly among the most refined and sophisticated red slipped vessels, are also characterised by the abundant use of rotational gestures and devices, and are all formed from the petro-class LHR-B, or Fine Mica and Quartz Fabric (~100%). Vessels-θ include the moulded ceramic materials, such as TC cakes and bricks. This is one of the most distinctive ceramics, show the consistent use of coarse ceramic pastes, and form the petrographic-class LHR-E, or *Coarse Phantom Chaff Fabric.*

The correlations between techno-groups and petro-classes point out both a level of homogeneity, as well as richness in terms of variable sources, recipes and clay processing techniques. Homogeneity is expressed by the dominant use of fine, fluvial or alluvial clay. This is at times mixed with types of limestone (LHR-C) or calcrete-*kankar* (LHR-D), which are used for the distinctive manufacture of, respectively, Vessels-α (applied rustication), and Vessels-β (perforated vessels). The petrographic characterisation points out the use of similar clay in most samples, likely regionally available raw materials in the Haryana plains, including the sporadic use of calcrete-*kankar* in the manufacturing process. The low-, medium-, and higher- quality vessels (i.e. Vessels-α1; Vessels-α2; Vessels-α3), and the chocolate slipped ceramics (Vessels-δ) represent the most abundant ceramics in the LHR I trench EA corpus, and the petrographic fabric characterization indicates that they were made from homogeneous raw materials.

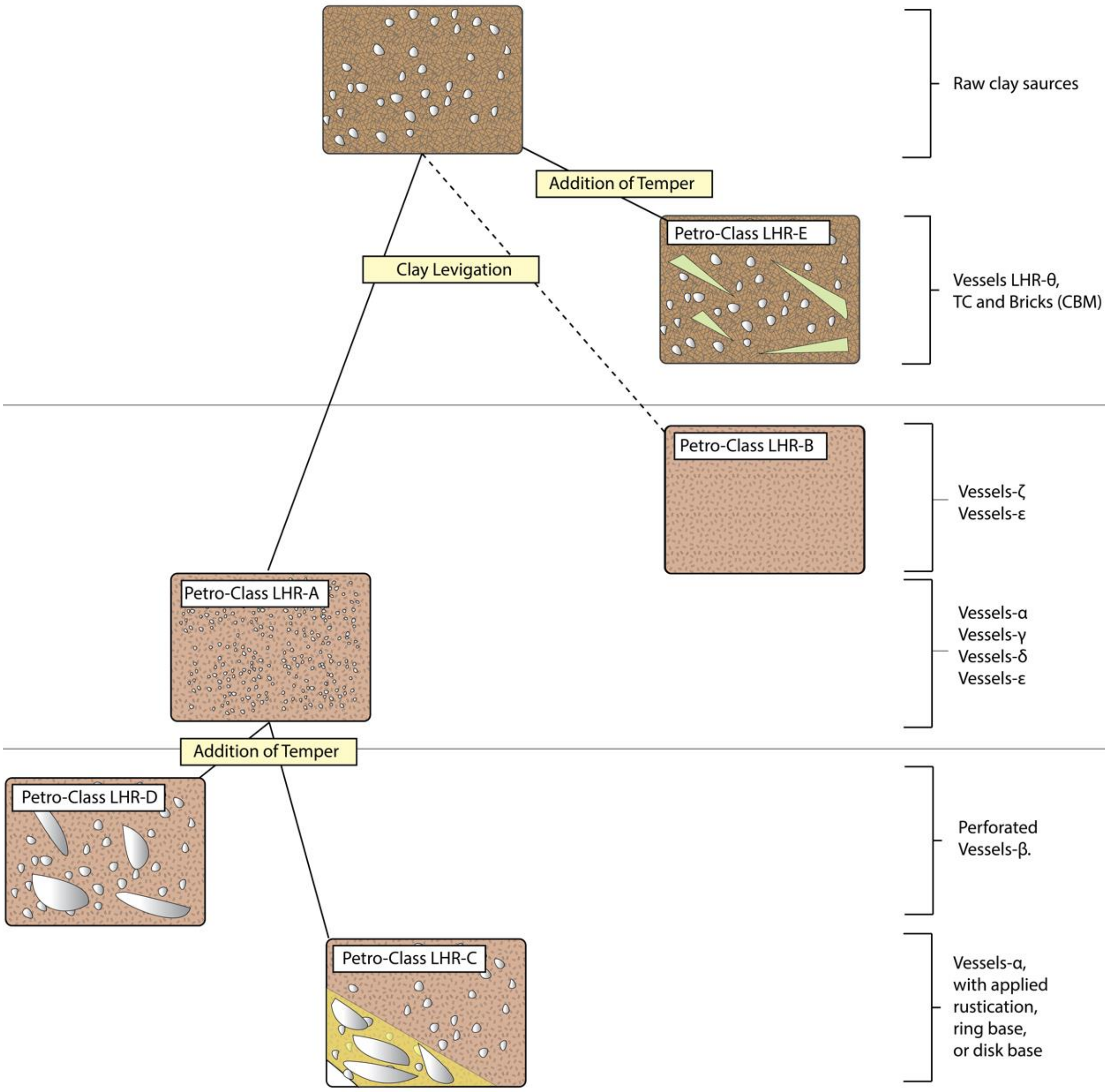
As discussed in Chapter 3.16, rivers and rain patterns both contribute to the hydrological configuration of modern Haryana plains, where LHR I is situated. This is especially true during the winter and summer monsoons seasons. These complex and mutating systems of large and small channels have now largely been controlled by the modern networks of canals which dominate the plains of Haryana, alimented by major rivers such as the Sutlej and Yamuna. Similarly, a large number of small ephemeral channels shape the landscape, e.g. the Chautang, Sarsuti, Markanda, and the Ghaggar systems. A combination of rain patterns, the winter and summer monsoons seasons, along with the Himalayan hydrology might explain the abundance of locally available alluvial or fluvial clay in close proximity to the archaeological site. This might also explain its apparent homogeneity of the clay fraction.

The presence of distinctive petrographic classes, such as classes LHR-C (or *Lime-kankar Fabric),* LHR-D (or *Limestone Fabric),* and LHR-E (or *Coarse Phantom Chaff Fabric)* seem to suggest a significant understanding of recipes and raw material properties, and mindful technological and cultural choices behind the use of recipes for the production of certain ceramic materials. This situation may help to explain the homogeneity in terms of provenance of the raw materials and the heterogeneity in terms of clay paste preparation. For instance, a finer type of clay, due to profuse refining or to the use of different sources, may be inferred from the composition of the sophisticated black-on-red Vessels-ζ (petro-class LHR-B). The implications of the clay pastes variability will be further discussed below and in the related discussion (see Chapter 9).

6.10 Technological observations

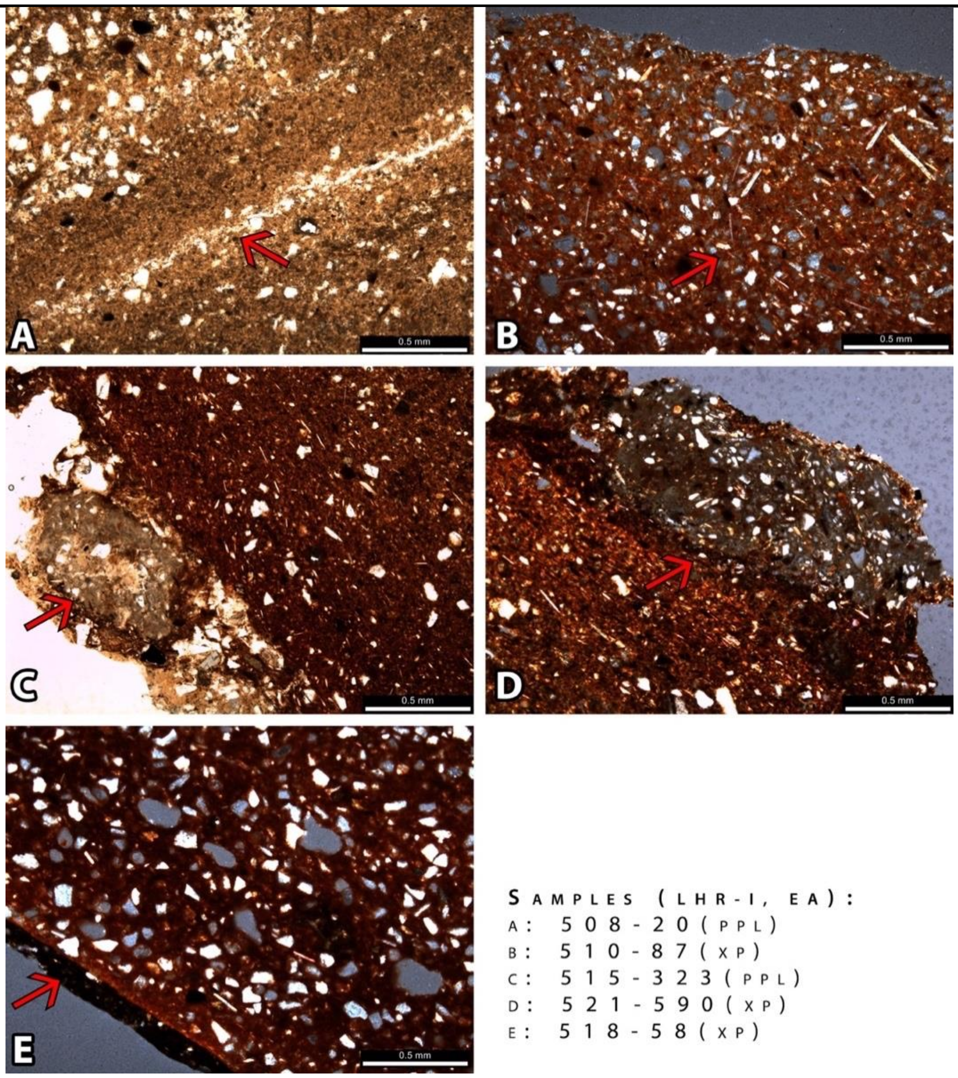
As mentioned in the previous section, the description of petro-classes already included some microscopic features concerning technological aspects of ceramic production, in particular related to forming and finishing techniques. For instance, a number of samples show more or less evident swirls of the clay-rich matrix or relic coils, when aplastic inclusions seem to align in a spiral pattern. That is the case of Figure 6.25:B, where an example of relic coils is shown. This corroborates macroscopic observation on fine ware vessels, which show macro-traces indicative of preliminary forming methods, including coiling technique. Similarly, the descriptions of petro-classes also mention where aplastic inclusions or voids are aligned (or not) to the margin of samples, referring to the possible use (or not) of RKE and rotational devices, as well as polishing or burnishing surface treatments.

Figure 6.24 Visual schematic representation of Petro-Classes, “recipes”, and associated Techno-Groups.



Applied slips are quite common in the assemblage, and a variety of slips are also observable via petrographic analyses. Slips or clay-rich slurries are mostly produced using raw materials very rich in clay minerals. Even though inclusions in applied slips are usually neither particularly frequent nor large, temper is not always absent. For instance, ceramics with a thicker slip (> 0.3 millimeters) may also show a coarse fabric (see Figure 6.25: C and D). That is the case, for instance, with petro-class LHR-C, which shows the use of calcrete-Kankar fragments in its fabric. Finer slips are also visible, especially when the texture, composition and porosity is remarkably different from the ceramic body. For instance, Figure 6.25:E shows an example of an iron- and/or manganese- rich slurry applied to the surface of red vessels.

Figure 6.25 Petrographic observation for investigating ceramic technologies: (A) clay mixing; (B) Relic coils; (C; D) use of calcrete nodules or Kankar on the surface of vessels; (E) use of iron-rich clay slurry applied on the surface of vessels. Scale 0.5 mm.



Technological observations also concern the preparation of ceramic pastes and clay mixing. Thin section photomicrographs reveal the mixing of different types of clays, more or less calcareous, resulting in more of less homogeneous, multi-coloured fractions and fabrics (e.g Figure 6.25:A).

6.11 Geochemical Results

The final LHR I dataset comprised to statistical analysis comprised data on 10 elements for 100 archaeological samples and 13 clay-rich soil samples. The archaeological samples are the same as those used for producing thin-sections for petrographic analysis, and the complete method is outlined in Chapter 4. Clay-rich soil samples were collected using a combination of methods, including satellite imagery, geoarchaeology and ethnographic study (see Chapter 4). A complete list of chemical samples is presented in Appendix C. The statistical analysis of the chemical data was performed considering the most accurate and meaningful elements. Details concerning the assessment of the performance of pXRF data calibration and the statistical methods can be found in Chapter 4 and Appendix E.

6.11.1 Hierarchical cluster analysis

The chemical variability within the compositional dataset was estimated by determining its total variance. Before performing any analyses, all data were Log10 transformed (see Chapter 4). The selected elements and the calculated principal component explain c.75% of the total variance (see Tables 6.4 and 6.5). Among the 10 elements, Zr, Sr, Y and K seem to be the most relevant for determining compositional groups (see Figure 6.26). Cluster analysis was performed on the whole dataset, to identify possible clusters and outliers and differentiate the main chemical groups, producing the dendrogram shown in Figure 6.26. This image shows two macro compositional groups, within which most archaeological samples (Groups 1 to 4) and most clay-rich soil samples (Group 5) seem to fall. When compared alongside the techno-petrographic groups, certain correlations and trends could be observed, and these will be discussed in conjunction with the results of the PCA (see below).

6.11.2 Principal Component Analysis (PCA)

Principal component analysis (PCA) was then performed on the elemental data in order to produce scatterplot and further investigate clusters and outliers. As shown in Figure 6.26, a number of clear chemical clusters could be distinguished from the principle component analysis (PCA). Group 5 seems to describe most of the soil samples, putting the majority of the clay-rich deposits in a different group from most archaeological samples. However, some soil samples are compositionally different from Group 5, and fall within Groups 1 and 2. This might be evidence of the variety of compositionally different clays

Figure 6.26 *Above*: Cluster analysis was performed on the whole dataset, in order to identify the main chemical groups, pro this dendrogram. Soil samples (see Chapter 5) appear to group mostly in Chemical Group 5 (green). *Below*: Grouped scatter of transformed data. Component plots on the right side of the figure.

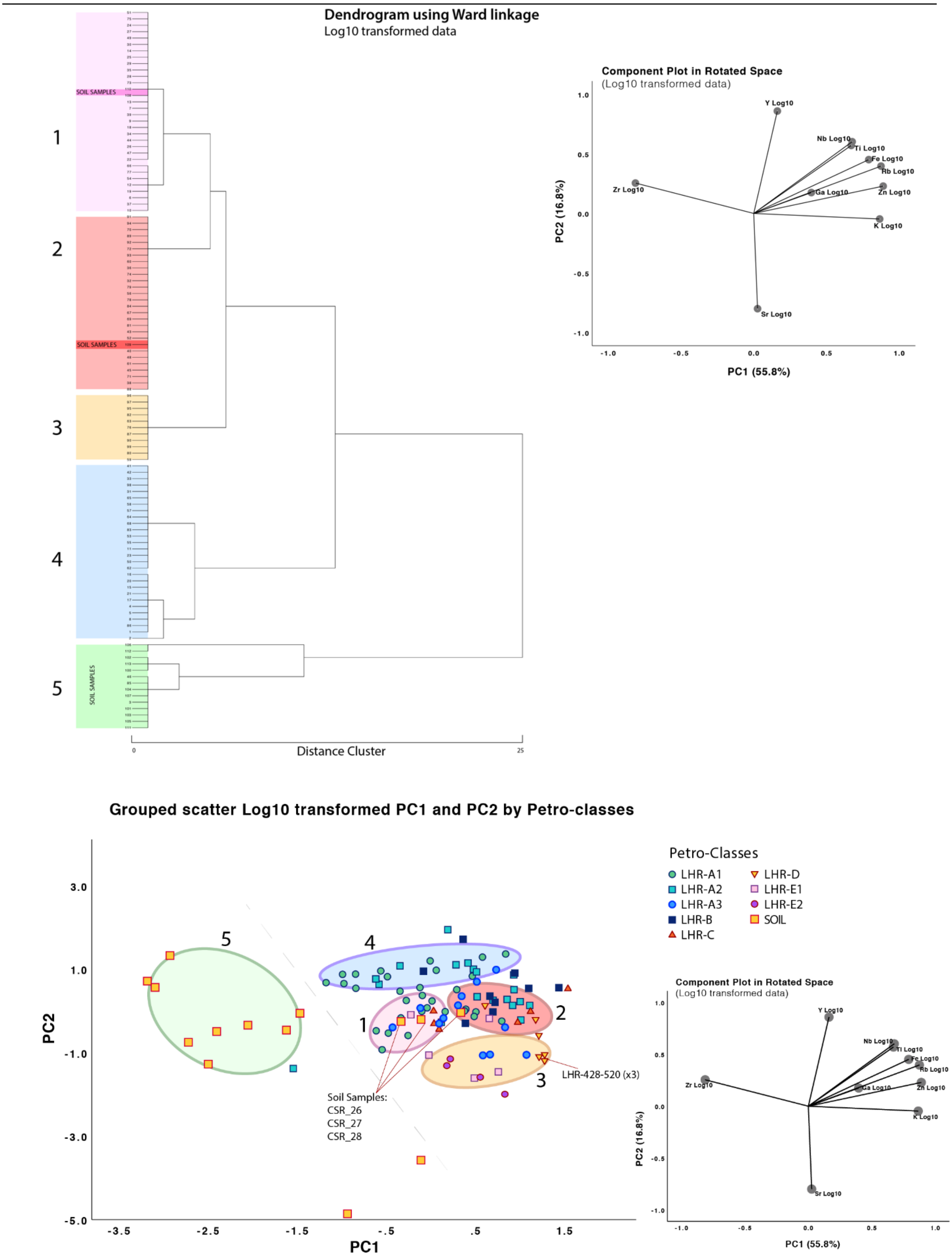


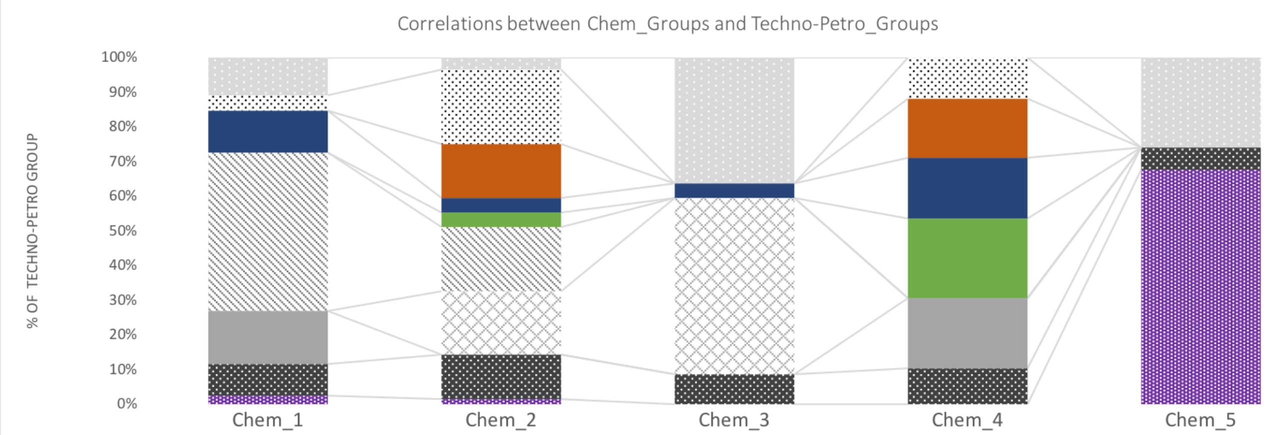
Table 6.5 Descriptive Statistics. Log10 transformed chemical data from 113 samples, Lohari Ragho I.

	N.	Range	Minimum	Maximum	Std. Deviation	Mean	Variance
Fe % (log10)	113	0.317204327	0.424327066	0.741531392	0.063482924	0.616185	0.004
Ga % (log10)	113	1.059501489	-3.726742881	-2.667241392	0.109528312	-2.798957	0.012
K % (log10)	113	0.358104755	0.228862777	0.586967533	0.069380773	0.442558	0.005
Nb % (log10)	113	0.297217176	-3.046023729	-2.748806553	0.059941428	-2.858363	0.004
Rb % (log10)	113	0.348729861	-2.066539608	-1.717809747	0.078601255	-1.847562	0.006
Sr % (log10)	113	1.078881239	-1.957063155	-0.878181915	0.146264944	-1.736903	0.021
Ti % (log10)	113	0.179444607	-0.481051526	-0.301606919	0.033938022	-0.367629	0.001
Zn % (log10)	113	0.442840354	-2.21486463	-1.772024276	0.085773096	-1.939079	0.007
Zr % (log10)	113	0.291138051	-1.81869433	-1.527556279	0.05407145	-1.683176	0.003
Y % (log10)	113	0.308214365	-2.818711908	-2.510497543	0.04838866	-2.613573	0.002

Table 6.6 Total Variance Explained. Extraction Method: Principal Component Analysis, see Figure 6.26 (Log10 Transformed data).

Comp.	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.657	56.568	56.568	5.657	56.568	56.568	4.593	45.927	45.927
2	1.573	15.729	**72.297**	1.573	15.729	72.297	2.637	26.37	72.297

Figure 6.27 Correlations (%) of Techno-groups and Petro-Classes.



	Chem_1	Chem_2	Chem_3	Chem_4	Chem_5
θ - LHR-E	14.29%	7.14%	42.86%	0.00%	35.71%
ζ - LHR-B	5.88%	47.06%	0.00%	47.06%	0.00%
ε - LHR-B	0.00%	33.33%	0.00%	66.67%	0.00%
ε - LHR-A	15.87%	9.52%	4.76%	69.84%	0.00%
δ - LHR-A	0.00%	9.09%	0.00%	90.91%	0.00%
γ - LHR-A	60.00%	40.00%	0.00%	0.00%	0.00%
β - LHR-D	0.00%	40.00%	60.00%	0.00%	0.00%
α - LHR-C	20.00%	0.00%	0.00%	80.00%	0.00%
α - LHR-A	12.07%	27.59%	10.34%	41.38%	8.62%
SOIL - SOIL	3.39%	3.39%	0.00%	0.00%	93.22%

sources that can be found in the landscape, even in close proximity to the site. Moreover, this pattern confirms that the pXRF analysis, the calibration and the statistical processing of data successfully describe the variability of archaeological and soil samples (see Figure 6.27).

Groups 1 to 4 characterise the composition of the archaeological ceramics. They all seem to be closely related, which could be an evidence for the use of similar raw material sources in the macro-region. To some extent, the apparent close relationship of the geochemical samples may suggest the broad homogeneity available clay used in the production of vessels. However, the groups show some trends that appear too correlate with the heterogeneity of techno-petrographic observations. Vessels-α-LHR-A, especially sub-group A1 (geochemical compositional group_4), Vessels-α-LHR-C (*Lime-kankar Fabric*, geochemical group_4), and most Vessels-ε-LHR-A seem to fall within compositional group_1 and group_4. Three clay-rich soil samples seem to match the archaeological ceramics in this compositional cluster. The coarser ceramics, Vessels-θ-LHR-E (*Coarse Phantom Chaff Fabric*), seem to distinctively fall well within a different cluster (compositional group_3). While Vessels-δ-LHR-A, Vessels-ζ-LHR-B, and Vessels-β- LHR-D (*Limestone Fabric*), seem to fall mostly within compositional group_2 and group_3. In particular, the techno-petro group Vessels-ζ-LHR-B seems to suggest a trend, a further level of compositional variability when compared to the resto of the clusters. One of the most interesting observations is that majority archaeological samples seem to fall in one macro-cluster, and only two clay-rich soil samples of possibly fluvial or alluvial clay seem to be compositionally closely related to the archaeological ceramics.

6.11.3 Ceramic traditions and clay sources

Several implications can be inferred from the hierarchical cluster analysis and principal component analysis, and the resulting picture seems to point out a certain degree of compositional variability, within a broader apparent uniformity. First, the geochemical data seem to point out a high level of compositional variability among the clay-rich samples obtained from locations around Lohari Ragho village (see Figure 6.27). Only a few samples seem to match the composition of certain archaeological ceramic. This seems to suggest that, despite the abundance of clay-rich deposits in the landscape, possibly only a few types of clay were consistently used by ancient ceramic producers in the region. This may help to identify the location of possible clay sources.

Second, most of the archaeological samples seems to be closely related. This might be indicative of the use of a specific type or source of clay, perhaps a certain type of fluvial clay, or clay deposits related to rivers or seasonal channels that are abundantly available in the macro-region. The apparent compositional homogeneity might suggest that this type of fluvial clay was available across the landscape, possibly related to medium or large channels, and connecting multiple communities and producers.

Third, the chemical clusters seem to confirm certain techno-petro groups (see Figure 6.27). In particular, Vessels-α-LHR-A, Vessels-α-LHR-C, Vessels-ε-LHR-A all seem to fall within compositional group_1 and group_4, which appear to be closely related elementally (see Figure 6.27). Further, Vessels-δ-LHR-A, Vessels-ζ-LHR-B, and Vessels-β- LHR-D (the *Limestone Fabric*), seem to fall mostly within group_2 and group_3. Despite belonging to slightly different clusters, these groups show a strong sense of affinity. The close chemical characterization of the Quartz and Mica petro-class (Class LHR-A) and the Fine Quartz and Mica petro-class (class LHR-B) samples in chemical group_1 and group_4 correlates well with their mineralogical and textural homogeneity observed via thin section petrography.

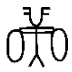
Finally, two techno-petrographic groups show a greater heterogeneity: the coarser Vessels-θ-LHR-E, the *Coarse Phantom Chaff Fabric,* and the Vessels-ζ, the deluxe black-on-red vessels. The trends observable in the PCA may reflect differences in the composition of their base clay, rather than in the source or quantity of the added temper. The diversity of recipes of Vessels-θ-LHR-E and Vessels-ζ-LHR-B was also noticed via petrographic analysis, which seems to suggest a similar picture. In particular, this may suggest the use of a differ base clay for producing bricks and terracotta cakes; and it may point out to a different province or group of producers related to Vessels-ζ, the deluxe black-on-red vessels.

The LHR ceramic traditions will be discussed in Chapter 9, and will be used to assess social relations and social structures at the settlement and in the region. These will be also compared with ceramic traditions identified at two sites described in Chapters 7 and 8 so as to reconstruct social networks and relationship between individuals and social groups.

6.12 Summary

The techno-petrographic and geochemical analyses presented in Chapter 6 indicate that vessels from trench EA at LHR I can be divided into seven meaningful techno-petrographic groups (Sections 6.7 and 6.9). These groups mostly correspond to five petrographic class (LHR-A to LHR-E), and show the use of multiple clay paste recipes. The techno-petrographic groups allowed the identification of at least three complex ceramic traditions, which can be used to explore questions concerning social groups, relationships between groups and individuals, and social structures and networks. These results will be further discussed in Chapter 9, and will be compared with data from other sites and from ethnographic observations.

Chapter 7. Masudpur I: Early Urban and Late Urban ceramic traditions



7.1 Introduction

This chapter will present data, results and a discussion concerning the study of the ceramic corpus recovered from trench XK2 at Masudpur-I (MSD-I), which is chronologically representative of transition from the Early Urban to Late Urban and of the Late Urban Indus production traditions. The first part (Sections 7.2-7.6) will be dedicated to the macroscopic assessment of ceramic fragments, where the fabrics, manufacturing techniques and surface treatments will be assessed to identify the technical actions employed in the production of vessels. In keeping with the *chaîne opératoire* approach, and by using a visual assessment of sherds, the chapter will begin with observations on clay pastes and recipes, moving to the description of primary and secondary forming techniques, and eventually culminating with finishing techniques, surface treatments and decorations of vessels.

The second part will combine the technical observations to reconstruct ceramic traditions (Section 7.7). Techno-groups will be presented by describing their characteristics in detail and cross-referencing to the technical actions discussed in the first part of this chapter. The techno-groups are differentiated using letters of the Greek alphabet, e.g. tradition MSD-α, tradition MSD-β, tradition MSD-γ, and so on. The description of each techno-group will resemble an identity card, outlining its manufacturing techniques, decoration and morphologies, and including references to similar synchronic traditions in the macro-region.

The third part (Section 7.8-7.9) will look at the mineralogical and elemental composition of vessels. Petrographic classes identified within the MSD-I, XK2 assemblage will be presented and discussed, together with chemical characterisation of ceramic vessels. The combination of petrographic and geochemical analyses serves to: (a) reinforce the macroscopic technological observations and groups; (b) better characterise paste preparation and recipes of vessels, resulting in a more detailed understanding of ceramic traditions; and (c) present preliminary results concerning local or non-local production of vessels. Even though it could be beneficial to present the petrographic and geochemical data before the techno-groups, the structure used here follows the sequence and approach successfully employed in other similar studies (see Chapter 2).

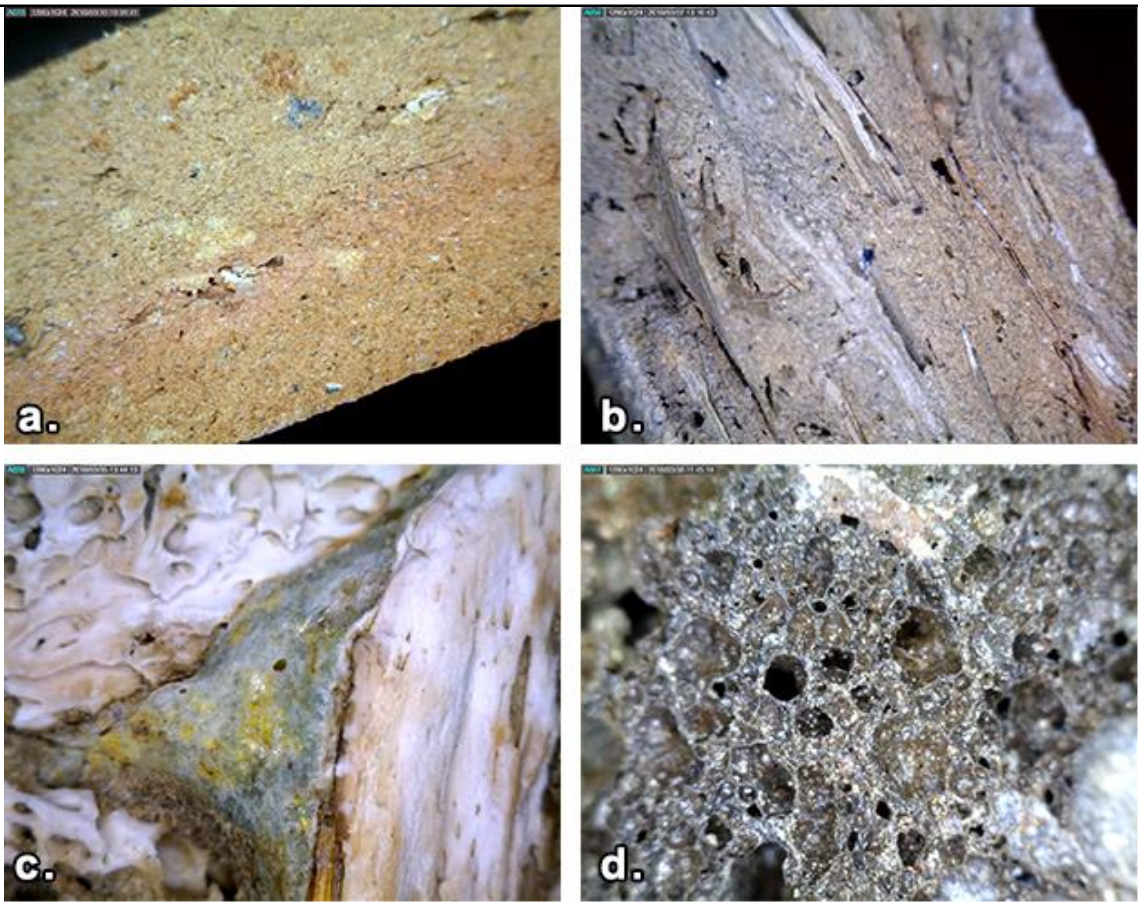
These techno-compositional results will contribute to the reconstruction of a system of overlapping landscapes of ceramic traditions, the variability of social units and functional variability of vessels at the site, as well as insight into the social identities of communities interacting in both a synchronic and diachronic perspective.

7.2 Macroscopic Results

The preliminary analysis of pottery was undertaken in two distinctive phases. The first stage took place *in situ* during the excavation of the site in January-February 2018, when all ceramic materials unearthed at the site were carefully assessed and documented. The second stage occurred during post-excavation in March-April 2018 at BHU. The first stage included the preliminary identification of technical-actions and technical-groups, documenting sherds according to their macro-fabrics, technical features, surface treatments, decorations and diagnostic parts. This process included the preliminary sorting, counting and weighing of all of the material after their assessment. As mentioned in Chapter 4, a total number of 126 distinct stratigraphic units were identified in Trench XK2, relating to at least four occupational phases which span both the Indus Urban (or Mature Harappan), including possible Early Urban and Late Urban phases, and Post-Urban (or Late Harappan) period. From the 67 distinct stratigraphic units that yielded ceramic materials, a total of 34,003 sherds, weighting 652.88 kg, were recovered, sorted and recorded. Once the preliminary assessment and recording was completed, a selection of the identified preliminary technical groups comprising c. 10% of the assemblage from each context was collected and stored in labelled bags and boxes for transport to BHU and further processing.

The techno-groups were defined according to broad fabric compositions and manufacturing techniques, and both the fabrics and the surface traces visible on the inner and outer walls of the sherds were used. Surface treatments were also considered at this stage of the analysis, but not the morphologies of vessels nor their decorative motives. The ODK database of sherds, which includes fields for fabric characterization, technological observations and quantity of sherds, is described in Section 4.2, from which the following data and percentages have been extrapolated.

Figure 7.1 Four macro-fabric groups. Fine Fabrif F- (a.); coarse fabric C- (b.); highly vitrified ceramic slag, and vitrified ceramic slag (c. and d.).



7.3 Fabrics

Sherds from each excavated deposit were first sorted into broad compositional groups, according to macroscopic observations of ceramic pastes. Through visual assessment, four main types of fabrics could be identified within the assemblage: a fine paste, a coarse paste, a glazed ceramic fabric, and a vitrified ceramic fabric (see Figure 7.1). During the documentation stage, to pottery sherds belonging to the first group were assigned the prefix 'F-', and those belonging to the second group has been given the prefix 'C-'. The glazed ceramic fabric and the vitrified ceramic groups, much smaller in number, have been marked together using the prefix "V-".

7.3.1 Fine (F-) paste

Fine ceramic pastes are identified in all deposits at MDS-I, XK2, and the fine paste represents c. 55% of the whole assemblage. Rare, small pores are visible on the surface of ceramics or in the paste, and fine mineral inclusions can be identified, such as quartz and mica. Such fine pastes were used to produce a variety of vessels, and were associated with a vast range of manufacturing techniques, surface treatments, decoration styles and vessel morphologies. Fine ceramic sherds are fragments of vessels that were well-fired in an oxidizing atmosphere, showing a red, dull-red or bright red surface and core colours (Figure 7.1: a). The rare voids measure between 0.2 - 1.0 mm in length, and are mostly equant and rounded in shape. Fabrics are not always homogeneously mixed, and can show varieties of mixed clay pastes, including more or less calcareous matrix.

*7.3.2 Coarse (**C-**) paste*

Organic tempered or coarse ceramic pastes are identified in almost all deposits in MSD-I, Trench XK2. This coarse paste (see Figure 7.1:b) represents c. 44% of the whole assemblage. The organic material likely used as temper is no longer visible, and the large pores of voids visible on the surface or in the paste of ceramics can only be indirectly attributed to burnt out vegetal material. As presented below (Section 7.6), vegetal or chaff tempered coarse pastes were mostly used to produce organic-rich clay paste vessels, ceramic building materials (CBM), terracotta cakes, and unfired mud-bricks. The voids can measures 0.5 - 3 mm in length, and show a range of different morphologies, which can be associated to straw, chaff, seeds and/or other vegetal temper.

7.3.3 Vitrified (V-) fabric

Fragments of vitrified ceramic, including vitreous ceramic slag, or possible fuel ash slag have been identified in MSD-I, Trench XK2. These are quite different from the vitrified material identified at LHR-I, Trench EA. Two main types of vitrified ceramics have been found, which can be defined as: (a) highly vitrified or glazed yellowish green ceramics; and (b) rare lumps of bubbly vitrified slag (see Figure 7.1: c and d; Figure 7.2). Vitrified material represents c. 0.1% of the whole assemblage, and was found in a small number of contexts. The second type, (b) the bubbly vitrified slag type, is similarly to vitrified ceramics found at LHR-I, Trench EA, and shows a foamy, bubbly texture. This type appears not to be diagnostic of any particular process, such as metallurgy or faience production. In fact, they could be understood as fuel ash slag (e.g. Dungworth 2007, 2009, 2015; Bayley, Dungworth, and Paynter 2009). Vitrified slag fragments tend to be lumps of 2 to 3 cm in length, remarkably lightweight due to their low density, and show a characteristics 'bubbly' and high porosity structure. The fragments are whitish, light grey, or yellowish brown in colour, have a glassy appearance and are quite fragile (see Figure 7.1: d). This type of vitrified material can be formed when alkali and silicate compounds (such as ash and burnt wood, sand and clay) react, often due to high temperature within a hearth, a kiln, furnaces or fire episode, such as a burning structure, and are not necessarily indicative of a specific industry. The first type (a) shows a more "glazed" appearance, and a range of colours spanning from white, to bright blue and yellowish green. These could be interpreted as diagnostic of production of highly fired glassy material, such as faience, or slag resulting from glazing process (Figure 7:1 c). Similar frothy vitreous yellowish green faience slag has been discovered at other Indus sites in the macro region (e.g. at Mitathal and Harappa; see Uesugi 2011; Kenoyer 1992: 87; Kenoyer 1994a; Kenoyer 2003). Copper oxide–rich minerals were used to colour the silica-rich glazed (e.g. quartz- glassy frit or glazed ceramics), possibly to resemble the blue of more precious stones such as turquoise or lapis lazuli. The frothy vitreous slag identified at MDS-I resemble the discarded materials or remains of the Indus faience industry, which involved the firing of glassy frit at c. 950 C° or above. The discovery of these vitrified fragments suggests that specific types of craft production were taking place at the site, but they will not be further discussed in the present chapter.

7.4 Manufacturing techniques

After sorting the ceramic fragments from MSD-I, Trench XK2 into broad fabrics groups, evidence for manufacturing techniques were considered to identify techno-groups. The evidence used for assessing technical actions and technical-groups will be discussed taking consideration of their relationship with the two dominant fine (F-) and coarse clay pastes (C-).

7.4.1 Fine (F-) fabrics associated technical actions

Fine ceramics were firstly divided into sherds that show evidence for the use of RKE (see Sections 3.11 and 3.12), and those which do not. In this first section, manufacturing techniques which required no or limited use of rotational gestures are discussed.

Figure 7.2 Measures of sherd quantity. Above: coarse ceramic fabric sherds; below: vitrified or glazed fragments.

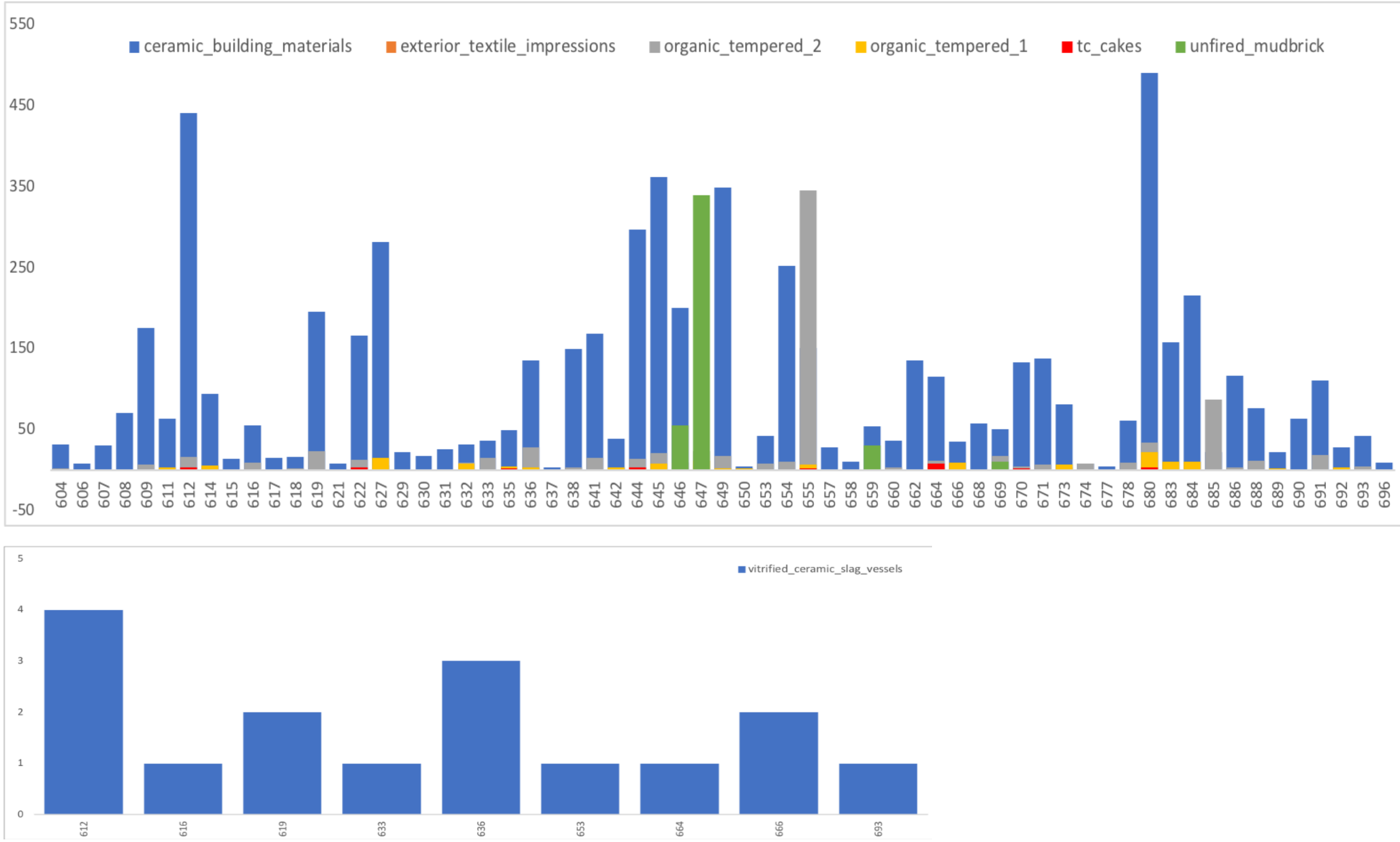
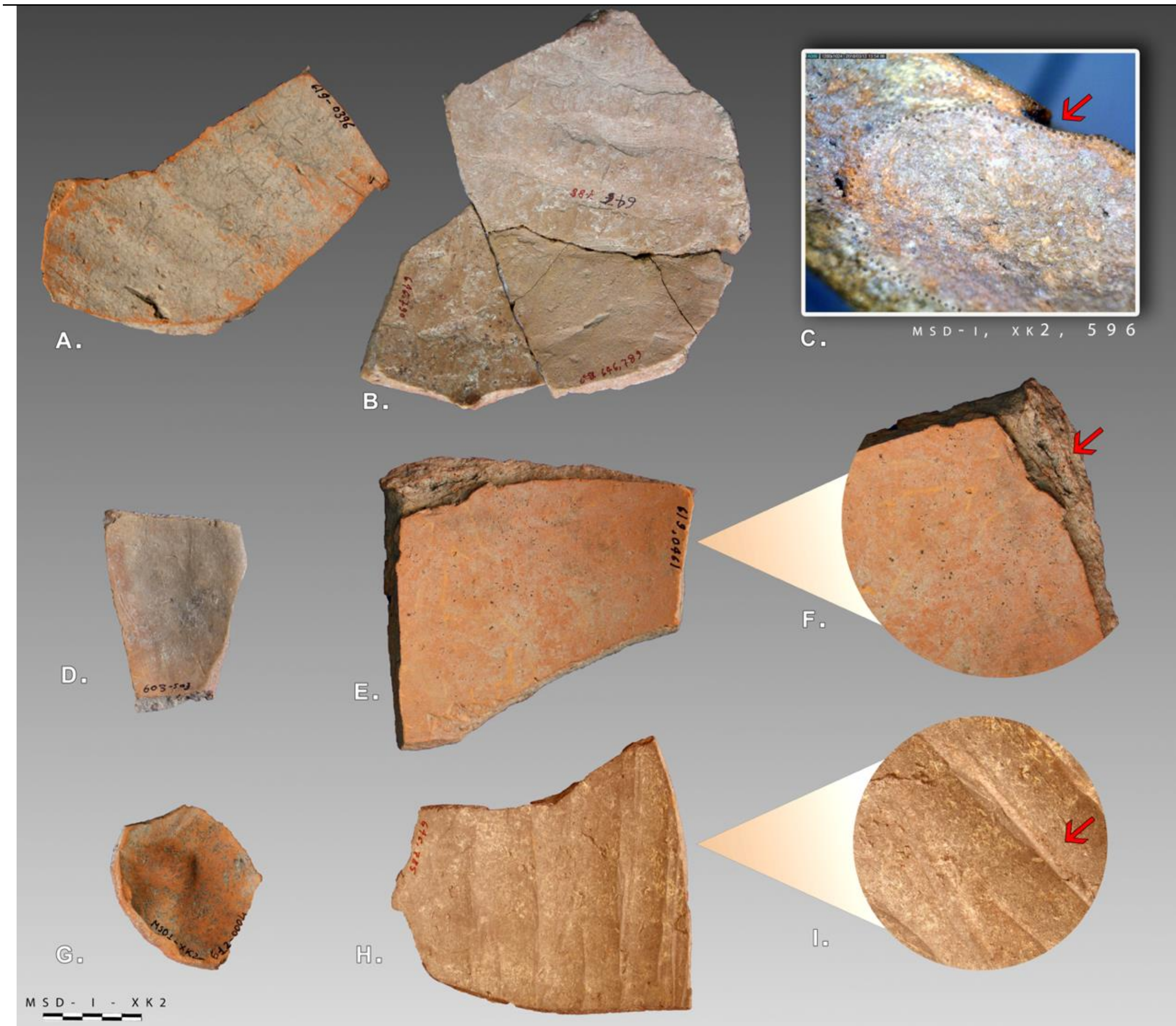


Figure 7.3 Preliminary or primary forming techniques, e.g. evidence for coiling, MSD-I, XK2. The macrotraces here visible have been used to identify multiple forming techniques, in particular by looking at surface topography, coil joints, and brakage patterns.



7.4.2 Coiling (with or without RKE)

A number of distinctive traces suggesting the use of preliminary forming techniques for shaping the rough-out of vessels were identified, including evidence for coiling. Figure 7.3 and Figure 7.4 show some of the macroscopic features that have been considered when assessing the forming techniques of vessels, especially in relation with coiling. Traces are not enough, however, to make a clear statement concerning possible wheel-coiling techniques. Overall, c. 32% of ceramic sherds seem to show evidence for a combination of forming techniques, including preliminary forming techniques such as coiling for forming the rough-out of vessels. This percentage is even higher if we exclude ceramics that are not containers from the corpus, c. 60% of vessels' fragments. The percentage of sherds showing these technical actions is notably high within the corpus. Given the fact that subsequent manufacturing techniques and surface treatments may have obliterated evidence for coiling techniques, it could be hypothesized that the number of ceramics produced using this forming method might be significantly higher. Scraping (with or without RKE).

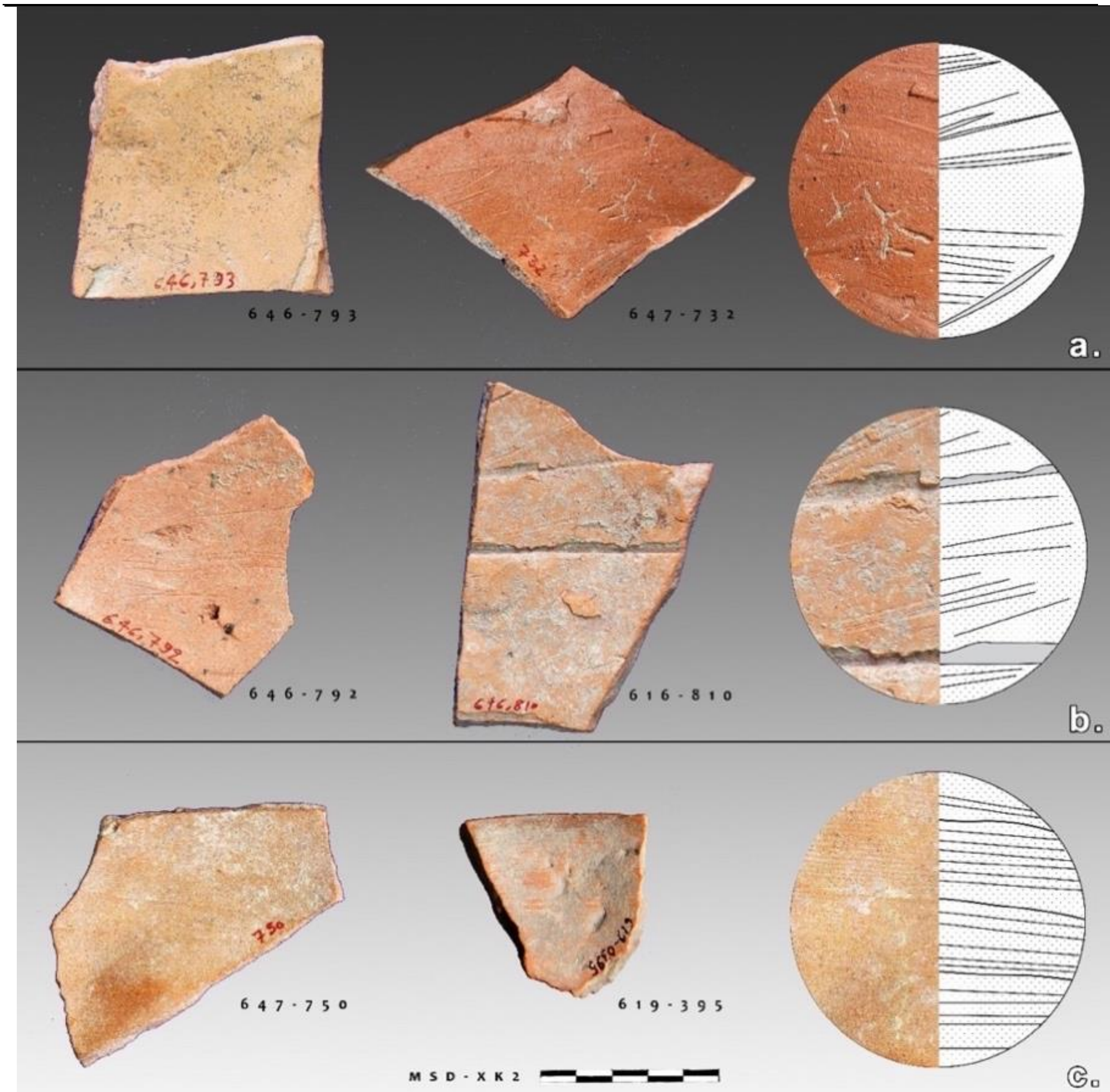
In terms of the macro-traces, the scraping technique was widely used and performed in a variety of ways: for instance, with or without the partial use rotational motion or devices, such as *tournettes* or turntables. The type of evidence that may suggest to partial use of rotational devise are presented in Figure 7.4:c and 7.6:b; while the lack of *RKE* could be inferred from sherds such as Figure 7.4:a and b, showing little to no parallel sets of grooves and striations (also see Table 7.1: methods 0-1). Overall, the percentage of sherds showing these technical actions is significantly high: c. 60% of vessels' fragments.

7.4.3 No or limited use of RKE

After forming the rough-out, possibly using coils, slabs or moulds, vessels appear to have been often finished using the scraping method. Fine (F-) paste ceramics, formed using non-RKE or without the use of a wheel or rotational devices (-NW), often show evidence for different degrees of scraping and smoothing. It could be hypothesized that the vast majority of ceramic vessels may have been produced using a combination of forming and finishing methods. Sherds bearing evidence for thinning and joining coils, scraping and smoothing with limited or no use of RKE, rotational gestures and/or devices could be sub-grouped as follow (see Figure 7.4):

a. *F-NW-A*: showing rare striations, from quasi-parallel to non-parallel orientation. The marks can be shallow or deep. Sometimes coils and coil-joins are visible.
b. *F-NW-B*: showing abundant striation, from quasi-parallel to non-parallel. Shallow as well as deep marks on the inner walls can be seen. Sometimes coils and coil-joins are visible.
c. *F-NW-C*: showing very abundant striations, can be consider to be the result of the use of abundant rotational motion or even rotational devices. These marks are mostly found in proximity of the neck and on rims of vessels, and can be misunderstood as evidence for the use of the wheel during all forming phases. The inconsistent nature of these marks seems to suggest rotational movements of tools and scrapers, rather than the use of a rotational device. If a rotational support was used, the RKE was minimum.

Figure 7.4 Secondary or finishing forming techniques, e.g. scraping with or without RKE, MSD-I, XK2. The uneven surface topography and the macrotraces on internal and external surfaces suggest different secondary forming and finishing technique, likely without the use of RKE or rotational devices.



7.4.4 Use of RKE and rotational devices

Fine vessels produced using abundant rotational gestures and/or devices and possibly finished on a potters' wheel has been grouped in a broad category *'F-W'*. Evidence for the use of these technical actions and tools in the corpus is limited, c. 13% of the whole assemblage, and c. 25% of all vessels' fragments (see Figure 7.5). The first feature that was considered is the type of marks that are visible on the sherds, as well as the overall vessels' structures when possible. These marks are usually indicative of multiple forming techniques used for shaping vessels, and they could be divided into two categories (see Figure 7.6):

F-W1: sherds showing parallel striations associated to scraping marks. These horizontal striations are mostly confined to the upper portion of vessels, and mostly on the interior surfaces of rims and necks. This seems to suggest that vessels' rims showing this configuration were possibly moulded separately and attached to the vessel using a rotational motion in a subsequent phase of manufacture; or that the rotational device was used only in the final stage of fashioning (see Table 7.1: Method 2). The lower portion of vessels tend to show evidence for the coiling and scraping techniques (see Figure 7.6:b).

F-W2: sherds showing perfectly parallel striations and grooves, which are often found throughout the whole inner walls of vessels – from rim to base, on both thick or thin walls (Figure 7.6:a). This seems to suggest the abundant use of rotational gestures and devices (see Table 7.1: Methods 3-4). Within this broad group, diagnostic parts are: *rim*, which tend to shows clear parallel striations or wheel marks; and *base*, where wheel-marks are visible, are mostly flat or concave for globular vessels.

7.4.5 Assembled necks, rims and ridges

The traces on the interior surfaces of vessels and breakage patterns seem to suggest that necks, rims, and ridges on the walls of certain vessels were formed in a subsequent phase of the manufacturing process, independently from the rest of the vessel's body. Figure 7.6 shows changes in terms of striation's patterns in close proximity to the neck and rim of certain vessels, suggesting a specific set of actions for obtaining the desired morphologies. The presence of visible coils in close proximity to the neck, associated with changes in striation patterns (e.g. Figure 7.6:b) seem to suggest that the rims where often finished using RKE and possibly rotational devices. It is not clear whether the rims or necks were formed separately, and subsequently attached to the body of vessels, but this possibility should not be discounted. Similarly, decorative carinations and ridges on the shoulders or body of vessels seem to be applied in a subsequent phase of production, likely after the final form of the vessel was achieved (see below Figure 7.8:E). This applied carination seems to resemble the distinctive features of Indus carinated cooking vessels. However, whether this applied decoration is directly inspired by the contemporary Indus cooking vessels can be suggested but not confirmed.

Figure 7.5 Types of wheel-marks: F-W1 (above) and F-W2 (below), MSD-I, XK2. Below: parallel striations are present only on the neck and rim, but not on the body of vessel.

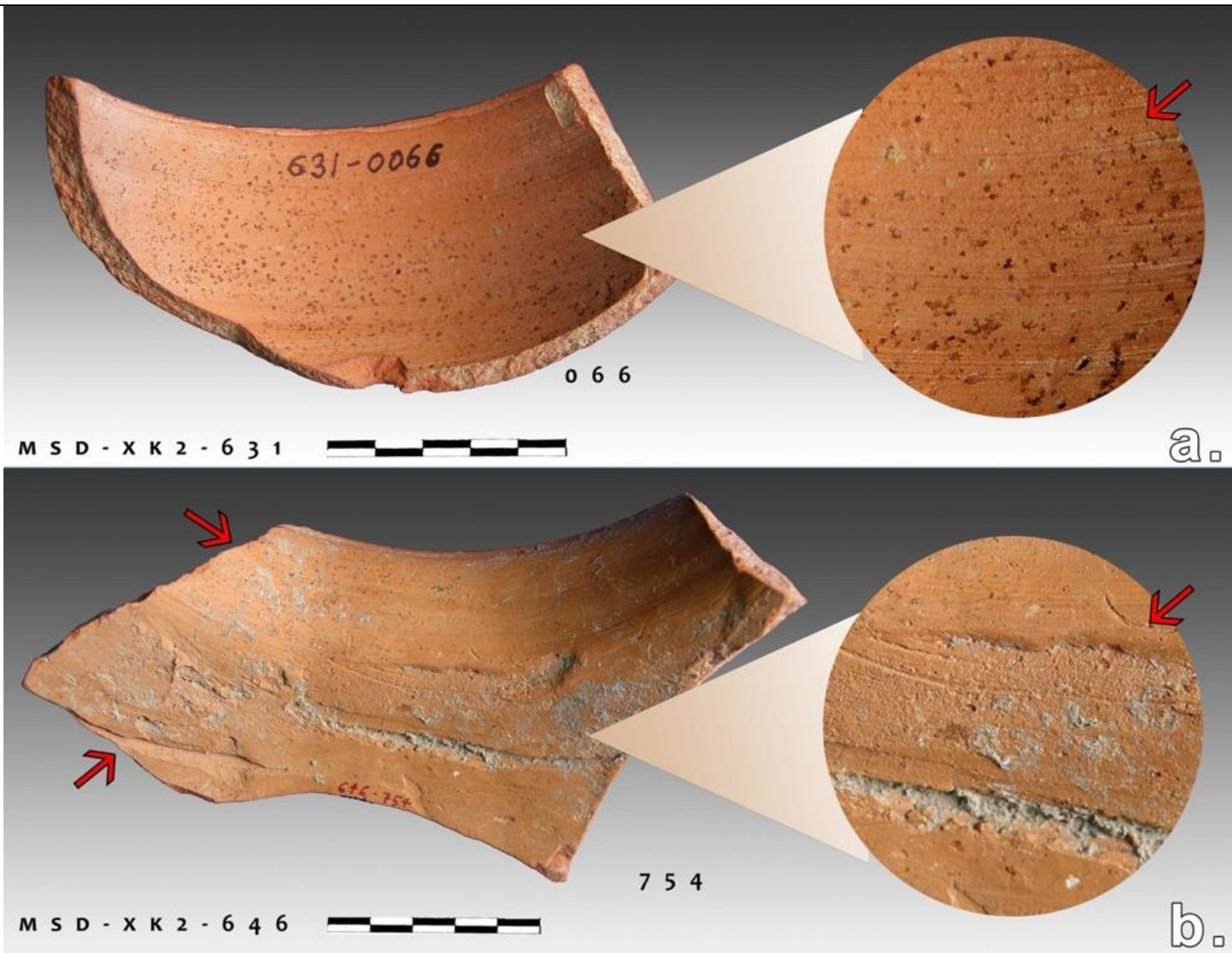


Figure 7.6 Count of sherds showing evidence for the use RKE, rotational gestures and/or devices.

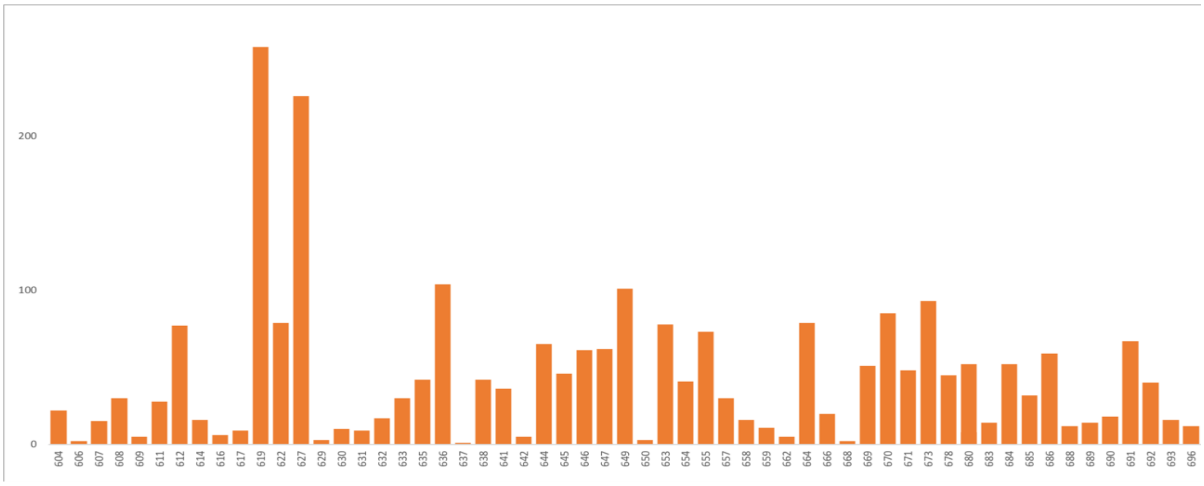


Table 7.1 Combinations of forming methods, with an emphasis on use of RKE and correlations with Groups, MSD-I, XK2.

Method	*Forming the coils*	*Joining the coils*	*Thinning the coils*	*Shaping the rough-out*	*Group*
Method 0	Non-RKE	Non-RKE	Non-RKE	Non-RKE	F-NWA; F-NWB
Method 1	Non-RKE	Non-RKE	Non-RKE	RKE	F-NWC
Method 2	Non-RKE	Non-RKE	l RKE	RKE	F-W1
Method 3	Non-RKE	RKE	RKE	RKE	F-W2;
Method 4	RKE	RKE	RKE	RKE	

7.4.6 Bases and pedestals.

The most recurrent types of bases are flat to slightly concave types. Ring, pointed, and disk types are also observed. Both disc and ring type bases seem to have been crafted by adding clay to a rounded, globular base. The concave base of vessels with an attached ring can, at times, project downwards beyond the ring (see Appendix D). Rare flat and pointed bases or pointed bases with string-cut marks are also found. Where parallel striations or RKE marks are visible, bases are mostly flat and may show string-cuts, or evidence of having been assembled on a pedestal. The morphology of the pedestal or stand of 'dish-on-stands' suggest that they were likely made separately and attached to the base of bowls and dishes. The base of the dish or bowl appears to have been attached horizontally to the foot or stand (see Appendix D). The joints are usually easy to identify between the dish or bowl and the pedestal, and coils and coil-joints are usually visible on the fractured pedestals. As we shall see in the second part of this chapter, concave and almost flat bases, and bases with an applied ring seem to be more dominant in one specific tradition (**Vessels MSD-α**); while flat, pointed and pedestalled bases seem to be more recurrent in another tradition (**Vessels MSD-ε**).

7.4.7 Sequential construction and rope binding

In order to build one particularly large vessel that was recovered, a combination of techniques was required, which included moulding, coiling, sequential forming, scraping and wheel-finishing (see Figure 7.7). Moulds in the form of cones or truncated cones were likely placed with the narrow opening as the base to begin the production of large storage jars, likely centred on rotational devices (see Dales and Kenoyer 1986: 78, 83, 85; Kenoyer 1998: fig. 8.6; Vidale 2000: 80;), and fixed on the *tournette* or on a bat with lumps of fresh clay. Such moulds have been discovered at sites such as Nausharo (Mery 1994: fig. 41, 5) and Lai Shah near Mehrgarh (Jarrige C. et al. 1995: fig. 10.3lb), and they show regularly incised lines likely for the better adhesion of the clay. Dales and Kenoyer (1986: 79, 83) and Wright (1991: fig. 6.6) have argued that the largest vessels were built at least in three different sections, either via sequential forming, or separately shaped sections being joined together. These large vessels may have been raised progressively with large coils and eventually shaped on the revolving wheel, periodically interrupting the forming process to allow the structure to dry at critical points to stand their own weight (see Vidale 2000: Fig. 35). During the forming process, the body of the large jar was supported by ropes or strings, evidence of which are still visible on ceramic sherds (see Figure 7.7). It has been suggested that the production of the large storage jars is so complex and sophisticated that it had to be performed by narrowly specialized potters (Kenoyer 1994b).

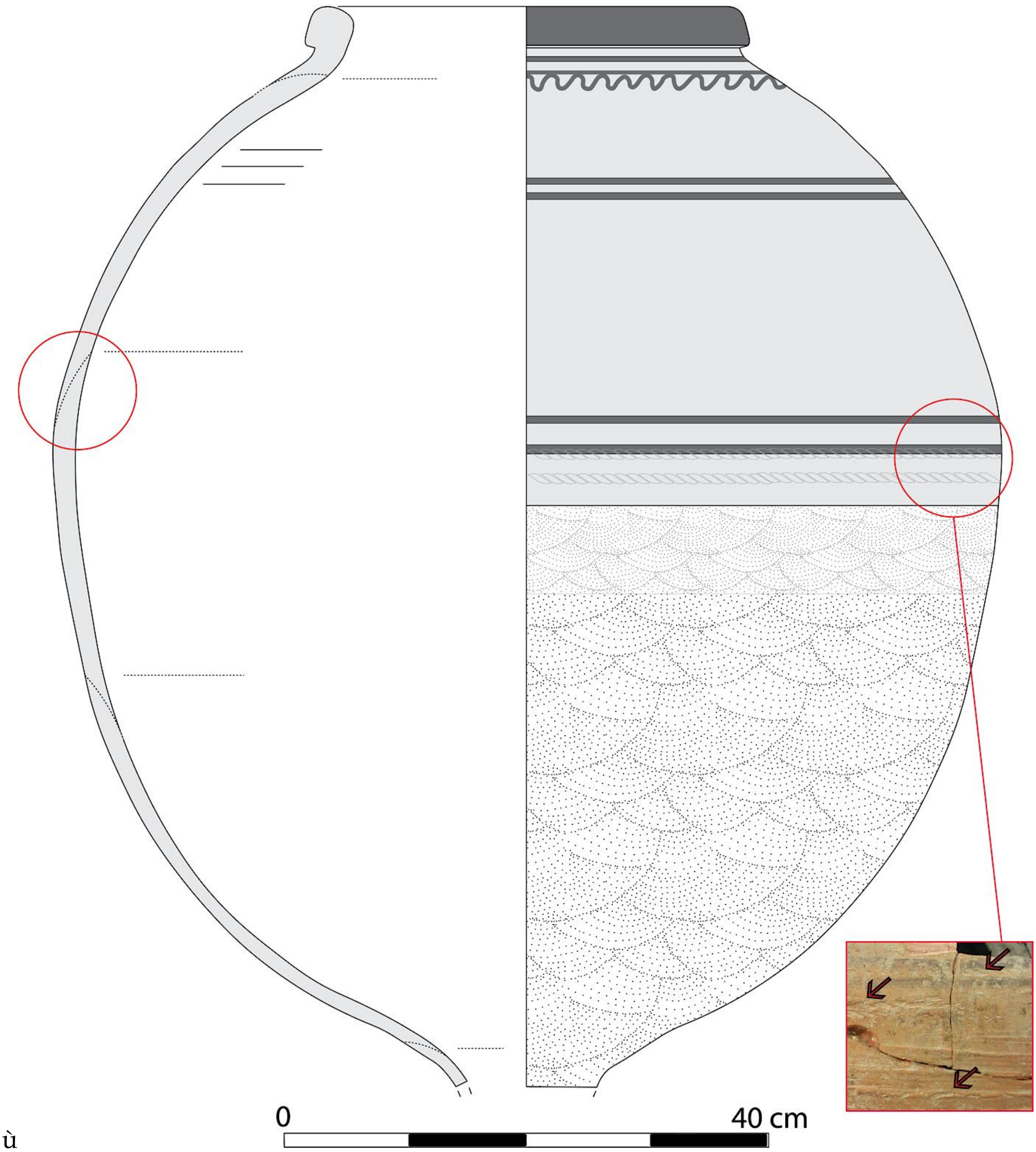
Regarding rope binding, no actual twisted strings have survived in the archaeological record at major Indus archaeological sites. However, the impressions on the pottery are clear and often allow identifications of fibres and manner in which the cord was crafted. The majority of rope impressions found at sites such as Mohenjo-Daro and Amri suggest two strands being twisted, and that they were used "to prevent sagging during the drying preliminary to baking" (see Marshall 1931: 291; Mackay 1938: 212; Dales and Kenoyer: 67; Casal 1964: Fig. 71: 289; see also William Hurley 1979: chap. 2, Figs. 5 and 10; and see also comparative rope binding of storage jars at Hazor and Megiddo, Yadin 1972: 130). This technique was also well known contemporaneously in neighbouring regions, such as Seistan and Central Asia (see Vidale 2000: 80-81).

7.5 Surface treatments

7.5.1 Slip, polishing and burnishing

There are relatively few distinctions between types of slip found on vessels in MSD-I, Trench XK2. The surface treatment of the outer surface can be quite different in terms of quality of slip and polishing. These cannot be considered as fixed categories, but overall five degrees of surfaces finishing could be observed: from self-slipped and non-polished, slipped and polished, and slipped and highly polished or burnished. A description of these varieties and their database codes are as follows:

Figure 7.7 Sequential construction of large storage jar. Focus on sequential building (left) and use of ropes (right), MSD-XK2.



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F-NW-S: Fine paste non-wheel finished red slip. Res slip on the exterior, possibly self-slip. The interior does not usually show wheel-marks, only scraping. Wheel marks visible only in proximity of the shoulder or rim. A ridge (triangular section) is visible on the belly of the vessels. Black paint was often applied on the ridge. Black paint was also found on the upper half of vessels, including: lines, curved lines, arcs, half-moons, dots, and net motifs (see below Figure 7.11). It is possible that the rim was produced separately, and applied or moulded during a final stage of production, using a rotational device.

F-NW-SB. Fine paste Non-RKE or Non-Wheel (NW) finished, semi-burnished (SB) red slip: sporadic striations on the external surface, possibly produced using pebbles or a rounded hard tool on a leather-dry wall. Usually red or yellowish red in colour. Sherds are non wheel finished. Burnishing is often found on the upper portion of the body. They are associated with rustication in many vessels present on the lower portion of the vessel (see Figure 7.8:B)

F-W1-S or F-W2-S: Fine paste vessels finished using RKE or rotational devices with applied red slip. The 'true' red slip is relatively easier to classify (see Figure 7.8 and 7:11). It usually appears bright red or dark red in colour, depending on the thickness and composition of the slip, as well as the firing technique (Dales and Kenoyer 1986: 64). Superimposed layers of slip can also be found. This type of slip is vibrant-red to deep red in colour, and it can be associated with little polishing of the outer surface of vessels.

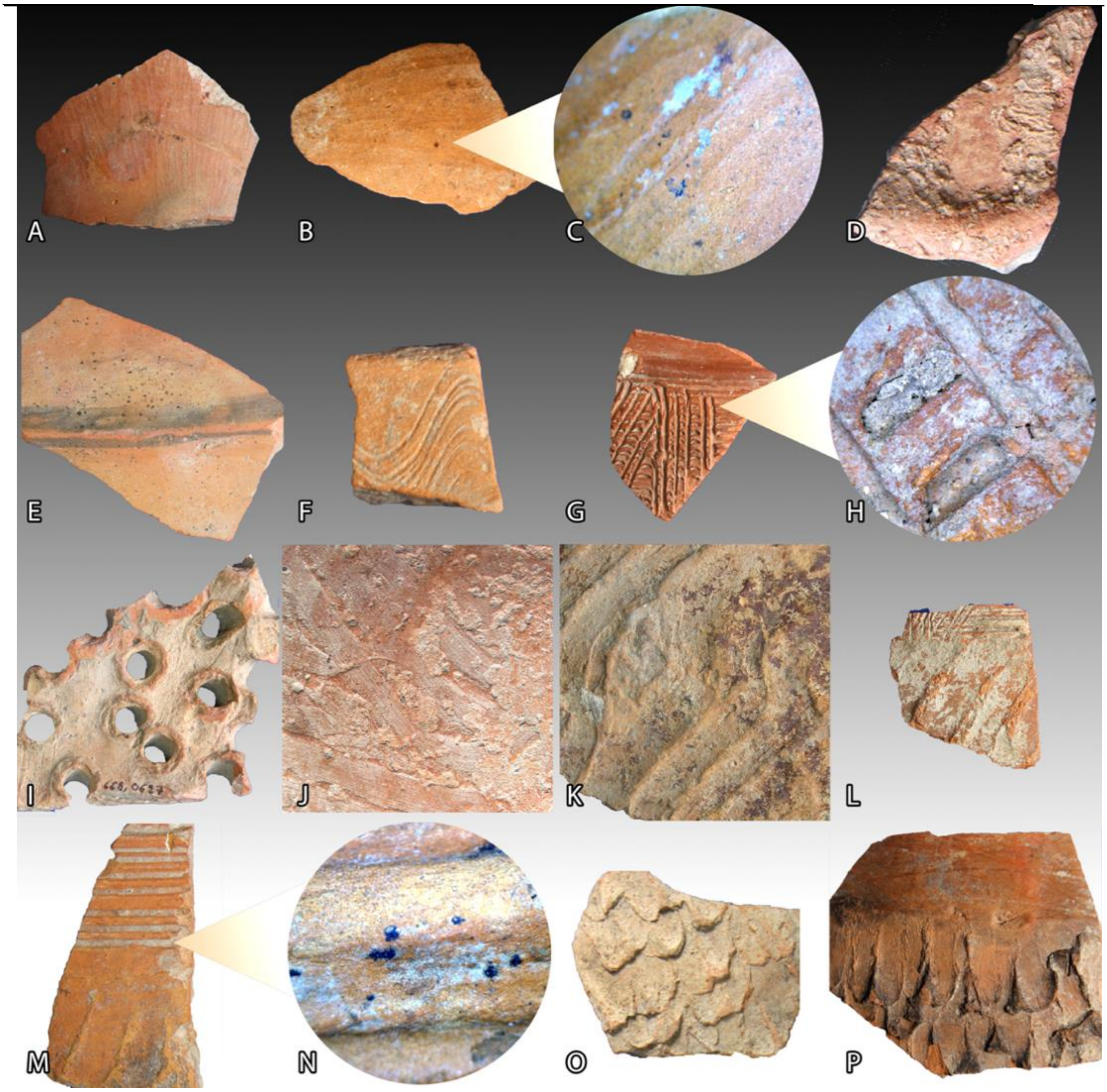
F-W-Poli-Burnished: Fine paste vessels finished using RKE or rotational devices with applied red slip and abundantly polished and/or burnished.

F-W2-L-S or F-W2-BnR: Fine paste vessels finished using extensiv rotational gestures or devices with applied bright red slip. The surface treatment is extremely fine. It looks almost completely polished or often burnished (see below Figure 7.18).

7.5.2 Applied rustication

Fine paste vessels, whether or not they show the use of rotational devices, may have a distinctive finishing treatment that involves the application of a slurry, or rustication. The letter R- is used to indicate this type of technical action or the presence of an applied rustication (R-). This category of sherds is also subdivided into RKE finished (-W) and non-RKE (-NW) finished ceramics, also considering types of slurries which tend to show compositionally different pastes.

Figure 7.8 Some of the most recurrent surface treatments at MSD-I, XK2. A-B-C: burnishing; D: Mud Appliqué 1; E: applied ridges; interior wavy incisions; G-H: 'crisscross' incision; I: perforations; J-K-L-M: applied 'fingers' rustication; O-P: fish-scale rustication.



F-NW-R-K. Fine paste Kankar Rustication (Mud Appliqué 1): exterior surface shows application of a slurry with calcrete, kankar or limestone inclusions. The interior surface of these sherds is often unfinished or smoothed using rotational gestures or devices, and shows evidence for scraping (see Figure 7.8: D; Figure 7.10). A total of 880 fragments of these sherds have been found in MSD-I, Trench XK2, representing c. 5% of the whole assemblage (see Figure 7.9).

F-NW-R-C. Coarse Rustication (*mud appliqué* 2), a coarser variety of **F-N-R-K**.

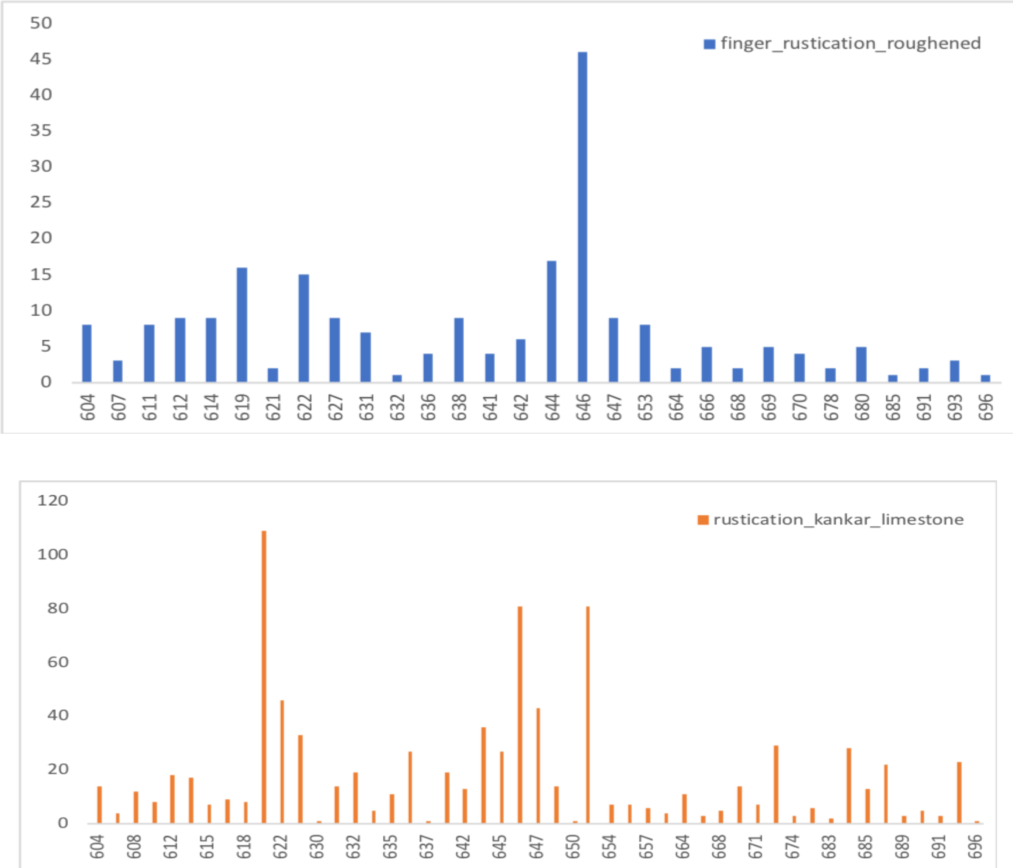
F-NW-R-FS. Fish Scale Rustication (*mud appliqué* 3). Rare, distinctive rustication applied on the lower portion of vessels. It is associated with carinated, non-wheel finished vessels, and wheel finished burnished vessels (see Figure 7.8: O and P).

F-W2-R-F. 'Fingers' Rustication (Mud Applique 4). Usually applied on wheel finished vessels, it shows a mud appliqué made of medium coarse to fine slurry, similar to the paste of vessels. It seems to have been applied with fingers and following an undulating movement. It is often, but not exclusively, found on large jars, likely storage jars, with pointed base or globular base. It is also found associated with combed incisions, and criss-cross incisions, where the rustication is on the lower half, and the incisions are located in the middle portion of the body (see Figure 7.8: J, K and L). A total of 222 fragments of these sherds have been found at MSD-I, Trench XK2, representing c. 1.23% of the whole assemblage (see below Figure 7.9).

7.5.3 Perforations and incisions

A distinctive set of manufacturing techniques was observed on fragments of perforated vessels. Perforations (**-P**), or small holes, are pierced from the outer surface towards the interior through the walls of cylindrical tall jars (see Figure 7.10: sherd 627; also see Appendix D). After the holes where made from outside the vessel inwards, the inner surface was scraped to remove the resulting surplus of clay and flatten the edge of holes (see Figure 7.10). Such perforated vessels are made out of a fine clay paste (**F-**), sometimes showing small calcareous inclusions. These jars seem to have been formed without the use of any RKE **(-NW**), or very limited use of rotational motions or devices. A larger hole is often found in the middle of the bases of such vessels. This vessel form has been found at sites excavated by the *Land, Water and Settlement* project including the initial excavations at MSD-I, and also Khanak and Alamgirpur (Petrie et al. 2009: Pl. 4), and is often found at Indus sites, as mentioned in Chapter 3, and they are usually referred to as *Perforated Jars* or *Cut Ware* (see Marshal 1931: 465; Mackay 1938: 181; Dales and Kenoyer 1986: 57, 423; Rice 1987: 147; Madhu Bala 2015: 405-407). Interestingly, at MSD-I, Trench XK2 two types of perforated vessels have been identified: the classical Indus perforated jar type, which has holes on the body and base; and globular vessels with a single, central perforation on the base (see Figure 7.10). Only a few fragments of perforated tall jars have been recovered from contexts 612, and 668.

Figure 7.9 Above: count of F-W2-R-F sherds; below: count of F-NW-R-K sherds.X: count of sherds; Y: contexts.



Besides perforations, two styles of decorative incisions could be identified at MSD-I, Trench EA. They are mostly performed on the exterior surface of jars and bowls, or on the interior surface of bowls. It is not clear what tools were used for performing the incisions; however, Durrani suggested the use of bone points or comb for carving the surface of vessels before firing at Rahman Dheri (Durrani 1981: 205). The two types of incisions can be classified as follow:

F-W2-Comb, or fine paste vessels finished using abundant RKE and with combed incisions on the exterior surface. One of the most recurrent decorative styles at MSD-I, Trench XK2 is combed incisions on the external surface, which tend to be particularly deep, with the upper, first incision usually more prominent (see Figure 7.8: F and M). Combed incisions are usually found in the middle or upper portion of the vessels, and incised vessels usually shows a rustication on the lower portion. Combed incisions are often found on **F-W2** sherds.

F-W2-Cross. This type of 'crisscross' incision on the exterior of vessels is frequently found associated with mud-applique 4 or Fingers Rustication (see Figure 7:8: G and H).

Figure 7.10 Top: sherds showing applied Kankar rustication (-R-K), MSD-I, XK2. Below: Evidence for the use of scraping on the interior walls of perforated tall jars. Contexts MSD-XK2-671 and MSD-XK2-666; sherd numbers shown near each fragment.

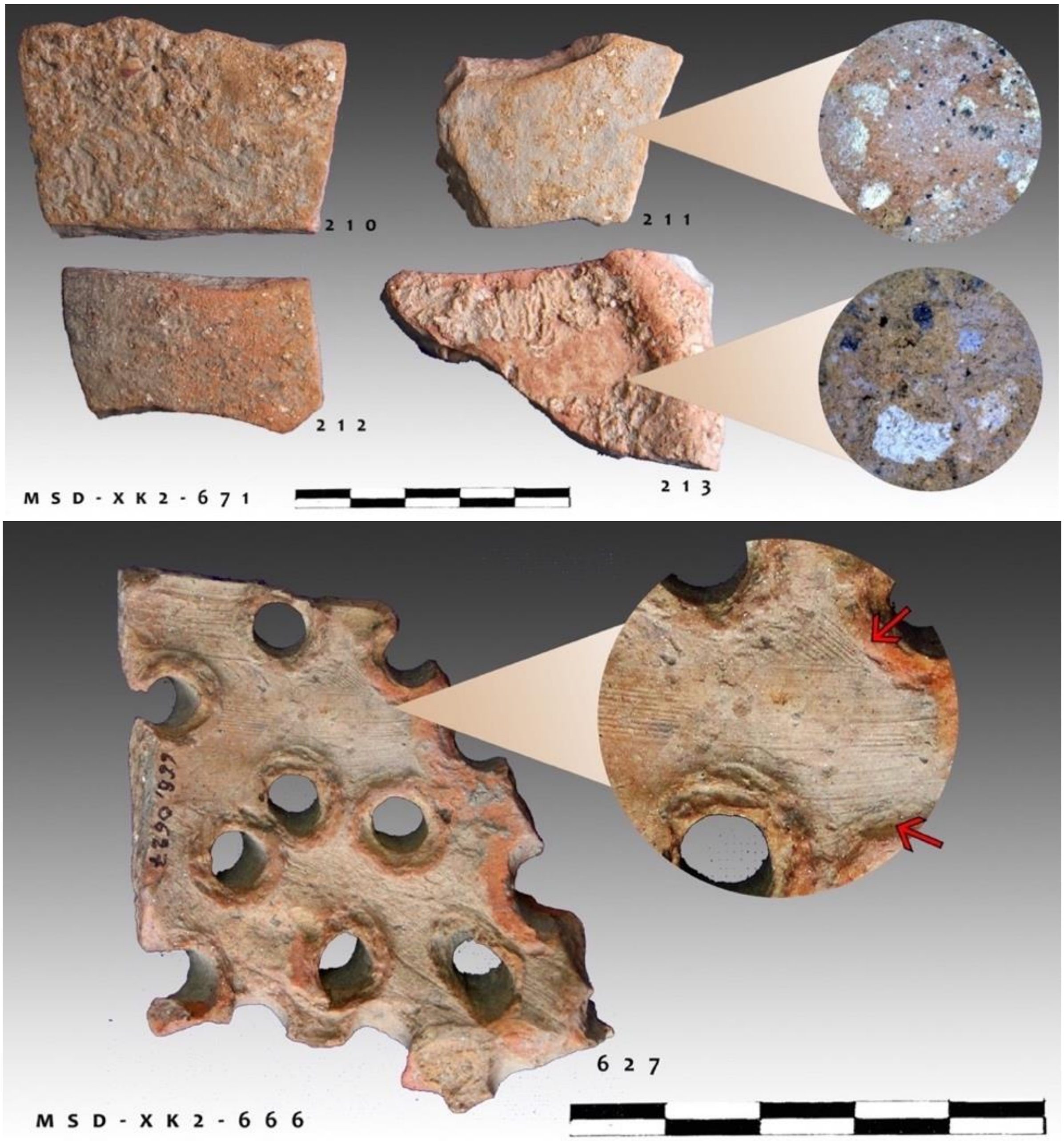
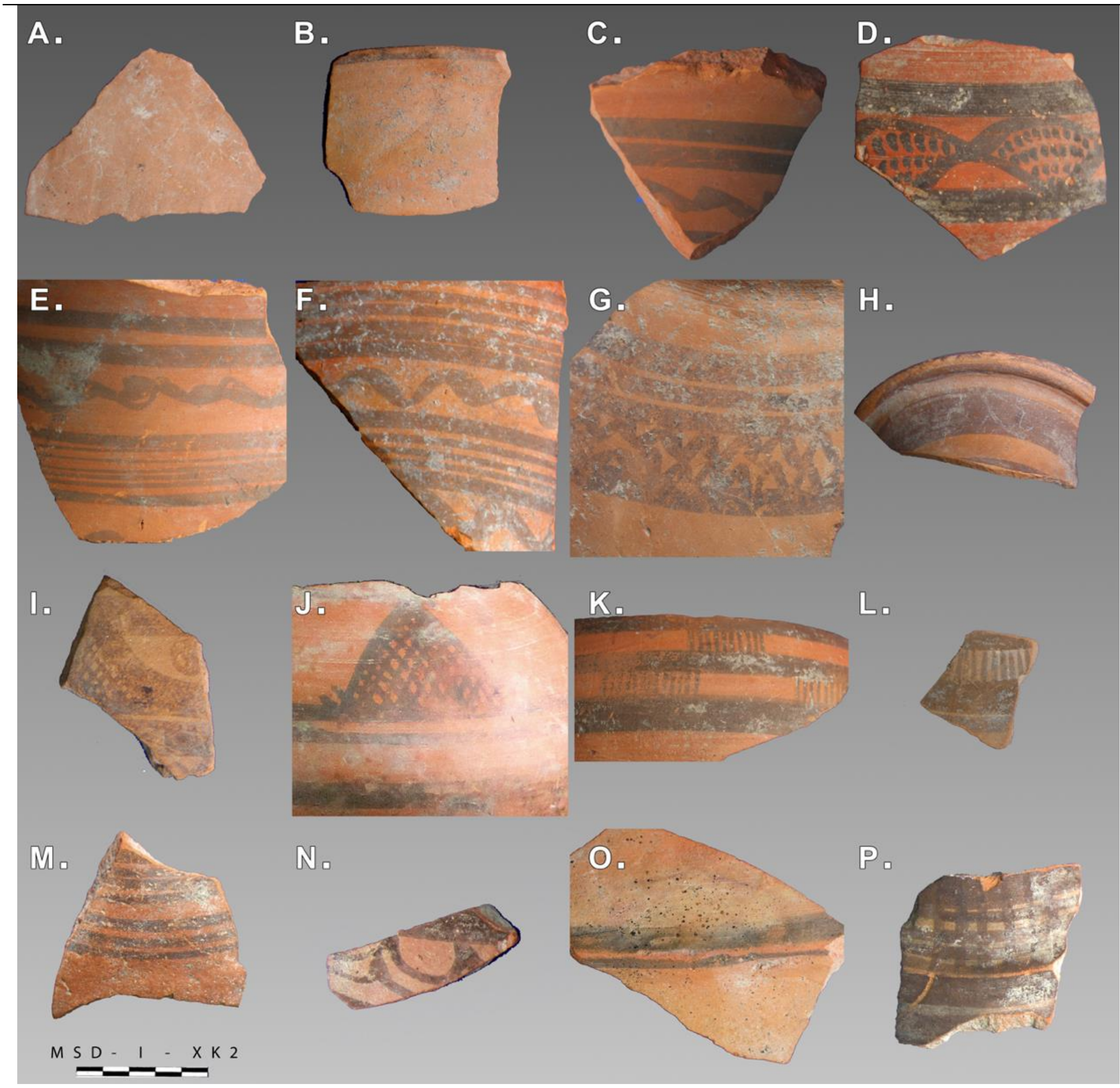


Figure 7.11 More surface treatments and decorations of vessels, MSD-I, XK2. Black paintings are frequent in the corpus, including lines (B-C-O-H); wavy motifs (E-F-G-N); net motifs (I-J-P); vertical lines (K-L); and possible flora and fauna motifs (D).



7.5.4 Painted decoration

Indus pottery from the Urban period shows distinctive painting styles that are somewhat different to that from earlier phases. These painted decoration styles are not particularly vibrant in terms of colours, but show a rich repertoire of figurative motifs. These include mainly single, multiple or wavy lines, circles, dots-and-loop, net and grid motifs, peacock, pipal leaf and other plants (see Parikh and Petrie 2016). In terms of colours, black painted decoration on red vessels are the dominant combinations (see Figure 7.11). Although decorative motifs are not considered In detail in this technological study, it was noted that certain painted motifs seem to recur more frequently in certain traditions, rather than being equally spread across all of them. For instance, as we shall see in the second part of this chapter, the most sophisticated figurative motifs seem to dominate Vessels MSD-ε and Vessels MSD- ζ. while simple black lines, single or multiple lines, and painted black bands are more recurrent in techno-group Vessels MSD-α.

7.6 Coarse (C-) fabric associated techniques

*7.6.1 Moulding (**C-M**)*

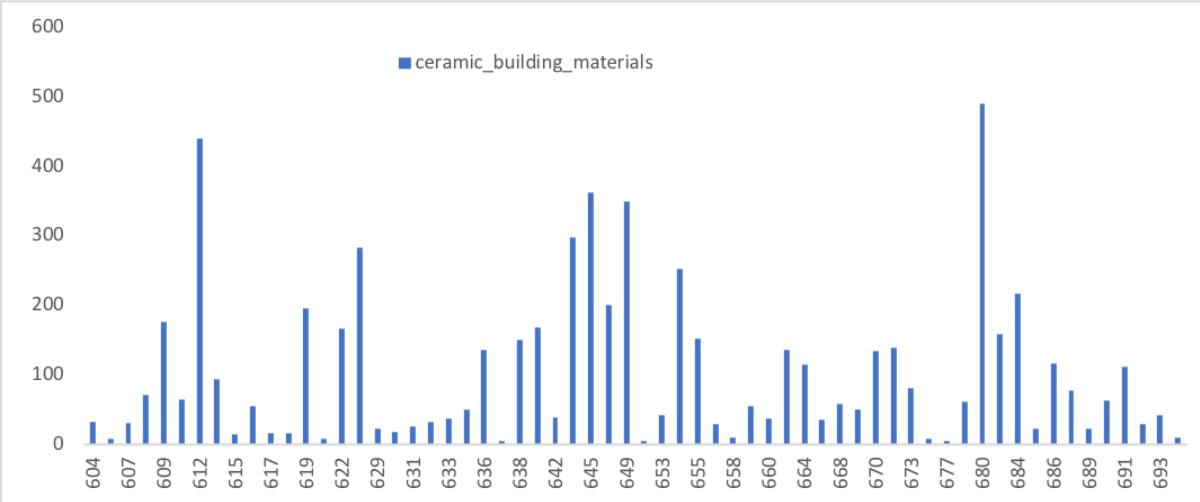
Fragments of coarse ceramics that seem to show evidence of moulding as the main forming technique were sorted as a separate group (see Figure 7.13). Majority of these ceramics have been produced using a medium coarse to very coarse clay paste, often mixed with vegetal or chaff temper. Moulded coarse ceramics include bowls (**C-M-NW**), fragments of bricks, either fired (***C*-M-CBM**) or unfired mud-bricks (**C-M-UM**), and the so-called 'terracotta cakes' (**C-M-TC)**. A description of these groups shall follow:

C-M-NW: Coarse organic-rich paste vessels usually show thin walls, c. 8-10 mm, that are greyish red in colour, with a black or grey core. The most typical shape is a bowl with upright straight rim. Depending on the thickness, these coarse vessels have been broadly devided into C-M-NW-1 (thin) or C-M-NW-1 (very thick). The morphologies of the latter group cannot be securely identified.

C-M-TC, or *Terracotta cakes.* This category of object has already been described in Chapter 6 (see Figure 7.13). At MSD-I, Trench XK2, just 37 fragments of terracotta cakes were identified, c. 0.3% of the whole assemblage. This is in sharp contrast to the earlier excavations at MSD-I, where hundreds of fragments of terracotta cakes were recovered (Petrie C.A. pers. comm.).

C-M-CBM; and **C-M-UM***, or Ceramic Building Material and unfired mud-bricks.* Ceramic building material (-**CBM**) is here defined as a clay body that has been deliberately fired for use as part of a structure. Within the context of Indus sites, they include bricks, floor tiles, kiln firebars, and kiln lining. They have been likely produced using local easily obtained clays, that are mixed together with sand and vegetal or chaff temper, and rarely with grog and ash. CBM is found at most Indus archaeological sites. As they tend to be durable and form a major constituent of many structures, CBM fragments often make up a vast percentage of any ceramic corpus and the bulk of the ceramic material found at Indus sites.

Figure 7.12 CBM in the MSD-I, XK2 assemblage (sherd count).



At MSD-I, Trench XK2, CBM represent 35.8% of the whole assemblage (see Figure 7.12). Although there is neither highly variability of morphology, nor extensive available studies on Indus CBM, fragments can be used to observe variations of fabrics, as well as to identify local clay sources.

7.6.2 Fabric Impressions

C-NW-FI Coarse paste Fabric Impression. Fabric impressions are usually found on the possible interior side of a ceramic object, made of coarse organic clay paste. Within the corpus, only 9 fragments of this type have been identified (see Figure 7.13). Figure 7.13 shows very clear fabric impressions on coarse ceramic fragments from MSD-I, Trench XK2. The twisted textiles are relatively open, balanced tabby or plain weaves, woven in what looks like Z-plied (doubled) yarn. The impression on the clay is a mirror image, which is S-plying. The origin of the fibres could possibly be spliced, likely plant fibre similar to bast, stem, or flax (personal communication by Dr Margarita Gleba, Department of Archaeology, University of Cambridge, UK). The fibre identified on the coarse ceramic sherds seem to be similar to those recovered at Judeirjo-Daro (Shar and Vidale 2001) and different from those identified on ceramics at Harappa (Mound E) which preserved jute structure (Wright et al. 2012). According to Fairservis (1956) and J.-F. Jarrige et al. (1995: 90), fabric-marked wares, seem to be understood as coarse cooking pottery with cloth impressions' on the bottom or walls, and are likely dated to the second half of the third millennium B.C, or the beginning of the Harappan occupation at Nausharo (Period III). Similar coarse ceramics with fabric impressions seem to occur at Sibri (Period VIII) of the Mehrgarh sequence, likely dated to the last couple centuries of the third millennium BC (also see Parikh and Petrie 2019: Fig. 4). Other documented cases of Indus coarse ceramics with fabric impression are documented associated with the production of faience (Kenoyer 1994a; Kenoyer 2003; Kenoyer 2004).

Figure 7.13 Coarse Ceramics: (C) CBM, (A) unfired mud-bricks, (B, D-H) coarse paste vessels, and (I-K) Terracotta cakes. Below: Textile or fabric impressions, MSD-I, XK2.

Table 7.2 Summary and significant features of MSD techno-groups.

Group	Sub	Code	Paste	Forming Method	Finishing	Rustication	Slip	Polishing or Burnishing	Cutting or Incisions	Painting	Most common Shape
MSD-α		F-NW-A, -B, -C		Method 0, Method 1	Scraped	F-NW-KR, mud appliqué 1 or 3	Red	Smooth	None or F-Wave-Incisions	Black	Bowl or Globular Jars
MSD-β		F-NW-		Method 1/3	Scraped	-	Red	-	Perforations	No	Tall, cylindrical Jars
MSD-γ		F-NW-RSW	Fine (F-)	Method 1/3	Assembled (Stand)	-	Reserved Slip	Polished		Black and Red	n/a
MSD-δ		F-FSR		Method 3/1	Scraped	Applied Fish Scale Rustication, mud appliqué 2	Red	Polished		No	Jars
MSD-ε	LHR- ε1	F-W1		Method 3	Scraped with/ without RKE	None, or F-W-FR	Red	Polished		Black; Black and White	Bowls, dishes and jars
	LHR- ε2	F-W1		Method 3		None, or F-W-FR	Red	Burnished		Black	
MSD- ζ		F-W2 (?)		Method 4 (?)	With RKE	-	-	Polished	-	Black	Small Jars
MSD- η		C-Org-1; C-Org-2	Coarse (C-)	Coild and SSC	-	-	-	-		No	Shallow, large bowl, tray-like vessels
LMSD-θ		C-M		Moulding	-	--	-	-		No	Cakes or Bricks

7.7 Technical groups

Depending on the method and scale of observations, the ceramic assemblage discovered at MSD-I, Trench XK2, can be considered both slightly homogeneous and highly variable. Homogeneity is expressed at the level of the clay pastes, including macroscopic variations of colours and composition, and partially at the level of the morphologies. The diversity is expressed on two levels: forming techniques, and finishing operations. The vast majority of vessels (large or small, open or closed) seem to show preliminary forming techniques, such as coiling. The coils were likely joined and thinned using a scraping technique, with or without the use of RKE or rotational devices. Finishing techniques include those operations which aimed to transform the walls and surfaces of vessels, and decorations. The analysis of technical actions identified eight main technological groups of vessels. The groups have been organised using letters of the Greek alphabet, from *α* to *θ*. The technical actions and macroscopic technical features identified and described in the first part of this Chapter are here combined to present a comprehensive understanding of each ceramic tradition and the production of groups of vessels. Preliminary forming techniques and the use (or not) of RKE and rotational devices are both still central in this second part of the Chapter, as well as certain finishing techniques and surface treatments previously described. Whether needed, Chapter 3 can be used as reference and offers a list of technical concepts and nomenclature used in the following section.

7.7.1 Vessels MSD-α

Red ware vessels produced with very limited use of rotational gestures (Figure 7.14) have been identified in all deposits at MSD-I, Trench XK2. These vessels seem to have been formed using a combination of techniques, including coiling, scraping and smoothing (see above technical actions, ***F-NW-A, -B,*** and ***-C***). This approach mostly corresponds to forming Method 0 or Method 1 (see Table 7.1). The quality of vessels range from low to high. Rims and walls are often irregular, reflecting a certain degree of variability in the forming process. The outer surface tends to be smooth and red slipped and/or painted; while the inner surface tends to show scraping marks and incisions. The core of the walls tends to be red, thus indicating a thorough oxidising firing process. Bowls, small and medium jars, and jars with applied ridge seem to be the most frequent morphological categories. They are mostly

Figure 7.14 Examples of Vessels MSD-α.

bowls with upright rims or jars upright necks, hemispherical body; or with out-curved rims. Bases are usually concave or flat, and applied rings can also be found on the external surfaces of the bases. Some jars can show an attached handle, directly on rim and body of vessels.

In terms of surface treatments, the lower portion of certain vessels, especially globular jars and bowls, show an applied rustication (-KR, or mud appliqué 1). The rustication can be thin or thick (3) and is applied on the external surface of ceramics, often associated with scraping marks on the inner surfaces of the sherds. Incised wavy lines and parallel combed incisions on vessel surfaces (F-Wave-Inc), as well as black painting, mostly bands or parallel black lines (e.g. Figure 7.11 : I, J). Rare fragments of red bowls with black painting show incised Mud Applique 1 or patterns on the inner surface, which resembles Fabric D bowls from Kalibangan (Madhu Bala 1997; 2003). Red slip (F-NW-S), including pale reddish-brown to red in colour, is visible on both the outer and inner surfaces.

7.7.2 Vessels MSD-β

Perforations are applied to distinctive tall, cylindrical jars, whose body was entirely pierced with a small tubular object (see section 7.5.3). These vessels (**F-Perf**) represent 1.34% of all ceramic fragments, or 1.55% of the total weight. They seem to have been formed using a fine clay paste and shaped with little to no use of rotational gestures or devices. Coils, possibly large coils or slabs, along with scraping technique seem to be the most used manufacturing techniques (Method 0 or 1, see Table 7.1). Perforations were likely undertaken at a semi-dry or leather-dry stage, piercing the walls of vessels from the outer surface towards the interior of vessels. The resulting excess of clay material was then scrapped out and levelled from the inner surface, resulting in distinctive rings around the holes on the inner walls (see Figure 7.15). The core of the walls tend to be red, thus indicative of a thorough oxidising firing process. Tall, cylindrical jars are the dominant morphological category. Bases are usually flat, mostly showing a large circular hole in the middle of the base.

Figure 7.15 Vessels MSD-β. Perforated tall Jar from MSD-I, XK2.

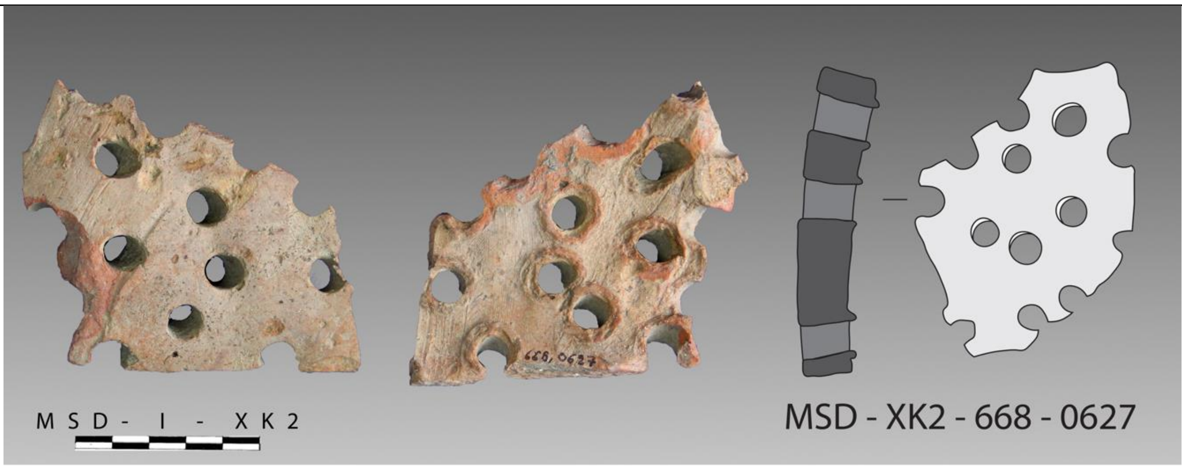
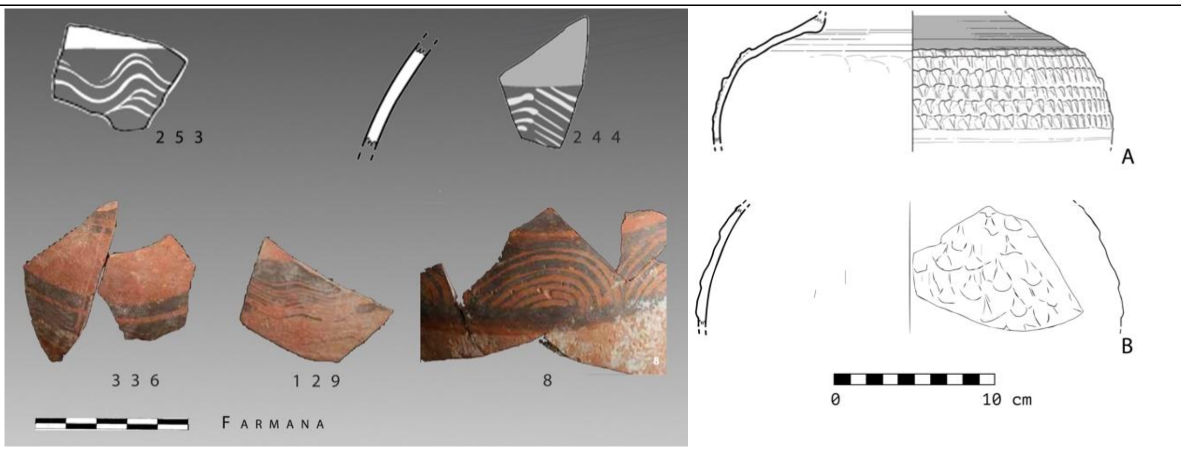


Figure 7.16 Left: RSW recovered at Farmana (after Uesugi 2011; Parikh and Petrie 2016, 2019). Right, examples of vessels showing a similar surface treatment to the applied fish scale rustication: A from Farmana (sample 1074); and B from Kanmer (Sample 978), after Uesugi 2011.



7.7.3 Vessels MSD-γ and Vessels MSD-δ

Two types of vessels are remarkably rare in the MSD-I, XK2 corpus; yet, they appear in a few contexts, showing a unique set of surface treatments. The first one is a Black-on-Red ware which shows typical features of the so-called Reserved Slip ware (F-RSW). The second is a type of fine vessels with a peculiar applied rustication, here temporarily labelled 'Applied Fish-Scale Rustication (F-FSR or Mud Applique 3). The technologies behind the production of **Vessels MSD-γ**, or Indus Reserved Slip has been extensively studied at Indus sites (Dales and Kenoyer 1986: 44, fig. 7.3; Wright 1991: fig 6.4; Krishnan 2018; Shinde and Shirvalkar 2009). Data concerning Reserve Slip ware have mostly come from ceramic corpora recovered in Rajasthan, at sites such as Ahar (Sankalia et. al. 1969; Seth and

Kharakwal 2013), Gilund (Possehl et.al 2004), Balathal (Misra 2007), Desalpur (Uesugi et al.), Ojiyana (Meena and Tripathi 2000), and apparently at Ganeshwar, Lachhura, Maharaj ki Kheri and Chhatri Khera; in Gujarat at sites such as Dholavira (Bisht 2000); and in Haryana at sites such as Farmana (Parikh and Petrie 2019). Reserved slip ware is not to be confused with the so-called 'Sintered' or 'Glazed' Reserved Slip Ware, which has been profusely studied by Krishnan et al. (2005; also see Mackay 1938: 187-188). Unfortunately, given the paucity of samples in the corpus, its technological aspects will not be further discussed here (see Figure 7.16).

However, **Vessels MSD-δ** shows the distinctive Applied Fish Scale Rustication (F-FSR or Mud Applique 2), which seems to be quite an unusual technique within the Indus assemblage (see Figure 7.16). Even though a large variety of mud appliqué techniques and styles have been identified, this particular 'applied fish scale rustication' seems to be remarkably different and unique. The look of the latter applied rustication resemble the surface of a pineapple or a fish scale motif. These sherds show certain surface treatments and morphologies comparable to historical vessels rediscovered at Rang Mahal (Rydh 1959; Uesugi 2014), Sonkh VI (Hartel 1993), Kanmer (Uesugi and Meena 2012), and Sahet III (Aboshi and Sonoda 1997), as well as with historical pottery from Farmana Settlement Area and Central Area (Uesugi 2011, Fig. 6.10). If a larger number of samples could be studied from MSD-I, Trench XK2, a much more solid argument for possible similarities with historical ceramics, especially vessels from the Gupta period, could be put forward. Given that these sherds were recovered from a pit almost immediately below the modern mound surface, it is entirely possible that they are post-Indus in date (Petrie pers comm.).

7.7.4 Vessels MSD-ε

The second most abundant group of ceramics is the **Vessels MSD-ε** techno-group. This group is defined by a combination of sophisticated forming techniques and high levels of control during the manufacturing process (see Figure 7.17). This combination of techniques includes preliminary coiling and the abundant use of rotational gestures and devices. Parallel horizontal striations are not only confined to the upper portion of vessels where they appear mostly on the interior surfaces of rims and necks (e.g. Vessels MSD-α), but they can also be found throughout the whole length of vessel body – from rim to base, on both thick or thin walls (see above, technical actions **F-W1** and **F-W2**). Most diagnostic fragments of rims show clear parallel striations. These are indicative of vessel rims being possibly crafted separately and attached to the vessel using a rotational motion in a subsequent phase of manufacture; or the use of rotational devices more abundantly employed in the final stages of fashioning. This type of vessel tends to show a red slip, and black-on-red painted decoration. The painted motifs are more creative and vibrant than those seen on Vessels MSD-α, showing a range of floral and faunal themes, as well as geometric decoration. Other surface decoration styles may include incisions and carvings (see above, technical actions **F-Combed-Inc**, and **F-CrissCross**). Some jars, mostly medium or large jars, also show a particular type of surface treatment: (**F-W-FR**) a fine applied rustication, using small-grain size clay slurry. No temper or inclusions are visible in the slurry (see above Figure 7.8: K), which seems to have been applied by the producers using their hands and spreading it evenly using their fingers. Given the readily visible finger marks, this was named applied 'Fingers' Rustication (-**FR**, or *mud appliqué* 4):

Distinctive forms, such as dishes, bowl, jars with tall and narrow necks, jars with wide mouths, and goblets are some of the most common shapes. These have also been identified at other sites in the region, including Rakhigarhi (Amarendra Nath 2014), and Farmana, especially well-known Harappan-like jars (Uesugi 2014: Figure 6.30), Harappan bowl types (e.g. Farmana Burial no. 10; see Uesugi 2014: Fig 9.7) and non-Harappan bowl types (Uesugi 2014: Fig 9.19). Even though this group include vessels that have been defined as Harappan-like or non-Harappan containers, in terms of morphologies, this group of vessels is possibly one of the most evocative of a regional Indus or regional Harappan flavour (see Appendix D). However, several shared morphologies with **Vessels-MSD-α** are also produced within this technical groups (see Appendix D: Plate V), which appear to differ in terms of technical actions, certain morphologies, decorations and painted motifs, as well as skills and mastery of techniques. These aspects will be further discussed in the last part of this chapter.

Vessels MSD-ε2. If we consider the profuse use of burnishing tools and techniques of vessel surfaces, a subset of this overarching tradition may be identified: the group of **Vessels MSD-ε**2. In the database, (see Section 4.2), these vessels have been recorded as *semi_burnished_red*; *burnished_red*; and *burnished_red_and_black*. They represent c. 2.3% of the whole assemblage, and still resemble manufacturing techniques and morphologies similar to the broader Vessels MSD-ε. However, given the limited presence of these vessels, this will not be extensively discussed here (see above, Surface Treatments).

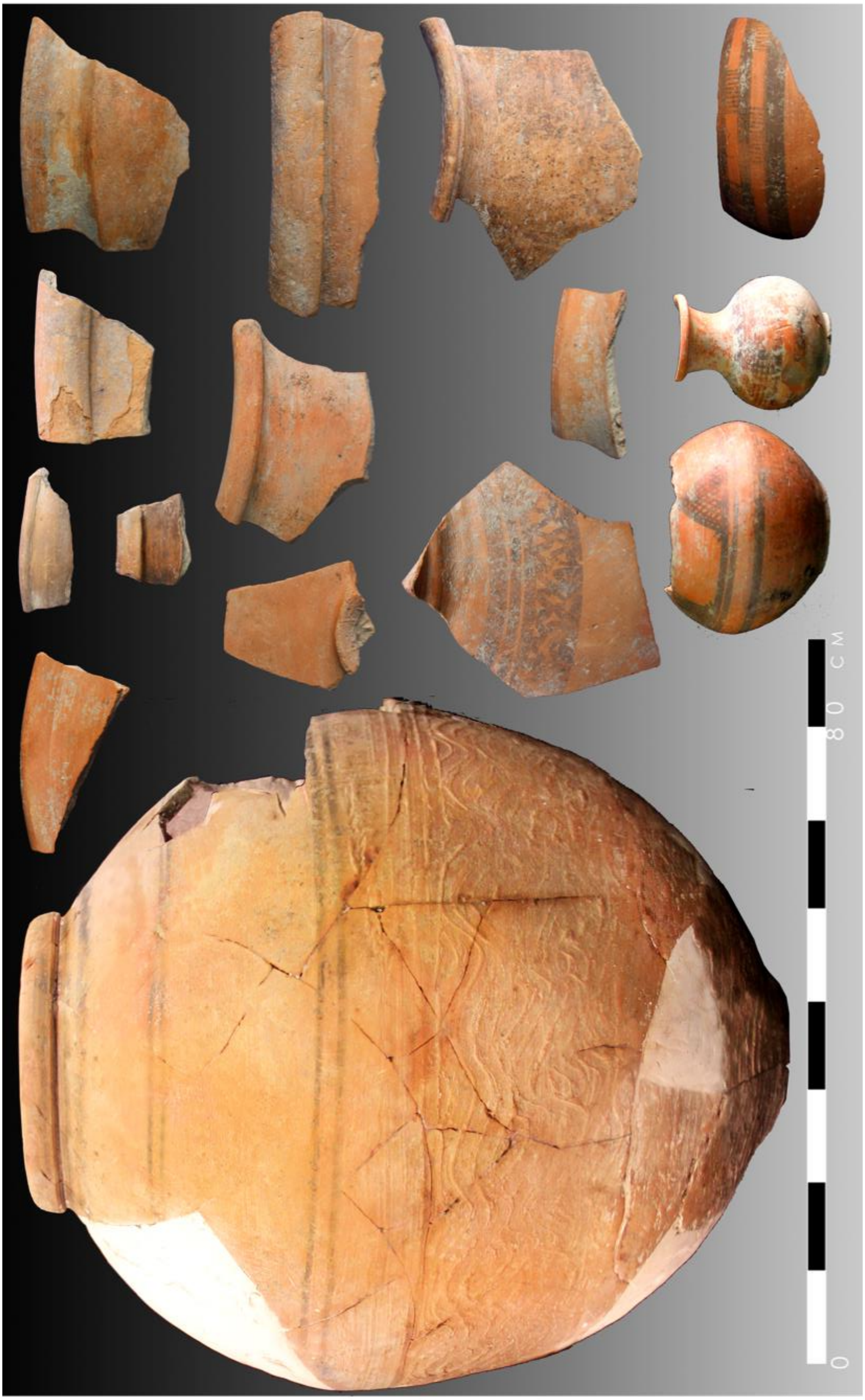


Figure 7.17 Examples of Vessels MSD-ε.

Figure 7.18 Examples of Vessels MSD- ζ.

7.7.5 Vessels MSD-ζ

These vessels, mostly small jars, show perfectly parallel striations and grooves, which are often found throughout the whole wall of vessels – from rim to base, on thin walls. Most diagnostic rims shows clear parallel striations (**F-W2)**. This type of vessels include a rare type of slip, vibrant-red to deep red in colour, with vivacious black painted decoration. It is usually associated with profuse polishing of the outer surface of vessels. Morphologically, it seems to show jars similar to **Vessels MSD-ε**. Only a few, rare specimens have been identified at MSD-I, Trench XK2 (see Figure 7.18). In the database, they have been documented as "F-W-L-S, or Fine_lustrous_bnr". These will be further discussed in Section 7.8.

7.7.6 Vessels MSD-η

There is a category of vessels that show a distinctive set of recipes and manufacturing techniques (database code C-Org-1; C-Org-2). They were produced using a coarse (C-) ceramic paste, abundantly mixed with vegetal or chaff temper. Morphologically, they seem to include shallow, large bowls, trays or basins (see Figure 7.13). The rims are usually upright. Given the friability of these vessels, which possibly a result of low firing conditions and the coarse paste, and also due to the highly fragmentary conditions of the sherds recovered, it is not possible to provide a comprehensive analysis of the coarse vessels. Nevertheless, the likely use of thick coils or slabs **(-S**) during the manufacturing process could be inferred from the traces on the sherd surfaces. Given the very limited presence of these vessels in the studied corpus, these will not be considered in subsequent stages of analysis and are not included in the following section. Coarse sherds with fabric impressions (see database codes *C-Impr*, or *exterior_basket_impressions*) have already been discussed in Section 7.6. To some extent, the combination of vegetal temper combined with the use of coils and slabs (**C-S**), and tray-like morphology resembles ceramic traditions discussed in section 3.7, including certain coarse wares of Iran (e.g. Iranian husking trays) and South Asia (e.g. SSC chaff tempered vessels, of the fourth to third millennium B.C.) (Rice 1999; Smith and Bagherzadeh 1976; Vandiver 1987; 1985). However, using these macroscopic similarities for tracing a direct connection or parallel histories of these ceramic industries would be premature, and shall not be here discussed.

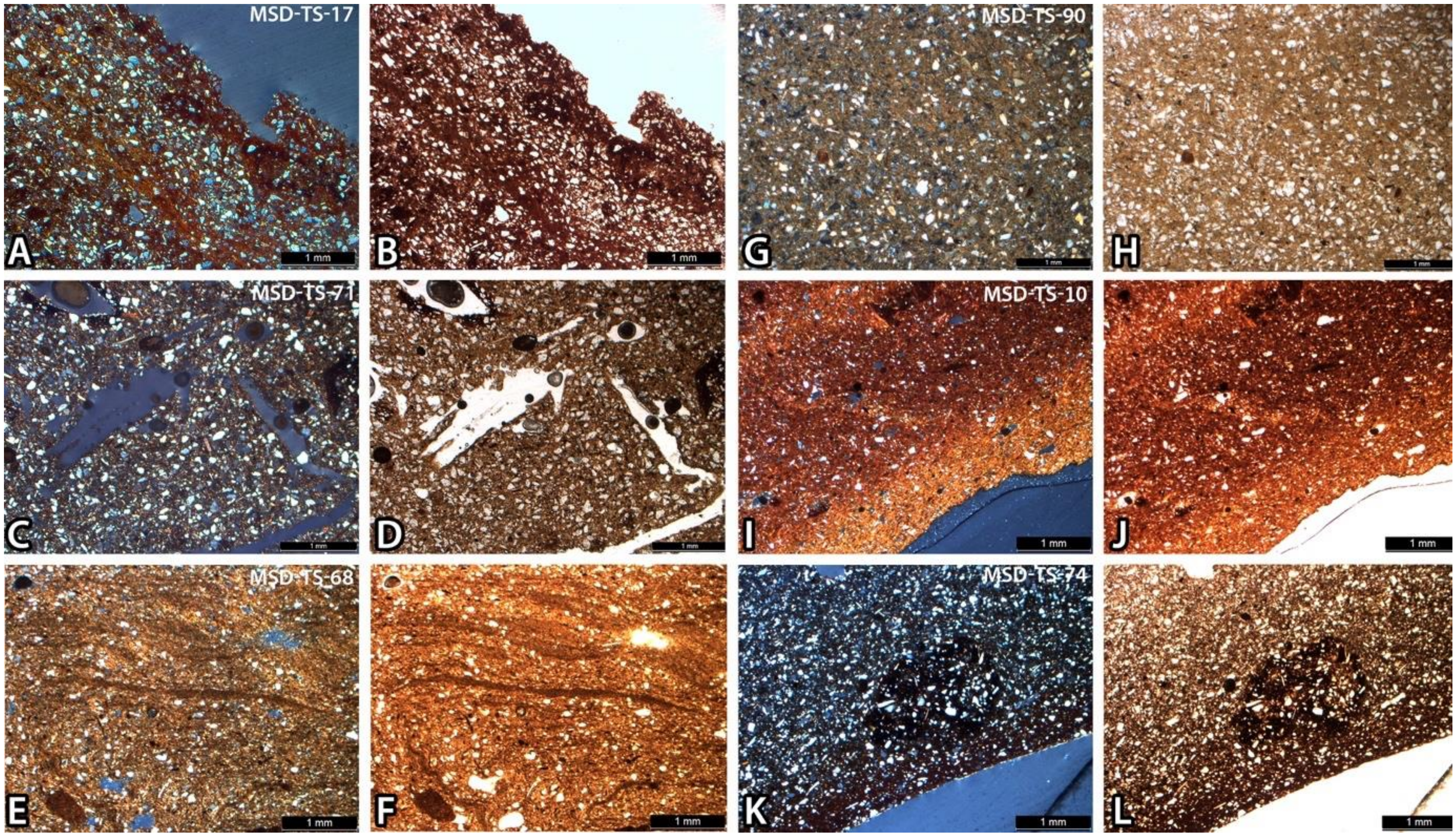
7.7.7 Ceramics MSD-θ

Terracotta (**C-M-TC**) cakes, *Ceramic Building Material and unfired mud-bricks* (**C-M-CBM**; and **C-M-UM**) have already been discussed in Section 7.6. Given their unique recipe and manufacturing technique, they can be grouped into one local tradition of ceramic production. Assuming that the recipes of ceramic building material (CBM) and terracotta cakes, overly abundant in the studied corpus, have been prepared using locally available raw material in proximity to the site, this will be considered in the following section and will be used in further stages of ceramic analyses, including petrographic and chemical characterization.

7.8 Petrographic results

The second sorting stage allowed the identification of techno-petrographic groups. Considering technical groups and diagnostic sherds, samples have been selected to produce ceramic thin-sections. As mentioned in Chapter 3, from MSD-I, Trench XK2, 100 thin-sections has been produced and studied, which provided information about raw materials, clay paste preparation, forming and firing techniques. Seven main petrographic fabrics (MSD-A to MSD-G; see Table 7.2) have been identified according to fabric components, including: particulate inclusions; size and shape of voids; clay matrix; nature, size and orientation of mineral and rock fragments. Details regarding samples and the Petrographic group descriptions are available in Appendix A and Appendix B.

Figure 7.19 Petro-Classes (see Appendix B). Class MSD-A (photomicrographs A-B, sample TS-M-17); Class MSD-B (C-D, sample TS-M-71); Class MSD-C (E-F, sample TS-M-68); Class MSD-D (G-H, sample TS-M-90); Class MSD-E (I-J, sample TS-M-10); Class MSD-G (K-L, sample TS-M-74).



7.8.1 Petro-technological classification

The seven petro-classes reveal data that can be used to explore the types of raw materials and recipes that have been used, and to make further technological observations. The fabric classes have thus been identified primarily considering not only the composition of clay matrix, but also nature, size and distribution of inclusions and voids, as well as possible clay mixing and other relevant technical features (see Appendix B). The seven classes, and their subgroups, have been named as follows (see Figure 7.19 and Table 7.2): MSD-A, Coarse Iron-Rich Organic Group; MSD-B– Coarse Calcareous Organic Group (sample 68, 36); MSD-C –Medium-Fine Calcareous Group (samples 5, 98); MSD-D –Fine Calcareous Group (samples 90, 91); MSD-E –Very Fine Iron-rich Mica and Quartz Group (10, 45, 51, 52, 62, 80); MSD-F – Vitrified Fabric (14, 73); and MSD-G - Fine Mica and Quartz Group. Detailed descriptions of the seven fabric classes are available in Appendix B.

In terms of composition, the petro-fabric groups seems to show some main qualifying characteristics. Considering inclusions, matrix and voids, these broadly range from coarse fabrics to fine fabrics, and from low to high iron-rich pastes, and from lowly to highly calcareous matrix. The descriptions in Appendix B often mention to the use of raw materials, or clay deposits frequently containing quartz, mica, plagioclase feldspar, polycrystalline quartz, and rare clinopyroxene and epidote group minerals. A careful analyses of petrographic classes seems to suggest a variety of recipes and uses of raw materials. For instance, petro-classes MSD-D and MSD-E appear remarkably different from other fabrics, given their textural aspects, and could be related to a different clay source or to a different tradition of clay processing and paste preparation. Similarly, certain parts of vessels, as well as certain clay slurries applied to vessels, seem to be tempered in quite specific ways. Such is the case of petro-classes MSD-C, which shows the use of calcrete-Kankar nodules in paste preparation. Finally, petro-classes MSD-A and MSD-B suggest the abundant use of vegetal or temper for the production of certain ceramics. This picture reveals a certain level of heterogeneity within the assemblage in terms paste preparation and/or provenance. Similar to LHR-I, Trench EA samples, petrographic data from MSD-I, Trench XK2 seem to point out the widespread use of fine grain raw materials across most of the analysed ceramics.

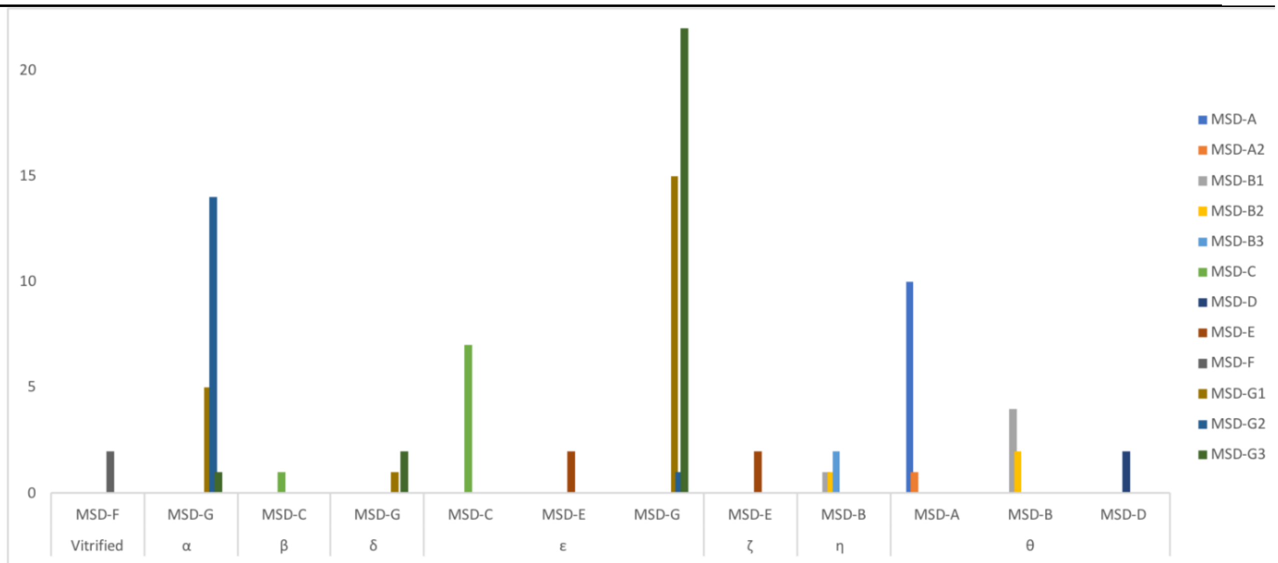
Petrographic observations suggest the prevalent use of clay rich possibly from fluvial or alluvial deposits from the plains of Haryana, or depositional basins in close proximity to water channels (see Chapter 3). Given the macroscopic and petrographic observations, the material from the site seems to corroborate the widely accepted assumption that at prehistoric or protohistoric settlements, the ceramic corpus typically includes a majority of locally made ceramics. In other words, clay sources could have been located in close proximity to the site, within a 10-km radius (e.g. Arnold 1985). To some extent, the majority of raw materials and assemblage at MSD-I, Trench XK2 could to fall within this category. As we shall see in the following sections, this hypothesis will be further tested using chemical data.

In terms of forming techniques, no coarse samples show microscopic evidence for the use of coils, wheel-coiling, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding can be suggested for the coarse groups. However, fine, medium-fine and very-fine fabrics do tend to show the presence of relic coils (e.g. MSD-TS-3, sample MSD-I-XK2-685-237; MSD-TS-53, sample MSD-XK2-619-423; MSD-TS-57, sample MSD-I-XK2-619-428). Some samples show frequent clay pellets or distinctive clay domains in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage (e.g. MSD-TS-16; MSD-TS-32; MSD-TS-42; MSD-TS-52).

Table 7.3 Petrographic classes and sub-groups, and related thin-section samples, MSD-I, XK2. Descriptions available in Appendix B.

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-A	MSD-A1	11, 12, 17, 35, 39, 67, 72, 75, 76
	MSD-A2	77
MSD-B	MSD-B1	20, 37, 71, 78, 88, 89, 92, 94
	MSD-B2	15, 79, 93
	MSD-B3	13, 36
MSD-C	MSD-C	5, 68, 98, 40, 28, 41, 66, 16, 67
MSD-D	MSD-D	90, 91
MSD-E	MSD-E	10, 45, 51, 52, 62, 80
MSD-F	MSD-F	14, 73
MSD-G	MSD-G1	65, 58, 86, 59, 64, 61, 84, 46, 1, 53, 30, 57
	MSD-G2	74, 63, 44, 8, 87, 81, 34, 42, 82, 56, 85
	MSD-G3	48, 60, 83, 95, 3, 49, 96, 47, 21, 55, 19, 43, 54, 100, 70, 97, 38, 99, 50, 22, 24, 26, 6, 18, 69, 31, 33, 23, 27, 32, 25, 2, 29, 7, 9

Figure 7.20 Correlations between Techno-Group and Petro-Groups (below) and sub-groups (left legend), MSD-I, XK2.



7.8.2 Correlations between petro-groups and techno-groups

As we noted above, Vessels-α to Vessels-θ have been identified according to their distinctive technologies, which include the set of recipes, forming techniques, finishing techniques and surface treatments. Their similarities and differences in terms of petrographic fabrics are particularly interesting (see Figures 7.20, Figure 7.24 and Table 7.3). Vessels-α, Vessels-δ, and Vessels-ε are dominated by the petro-class MSD-G, the *Fine Mica and Quartz Group*. Vessels α seems to show a stronger correlation with petro-class MSD-G2. The majority of vessels Vessels-ε (~80%) belong to MSD-G, in particular to MSD-G1 and MSD-G3, even though a small portion (~20%) seems to belong to MSD-C and MSD-E, a finer quartz and mica rich fabric or a more calcareous fabric. Compositionally, Vessels-δ and Vessels-ε appear to be remarkably similar. Vessels-ζ and Ceramics-θ show a match respectively with LHR-E, or Very Fine Iron-rich Mica and Quartz Group, and with MSD-A and MSD-B, the coarse fabrics, and MSD-D. Vessels η also show a perfect correlation with the coarse petro-class MSD-B. Vitrified or glazed ceramics belong to a distinctive petro-class MSD-F.

From a technological perspective, Vessels-α, which are manufactured with no or limited use of rotational gestures or devices, seem to form a consistent petrographic class (MSD-G). However, vessels- α with an applied rustication show the consistent use a combination of recipes. The body and core of Vessels-α coherently form the petrographic class MSD-G, while the applied rustication is mixed with *Lime-kankar* or calcrete fragments. This pattern suggests the use of a combination of recipes for the manufacture of vessels-α, especially globular vessels with applied rustications. Vessels-β, the perforated jars, show the use a recipe which shows the abundant inclusion of calcrete within the clay paste, and consistently form petrographic class MSD-C, which is characterised by the presence of fragments of limestone within the clay paste. Vessels-ζ, or the deluxe black-on-red vessels, show the consistent use of a very fine *Mica and Quartz* paste MSD-E, which is occasionally found associated with Vessels-ε as well. Broadly, Vessels-ζ resemble the composition of majority of Vessels-α and Vessels-ε. The latter techno-group shows the prominent use of RKE and possibly rotational devices, and they are particularly interesting due to the use of a fine ceramic paste (MSD-G3). Vessels-ε-MSD-G3 are also associated with the abundant presence of swirls and relic coils (e.g. MSD-TS-3; MSD-TS-53; MSD-TS-57).

Table 7.4 Correlations (%) of Techno-groups and Petro-Classes at MSD-I, XK2.

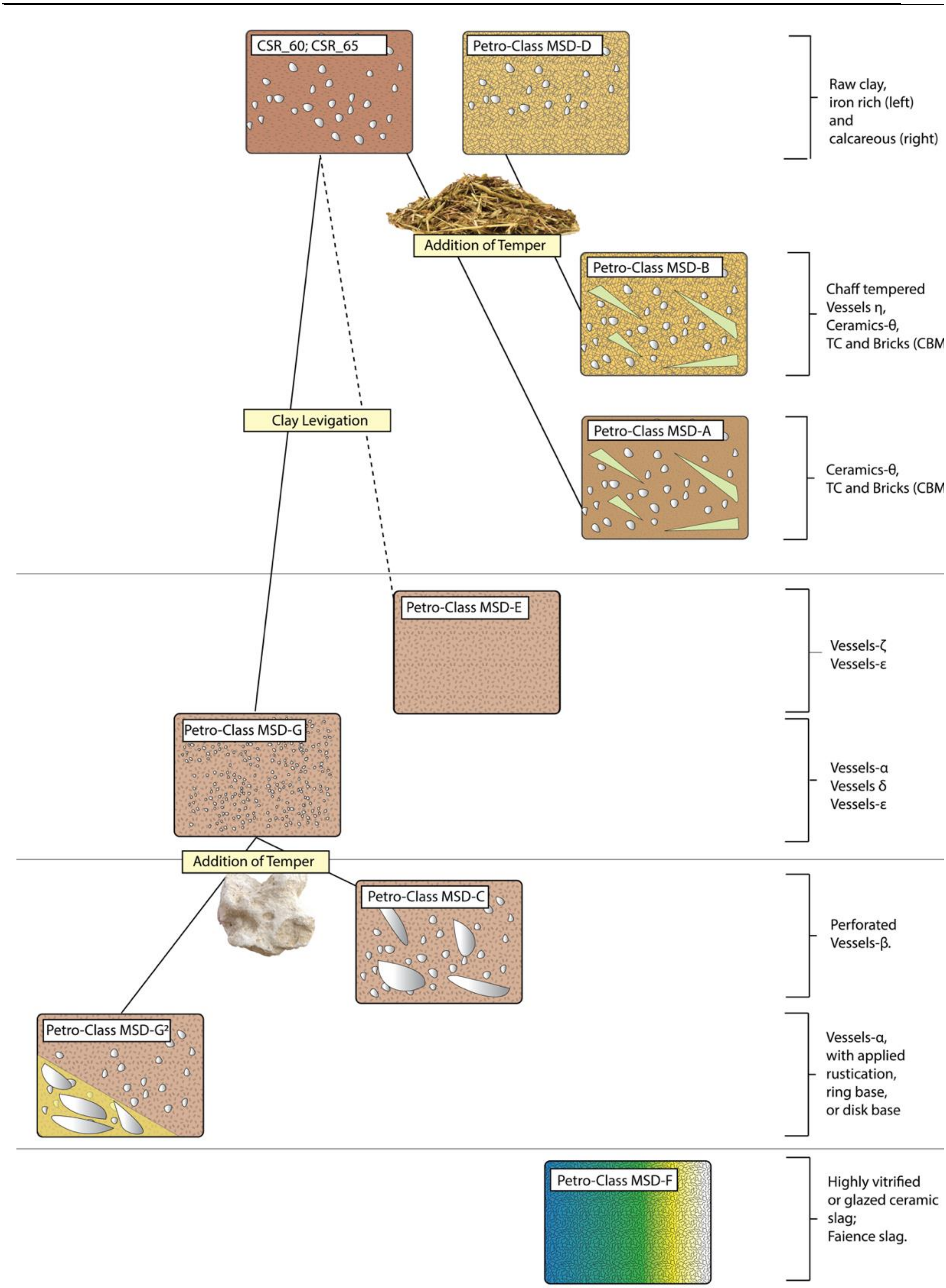
Techno-Group	Petro-Group	Sub-Class	Grand Total
Vessels α	MSD-G	MSD-G1	25.00%
		MSD-G2	70.00%
		MSD-G3	5.00%
Vessels β	MSD-C	MSD-C	100.00%
Vessels δ	MSD-G	MSD-G1	33.33%
		MSD-G3	66.67%
Vessels ε	MSD-C	MSD-C	14.89%
	MSD-E	MSD-E	4.26%
	MSD-G	MSD-G1	31.91%
		MSD-G2	2.13%
		MSD-G3	46.81%
Vessels ζ	MSD-E	MSD-E	100.00%
Vessels η	MSD-B	MSD-B1	25.00%
		MSD-B2	25.00%
		MSD-B3	50.00%
Ceramics- θ	MSD-A	MSD-A	52.63%
		MSD-A2	5.26%
	MSD-B	MSD-B1	21.05%
		MSD-B2	10.53%
	MSD-D	MSD-D	10.53%
Vitrified	MSD-F	MSD-F	100.00%

Vessels η appear not to show relic coils or swirls, but show unevenly mixed clay pastes and distinctive calcite inclusions and voids (petro-class MSD-B). In fact, abundant evidence for the use of plant or chaff temper, limestone, and clusters of micritic calcite with inclusions are observed. These ceramics do not show any evidence for the use of RKE or rotational devices, neither macroscopically nor microscopically, and the possibility of slab construction technique and moulding could be suggested. Similarly, Ceramics-θ show the dominant use of coarse fabrics for the production of CBM and Terracotta cakes, which also show evidence for the use of moulding technique.

The correlations between techno-groups and petro-classes point out both levels of homogeneity, and heterogeneity and richness in terms of variable sources, recipes and clay processing techniques. The homogeneity is expressed by the dominant use of fine, possibly alluvial clay that is abundantly visible in the dominant petro-class MSD-G. This fine-grained clay is at times mixed with types of limestone inclusions or calcrete-kankar, which are used for the distinctive manufacture of, respectively, Vessels- α with applied rustications, and for perforated Vessels β. Similarly to ceramics studied at LHR-I, Trench EA, the petrographic characterisation points out the use of regionally available raw materials in the Haryana plains, including the sporadic use of locally occurring calcrete-kankar nodules in the manufacturing process.

During the Early-Late Urban transition and Late-Urban period at MSD-I, Trench XK2, the fine Vessels- α, along with the less sophisticated Vessels ε, represent the most abundant ceramic industries in the corpus, and suggest a certain degree of homogeneity in terms of raw materials, expressed by petrographic fabric characterisation. As discussed in Chapter 3, rivers and rain patterns both contribute to the hydrological configuration of modern Haryana plains, where the archaeological site at MSD-I was identified (see Orengo and Petrei 2017, 2018; Walker in prep). This is especially true during the winter and summer monsoons seasons. These complex and mutating systems of large and small channels also describe the modern networks of canals which dominate the modern plains of Haryana, alimented by major rivers such as the Sutlej and Yamuna. Similarly, a large number of more or less ephemeral channels may have shaped the landscape in the past. The winter and summer monsoon rains combined with the Himalayan hydrology explain the abundance of locally available alluvial or fluvial clay in close proximity to the archaeological site. This might also explain the apparent mineralogical homogeneity of the clay fraction.

Figure 7.21 Schematic representation of Petro-classes, recipes and clay processing at MSD-I.



The presence of several distinctive petrographic classes, each showing a variety of processing and tempering techniques, suggests a significant understanding of raw material properties and choices behind the use of recipes to produce certain ceramic objects.

The petrographic data conveys a sense of homogeneity in terms of raw material provenance, and, at the same time, a great heterogeneity in terms of clay paste preparation and recipes. For instance, this pattern is evident in the case of coarser pastes (MSD-A; MSD-B) used for the production of CBM, Terracotta cakes and coarse Vessels-η. Similarly, this pattern is observed within pastes suggesting the use of calcrete nodules in the recipes of certain slurries for applied rustication (e.g. on Vessels α, see above Figure 7.10) or distinctive vessels recipes (e.g. perforated vessels- β). Another example worth mentioning is the case of the careful levigation of clay to produce the deluxe Vessels- ζ, which show very a fine and homogeneous fabric. This pattern could also be associated with the use of different sources, inferred from the composition on the deluxe black-on-red vessels- ζ (petro-class MSD-E), suggesting either the likely, yet occasional, movement of artefacts into MSD-I settlement from elsewhere, or raw material procurement not always from the same provenance, possibly collected from various places across the macro-region.

7.8.3 Other technological observations

Beyond the study of recipes and raw materials, thin section petrography can be used to observe evidence for manufacturing techniques, surface treatments and firing technologies (see Quinn 2013). As mentioned in Section 7.8.2, the description of petro-classes already included some microscopic features concerning technological aspects of ceramic production, in particular paste preparation, forming and finishing techniques. For instance, a number of samples show more or less evident swirls of the clay-rich matrix or relic coils, when aplastic inclusions seem to align in a spiral pattern. Figure 7.22 shows examples of feature indicative of technological aspects. For instance, Figure 7.22: C and D show relic coils, which corroborate macroscopic observations on fine ware vessels that show macro-traces indicative of preliminary forming methods, including coiling. Similarly, petro-classes descriptions (see Appendix B) also mention where aplastic inclusions or voids are aligned, or not, to the margin of samples, referring to the possible use, or not, of RKE and rotational devices, as well as polishing or burnishing surface treatments.

Figure 7.22 Technological observations via thin-section petrography, MSD-I, XK2. Images show the presence of calcium carbonate rich clay pastes (A-E), different clay mixing or firing outcomes (B), possible relic coils (C-D), as well as the negative impressions of burnt organic material, likely chaff (F).

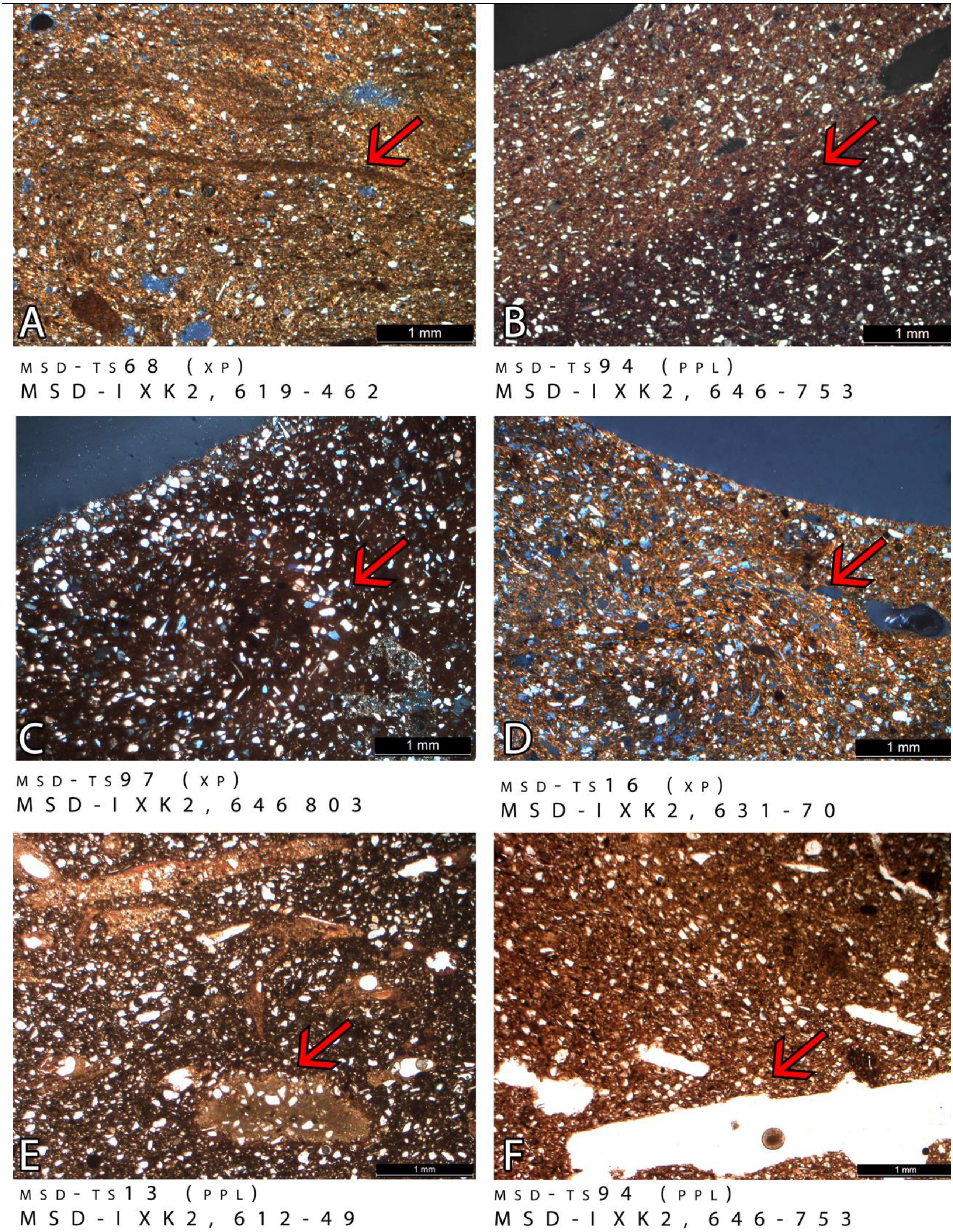
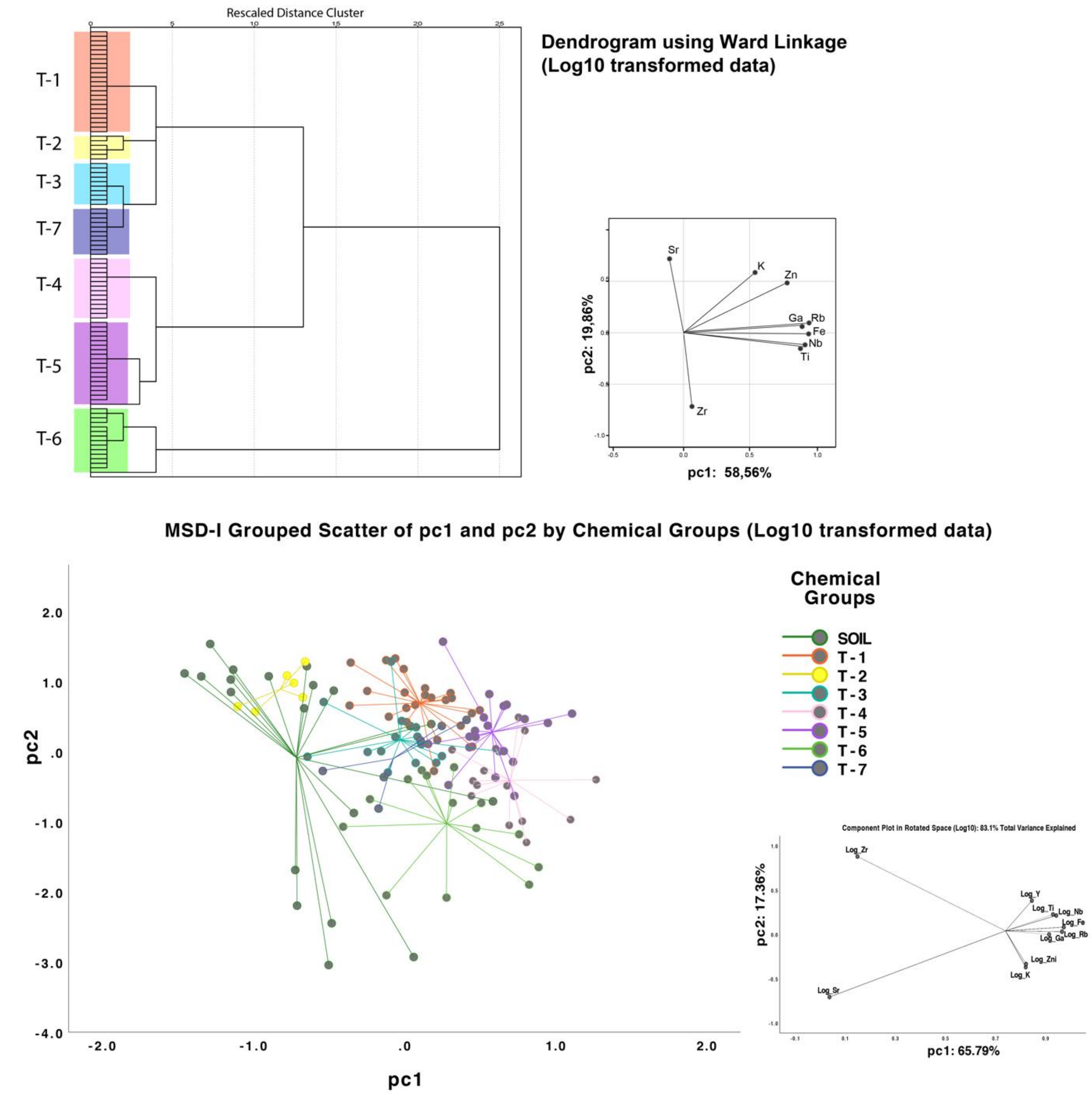


Figure 7.23 MSD-I Hierarchical cluster analysis and compositional groups. The description of each techno-petrographic group falling within each geochemical group is provided in Figure 7.25



Applied slips are quite common within the assemblage, and a variety of slips are also observable via the petrographic analyses. Slips or clay-rich slurries appear to have been mostly produced using raw materials very rich in clay minerals. Even though inclusions in applied slips are usually neither particularly frequent nor large, temper is not always absent. For instance, ceramics with a thicker slip (> 0.3 mm) may also show a coarse fabric (see Figure 7.22: A, E and F). That is the case, for instance, of petro-class MSD-E, which shows the use of calcrete-Kankar fragments in the fabric of the externally applied slurry. Calcrete-kankar fragments seem to be found in the recipe of petro-class MSD-F, used for the production of specific vessels. Technological observations also concern the preparation of coarse ceramic pastes (see Figure 7.22:) and clay mixing. Thin section photomicrographs reveal the mixing of different types of clays, more or less calcareous, resulting in more of less homogeneous, multi-coloured fractions and fabrics.

7.9 Geochemical results

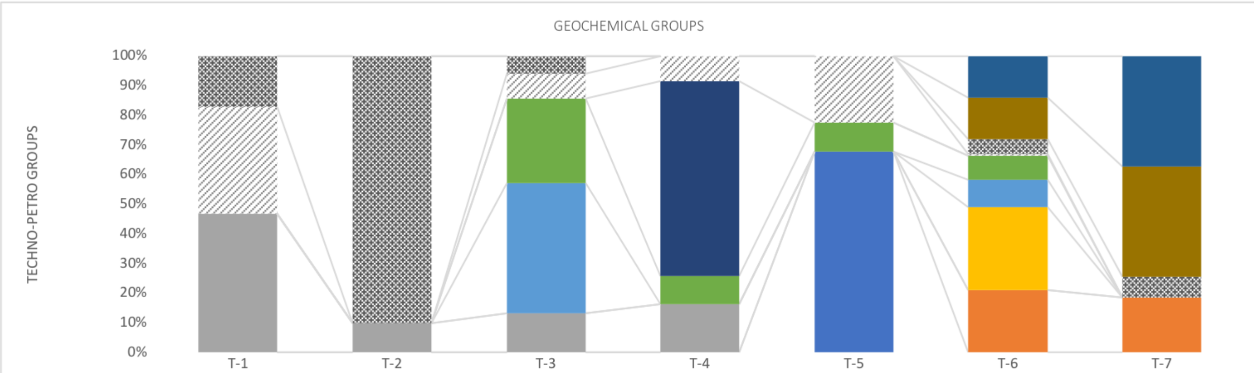
The statistical analysis of the chemical data was performed considering the most accurate and meaningful elements. Details concerning the assessment of the performance of pXRF data calibration can be found in Chapter 4 and Appendix E.

The final MSD-I, XK2 dataset comprised statistical analysis of 121 points (100 archaeological samples; 21 clay-rich soil samples) and 10 elements. The archaeological samples are the same used for producing thin-sections for petrographic analysis. Sample preparation, X-Ray fluorescence analysis and statistical methods for processing data are described in Chapter 4. The clay-rich soil samples were collected using a combination of methods, including satellite imagery, geoarchaeology and ethnographic study (see Chapters 2 and 3). A complete list of chemical samples is presented in Appendix C.

7.9.1 Hierarchical cluster analysis

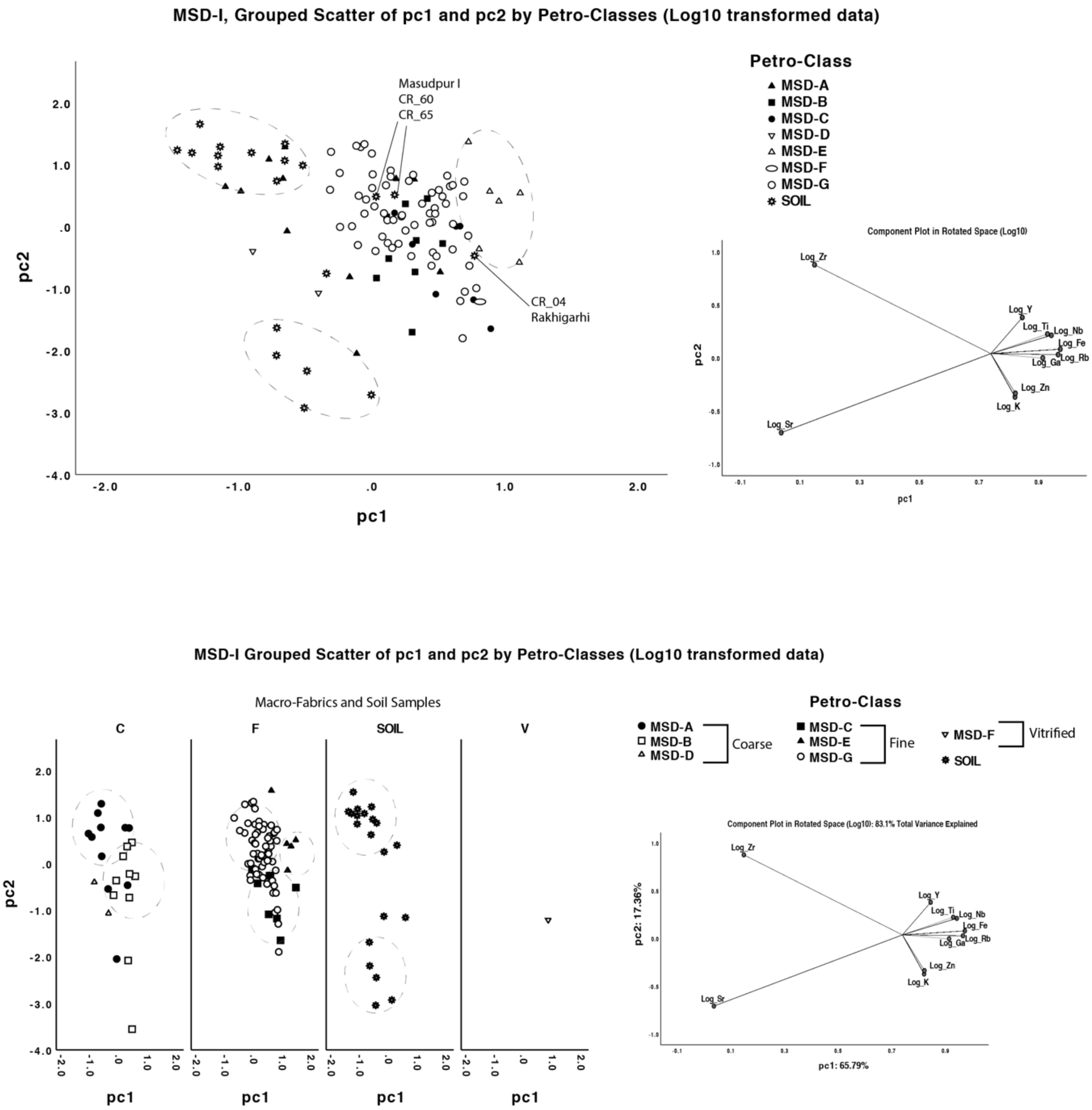
The chemical variability within the compositional dataset was estimated by determining its total variance. Statistical processing was performed on both raw data and Log10 transformed data (see Chapter 4). The selected elements and the calculated principal components explain c. 83.1% of the total variance (see Figure 7.23). Among the 10 elements, Zr, Sr, Y, K, Fe, and Rb seem to be the most relevant for determining compositional groups (see Figure 7.23). These elements also match the dominant elements used to explain certain patterning at the other studied sites (see Sections 6.12 and 8.9). Cluster analysis was performed on the whole dataset, in order to identify the main chemical groups, producing the dendrogram shown in Figure 7.23. This type of analysis examines patterning in the dataset by indicating hierarchical relationships between samples: from this, many different groups could be defined, based on the level of dissimilarity. The hierarchical cluster analysis was thus used to identify possible groups and outliers. Figure 7.23 shows two main compositional groups within which the archaeological samples (Groups T1 to T7) seem to fall. When compared alongside the techno-petrographic groups, certain correlations and trends could be observed, which will be discussed in the PCA section below. However, one of the most interesting results is that most ceramics samples and ceramic building materials seem to fall in one group (Groups T-1 to T-4); ceramics showing more complex manufacturing techniques, i.e. Vessels ζ, seems to represent chemical group T5; and the coarse chaff temper Vessels η appear to show a correlation with chemical groups T-6 and T-7 (see Figure 7.25).

Figure 7.24 Correlations bewteen techno-petro groups and chemical groups.



	T-1	T-2	T-3	T-4	T-5	T-6	T-7
MSD-θ - MSD-D	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	50.00%
MSD-θ - MSD-B	0.00%	0.00%	0.00%	0.00%	0.00%	50.00%	50.00%
MSD-θ - MSD-A	18.18%	45.45%	9.09%	0.00%	0.00%	18.18%	9.09%
MSD-ε - MSD-G	38.46%	0.00%	12.82%	12.82%	33.33%	2.56%	0.00%
MSD-ε - MSD-E	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%
MSD-ε - MSD-C	0.00%	0.00%	42.86%	14.29%	14.29%	28.57%	0.00%
MSD-δ - MSD-G	0.00%	0.00%	66.67%	0.00%	0.00%	33.33%	0.00%
MSD-β - MSD-C	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%
MSD-α - MSD-G	50.00%	5.00%	20.00%	25.00%	0.00%	0.00%	0.00%
MSD- η - MSD-B	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	25.00%
MSD- ζ - MSD-E	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%

Figure 7.25 PCA, scatter plot of MSD-I geochemical data, Log10 transformed. Above: groups by petro-classes; below: groups by macro-fabrics and petro-classes, PCA runs on the samples belonging to the three macro groups. PC1 and PC2 explain c. 83% of total variance.



7.9.2 *PCA, principal component analysis*

PCA is an alternative method of statistical analysis, though the results of the two techniques should be compared afterwards Principal component analysis (PCA) was performed and the scores of components 1 and 2 were plotted in order to further investigate clusters and outliers. As shown in Figure 7.25, a few chemical ‘trends’, rather than clear clusters, could be distinguished from the PCA. PCA scatterplots are read by looking at the distribution of samples in two-dimensional hyperspace. Soil samples seem to describe distinctively separate groups, presenting most of the clay-rich deposits in a different part of the plot from most archaeological samples. However, some soil samples are compositionally similar to certain ceramic fragments that fall within chemical groups T1-T4.

Groups T1 to T7 describe the composition of archaeological ceramics (see Figure 7.23, 7.24, and Figure 7.25). Mostly the ceramic samples seem to be closely related compositionally, which could be evidence for the use of similar raw material sources in the macro-region. To some extent, the apparent close relationship of the geochemical samples confirmed the broad homogeneity clay used in the production of vessels. However, the groups show some trends which appear to correlate with the heterogeneity of techno-petrographic observations. For instance, Vessels-α-MSD-G and Vessels-ε-MSD-G/E/C seem to fall within compositional groups T1 to T4. Among this, petrographic class MSD-C shows a minor compositional variation when compared to the other above mentioned groups, suggesting the possible use of multiple similar local sources in the proximity of the site for the production of Vessels-ε. Within this broad compositional group, three clay-rich soil samples seem to match the composition archaeological ceramic materials (e.g. CSR_60 and CSR_65; see Appendix A). The coarser ceramics, Ceramics-θ-MSD-D/B/A seem to be consistently different from the average chemical composition of the finer ceramics. Distinctively these coarser pastes fall within different cluster, chemical groups T6 and T7. However, within this group it is possible to observe two trends. On one hand, coarse Ceramics-θ-MSD-A are compositionally closer to unprocessed soil samples than petro-classes MSD-D/B; on the other hand, Ceramics-θ-MSD-D/B are compositionally closer to the archaeological finer vessels -α and -ε.

Perforated Vessels-β-MSD-C seem to fall mostly within chemical group T6, making it compositionally similar to the Chaff tempered Vessels η and coarse Ceramics-θ-MSD-D/B. In this respect, perforated jars, terracotta cakes and chaff tempered vessels seem to be made using specific recipes, that are mineralogically similar to the finer ceramics vessels, yet are chemically diverse. Finally, the techno-petro group Vessels-ζ-MSD-E, the deluxe black-on-red vessels, seems to suggest a unique trend (see Figure 7.25), and likely emphasise a further level of compositional variability when compared to the rest of the clusters.

7.9.3 Ceramic traditions and clay sources

The geochemical data seem to point out a high level of compositional variability among soil samples (see Figure 7.24). Only a few samples (CSR_04; CSR_60 and CSR_65) seem to match the composition of certain archaeological ceramic. This pattern may help to identify the location of possible clay sources (see Figure 7.25; also Chapter 5). Most of the archaeological samples seems to be closely related compositionally. This might be indicative of the use of a specific type of clay, perhaps a certain type of fluvial clay, or clay deposits related to rivers or seasonal channels, abundantly available in the macro-region.

The chemical grops seem to confirm some of the identified techno-petro groups (see Figure 7.24). In particular, Vessels-α-MSD-G and Vessels-ε-MSD-G/E seem to be closely related compositionally. Similarly, perforated Vessels-β-MSD-C, coarse Ceramics-θ-MSD-D/B and chaff tempered Vessels η-MSD-B seem to be similar compositionally. Vessels-ζ-MSD-E, however, suggest a slightly diverging trend. These groups belong to slightly different trend but show a compositional sense of affinity. For instance, the chemical characterisation of the MSD-E (i.e. Very Fine Iron-rich Mica and Quartz Fabric) and MSD-G (i.e. Fine Mica and Quartz Fabric) petro classes correspond respectively to chemical group T6 and group T3/T4, which correlates well with their mineralogical and textural differentiation observed via thin section petrography.

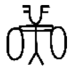
Besides the significant differences observed between most of the soil samples and the archaeological samples, two techno-petrographic groups show a greater level of heterogeneity, viz. the coarser ceramics, Ceramics-θ-MSD-A, and the Vessels-ζ-MSD-E, the deluxe black-on-red vessels. It could be suggested that the trends observable in the PCA may reflect differences in the composition of their base clay, rather than in the source or quantity of the added temper (see Figure 7.25). In particular, this may suggest the use of a different base clay for producing some CBM; and it may point out to a different provenance or group of producers related to Vessels-ζ-MSD-E, the deluxe black-on-red vessels.

The resulting picture seems to point to a certain degree of compositional variability, within a broader apparent uniformity. Several implications can be inferred from the hierarchical cluster analysis and principal component analysis. The apparent compositional homogeneity might suggest that this type of clay (possibly fluvial or alluvial) was available across the landscape by medium or large channels, and served to connect multiple communities and producers. This pattern also seems to suggest that, despite the abundant availability of clay rich deposits in the landscape, it is possible that only a few types of clay were consistently used by producers in the region. The MSD ceramic compositional variability and traditions will be discussed in Chapter 9, and will be used to assess social relations and social structures at the settlement and in the region. These will be also compared with ceramic traditions identified at two sites described in Chapters 7 and 8 so as to reconstruct social networks and relationship between individuals and social groups.

7.10 Summary

The techno-petrographic and geochemical analyses presented in Chapter 7 indicate that vessels from trench XK2 at MSD I can be divided into seven meaningful techno-petrographic groups (Sections 7.7 and 7.8). These groups mostly correspond to seven petrographic class (MSD-A to MSD-G), and show the use of multiple clay paste recipes. The techno-petrographic groups allowed the identification of at least four complex ceramic traditions, which can be used to explore questions concerning social groups, relationships between groups and individuals, and social structures and networks. These results will be further discussed in Chapter 9, and will be compared with data from other sites and from ethnographic observations.

Chapter 8. Alamgirpur: Indus ceramic traditions of the eastern fringe



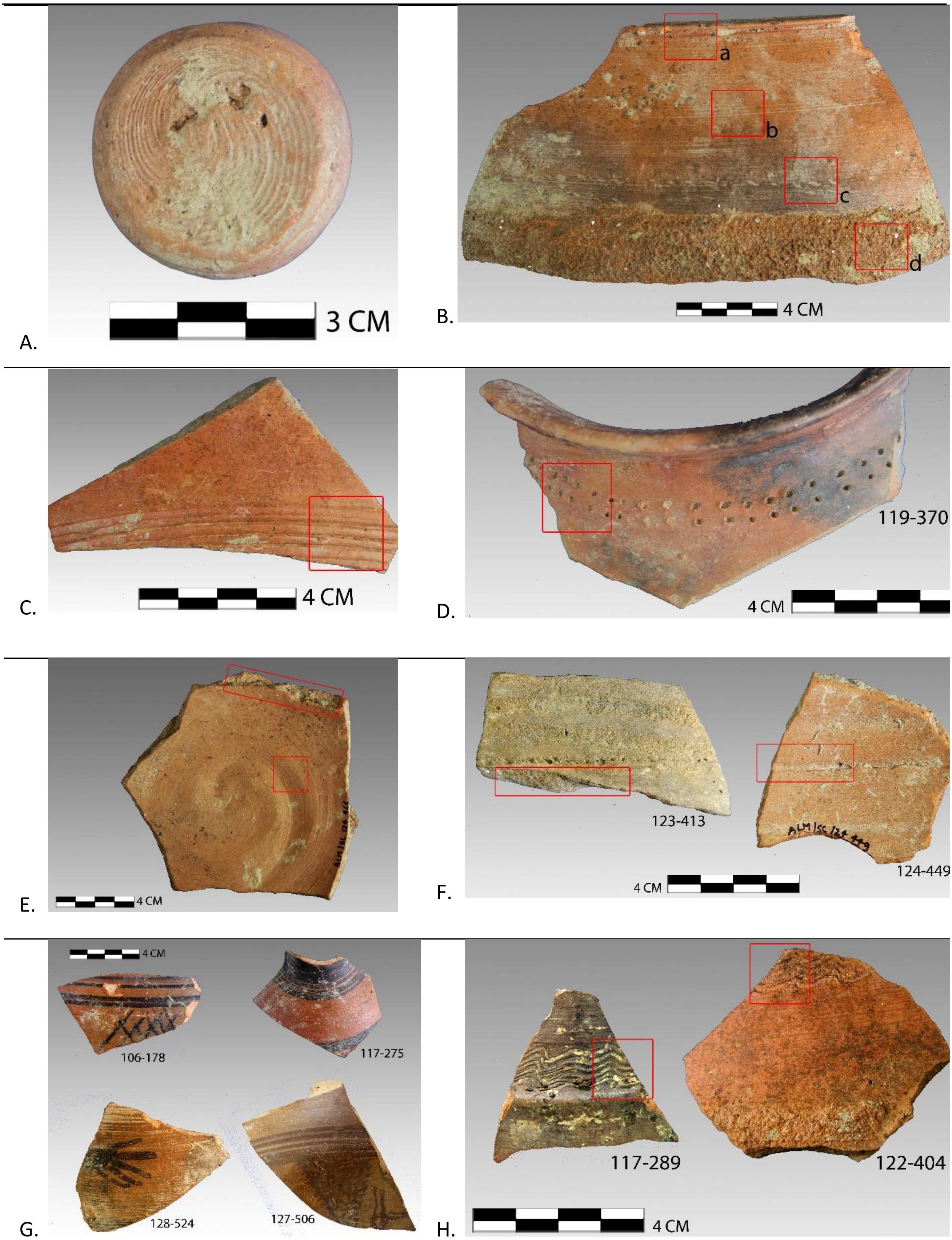
8.1 Introduction

This chapter presents the data, results and a discussion of the ceramic corpus rediscovered at Alamgirpur, trench SC, which is chronologically representative of the transition from the Indus Late Urban (e.g. contexts ALM-SC-114 to -128) to the Indus Post-Urban period (e.g. contexts ALM-SC-103 to -113). The first part (Section 8.2-8.6) is dedicated to the macroscopic assessment of sherds and vessels. Fabrics, manufacturing techniques and surface treatments will be assessed to identify the technical actions employed in the production of ceramics. In keeping with the *chaîne opératoire* approach, and by using a visual assessment of sherds, this chapter will begin with the reconstruction of ceramic techno-groups, which will be presented in a meaningful and comprehensive fashion, describing in detail their characteristics and cross-referencing the technical actions portrayed in the previous two chapters (see Chapter 6 and Chapter 7). The second part will combine technical observations to reconstruct ceramic traditions (Section 8.7). The description of each techno-group will present manufacturing techniques, decorations and morphologies, and including references to similar synchronic traditions in the macro-region.

The third part (Sections 8.8-8.9) will look at the mineralogical and elemental composition of vessels. Petrographic classes identified within the Alamgirpur SC assemblage will be presented and discussed, together with chemical characterisation of ceramic vessels. Petrographic and geochemical analyses prove to be an essential combination of methods: (a) to reinforce the macroscopic technological observations; (b) to better characterise paste preparations and recipes of vessels, resulting in a more detailed understanding of ceramic traditions; and (c) to present preliminary results concerning local or non-local production of vessels.

Eventually, the techno-compositional results will allow the reconstruction of the complex system of ceramic traditions at Alamgirpur, the variability of social units and functional variability of vessels at the site, and the social identities of communities interacting in both a synchronic and diachronic perspective.

Figure 8.1 Example of diagnostic macro-traces used to identify manufacturing processes, surface treatments and decorations, including string cutting (A), rope marks (B.d) and RKE marks (B.a; B.b), applied rustication (B.d), incisions (C), perforations (D), possible coils and RKE (E-F), applied splis, paintings and decorations (G), and waved incisions (H).



8.2 Macroscopic results

To answer the archaeological questions and undertake techno-morpho-stylistic studies and collect samples for petrographic and geochemical analysis of pottery from ALM-SC, the excavation archives at BHU was visited in April and May 2016, and again in July 2017. A total of 133 ceramic thin-sections were produced from pottery excavated at Alamgirpur. While selecting samples and producing thin-sections, the main aim was to have a comprehensive understanding of ceramic technologies and craft traditions throughout the whole chronological sequence, ranging from the Urban to Post-Urban periods. A detailed list of samples is presented in *Appendix A*.

From the 26 distinct stratigraphic units yielding ceramic materials, a total of c. 2,200 sherds were sorted, assessed and recorded. However, only sherds larger than 4 cm^2 found in Indus Urban and Post-Urban deposits have been considered for the analysis presented in this Chapter, making a total of 974 sherds. Techno-groups were defined by the broad fabric compositions and manufacturing techniques of ceramics. Both the fabrics and the surface traces, or macro-traces, present on the inner and outer walls of the sherds were used to identify the techno-groups (see above Sections 6.4 and 7.4; also see Figure 8.1). Surface treatments were also considered at this stage, but the morphologies of vessels and their decorative motives were not. The database of sherds is described in Section 4.2, from which the following presented data and percentages have been extrapolated.

8.3 Fabrics

First, from each excavated deposit, sherds where assessed and sorted into broad compositional groups, according to macroscopic observations of ceramic pastes. Through visual assessment, two main types of fabrics could be identified within the assemblage: a coarse paste and a fine paste (see Figure 8.2 and 8.3).

*8.3.1 Fine (**F-**) paste*

Fine ceramic pastes are identified in all deposits at ALM-SC, comprising 891 sherds , with 536 sherds identified in Indus Urban and 355 sherds identified in Post-Urban deposits. Rare, small pores are visible on the surface of ceramics or in the paste, and fine mineral inclusions can be identified, such as quartz and mica. Such fine pastes were used to produce a variety of vessels, were associated to a wide range of manufacturing techniques, surface treatments, decorations and morphologies. The fine paste ceramics are typically well fired in an oxidizing atmosphere, showing a red, dull-red or bright red surface and core colours (see Figure 8.1:C). The rare voids can measures 0.2-1 mm in length, mostly equant and rounded in shape. Fabrics are not always homogeneously mixed, and can show higher or lesser degrees of mixed iron-rich and calcareous clay.

*8.3.2 Coarse (**C-**) paste*

Organic tempered or coarse ceramic pastes were identified in almost all deposits at ALM-SC. The coarse paste ceramics included those ceramics that may have been tempered using organic materials, or large grain size, including ground fragments of rocks. These represent c. 83 sherds of the whole assemblage, with 44 sherds and 39 sherds identified respectively in Indus Urban and Post-Urban period deposits. The organic material likely used as temper is no longer visible, and the large pores of voids visible on the surface or in the paste of ceramics can only be indirectly attributed to burnt out vegetal material. As presented below (Section 8.6), vegetal or chaff tempered coarse pastes were mostly used to produce ceramic building materials (CBM), and coarse paste vessels with an applied coarse rustication. Unfortunately, the latter type is only a minor component of the assemblage likely due to the highly friable nature of their bodies. Coarse paste ceramics can be found in the state of unfired or fired ceramics in the corpus.

Figure 8.2 ALM-SC count of fine paste sherds

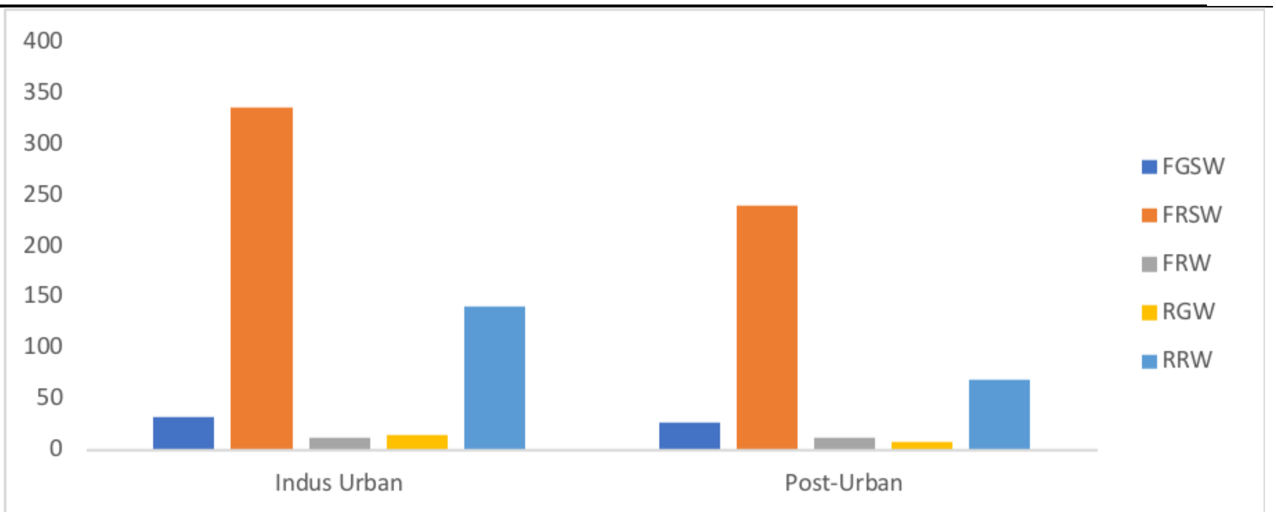
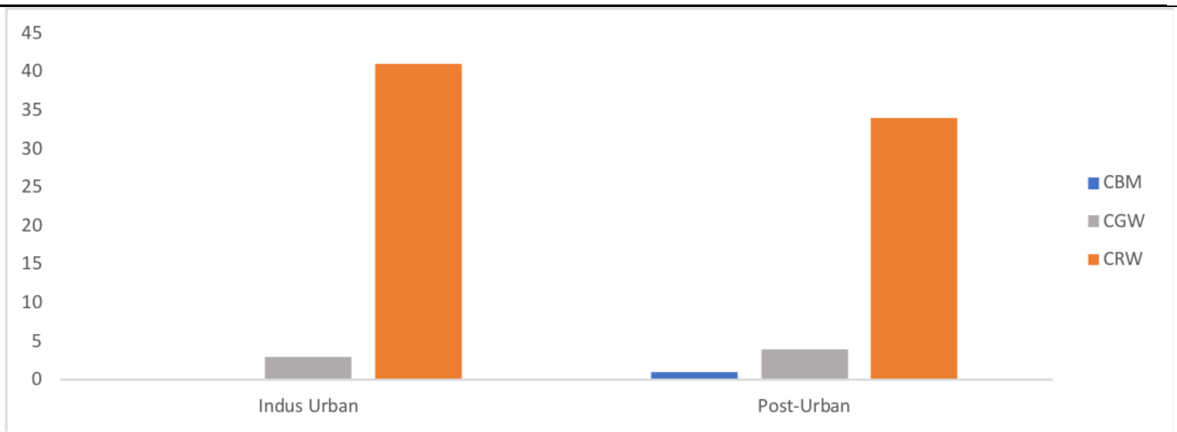


Figure 8.3 ALM-SC count of coarse paste sherds.



8.4 Manufacturing techniques

After the ceramic fragments were sorted into broad fabrics groups, evidence for manufacturing techniques were considered to identify techno-groups. The evidence used for assessing technical actions and technical-groups have already been discussed twice in the previous two chapters (see Chapters 5.4; 6.4), by looking at materials from the Early, Middle and Late Urban periods. Therefore, these parameters will not be extensively repeated here.

8.4.1 Fine (F-) fabrics associated technical actions.

Fine ceramics were firstly divided into sherds that show evidence for the use of RKE (see Chapters 3, 5, and 6), and those which do not. These include sherds showing the use of manufacturing such as *coiling (with or without RKE)*; *scraping (with or without RKE)*; fashioning via *non- or limited RKE; wheel finishing and wheel forming*. Combinations of technical actions also include sequential construction; rope binding; *assembled necks, rims*, and *bases.*

8.5 Surface treatments

8.5.1 Slip

Red slip: Two types of red slips have been identified at ALM-SC. The first and most common is deep reddish-brown to red in colour, and is visible on the outer and inner surfaces of vessels (see Figure 8.4). This slip is usually associated with profuse polishing or burnishing techniques. When assessing this kind of red slipped vessel, it is challenging to distinguish and clearly document an actual applied iron-rich clay slurry to the surface of some vessels, as opposed to a sort of 'self-slip'. The latter may have been produced during a finishing stage, such as through smoothing with abundant water. However, 'true slips' are relatively easier to classify (see Figure 8.1:B,C,D): they usually appear bright red or dark red, depending on the thickness and composition of the slip, as well as firing techniques (Dales and Kenoyer 1986: 64). Superimposed layers of slip can also be found. The second type of slip could be defined as a 'self-slip', dull or light red in colour (see Figure 8.4, FRW, Fine Red Ware).

8.5.2 Application of slurry or rustication

As mentioned in Chapters 5 and 6, the application of a rustication - a thin or thick coarse slurry - on the surface of vessels is abundantly found in the Indus zone and beyond. Fine paste sherds at ALM-SC show a fine type of rustication, broadly referred to as 'mud appliqué' by archaeologists working in Rajasthan, Haryana and Uttar Pradesh (REFS). Usually, the rustication is applied on the outer surface of the lower portion of vessels, starting from the jar's shoulders or mid-body downwards. Most shapes are globular vessels with concave base, ring base or flat base (e.g. sherds 201, 200, 202). No temper or inclusions are visible in the slurry (see Figure 8.5: RRW).

8.5.3 Incision

Two styles of decorative incisions could be identified at ALM-SC. They are mostly performed on the exterior surface of jars and bowls, or on the interior surface of bowls. Two sub-classes of incisions could be identified according to their most frequent patterns. These are wavy lines (-EXT-WL), and parallel combed incisions (-EXT-C). Similar incised decorations have already been discussed in Chapter 5 and 6 (also see Figure 8.1).

8.5.4 Polishing, burnishing and painting

Different degrees of polishing and burnishing have been observed. These techniques produce similar effects on pottery, a smooth, glossy surface, and they can be used in combination. Smoothing and polishing techniques seem to be quite common, and are found on most red slipped (Figure 8.1) vessels.

Similar to the MSD assemblage described in Chapter 7, pottery from ALM shows distinctive black painted motifs. Painted decoration is not particularly vibrant in terms of colours, but a rich repertoire of figurative motifs is evident. This include mainly single, multiple or wavy lines, circles, dots-and-loop, net and grid motifs, peacock, pipal leaf and other plants. In terms of colours, black painted decoration on red vessels were the dominant combinations (see Figure 8.1). The decorative motifs are not profusely considered in this technological study.

Figure 8.4 CBM, Ceramic Building Material, ALM-SC

8.6 Coarse (C-) fabrics associated techniques

8.6.1 Moulding and scraping

Fragments of ceramics that seem to show evidence of moulding and scraping as the main forming technique were sorted as a separate group (see Figure 8.3, 8.4). The majority of these ceramics were produced using a medium coarse to very coarse clay paste, often mixed with vegetal, chaff temper, but also crushed rock fragments. Moulded coarse ceramics include fragments of bricks, either fired (***C*-M-CBM**), and what is referred to here as 'Coarse Red Ware' (see section below**)**.

Ceramic Building Material (**C-M-CBM**) (also see Sections 6.6.1 and 7.6.1). Ceramic building material (-**CBM**) is here defined as a clay body that has been deliberately fired for use as part of a structure. Within the context of Indus sites, they include bricks, floor tile, kiln

firebars, and kiln lining. They have been likely produced using local easily obtained clays, mixed together with sand and vegetal or chaff temper, and rarely with grog and ash. CBM is found at most Indus archaeological sites. As they tend to be durable and form a major constituent of many structures, CBM fragments are often a vast percentage of the ceramic corpus and bulk material found at Indus sites. A limited number of CBM fragments were studied from ALM-SC. However, although there is neither high variability of morphology, nor extensive available studies on Indus building materials, including plaster, fragments can be used to observe variations of fabrics, as well as to identify local clay sources.

8.7 Technical groups

As noted above (Ssee ection 8.1), the first sorting of ceramics was carried out to identify broad technical groups. This preliminary sorting phase takes into account the composition of sherds, the ceramic paste or fabric, and surface features indicative of manufacturing processes (see *Figure 8.1*). This approach allowed the identification of comprehensive technical groups that show similarities in terms of forming techniques and ceramic pastes, but also firing technologies and surface finishes. Minor variations within technical groups are not reported, since the aim was to avoid splitting the assemblage into an excessive number of sub-groups, showing little or no significant variation. For instance, the term *Red Ware* indistinctly refers to ceramic materials which are red, deep red, dark red and light red in colour, and variation potentially resulting from minor variation in firing conditions. At this stage, the sorting process neither considered known pottery typologies, morphological or stylistic types, or painting motifs, which have all been included in third stage of analysis, which follows the petrographic assessment. Most sherds smaller than 4 cm^2 could not be assessed (labelled as N/A in *Figure 8.6*), due to the limited visible technological macro-traces; however, as already mentioned, sherds smaller than 4 cm^2 with thin walls (< 0.4 cm) have been considered. A brief summary of the identified technical groups shall follow.

CBM, Ceramic Building Materials. This group includes bricks and ceramics likely used as building materials. They are thick, sub-angular blocks of well fired clay and show a coarse iron-rich micaceous ceramic paste. Clay rich pastes were moulded into brick shapes, but a larger number of well-preserved samples are required to understand the forming process.

CGW and CRW, Coarse Grey Ware and Coarse Red Ware. These technical groups include ceramics showing a distinctive porous and coarse fabric. Compared to other groups, they present larger aplastic inclusions, mostly mica and quartz, and possible negative traces of burnt organic temper. The outer surface usually shows an applied slurry or rustication made of a similarly coarse ceramic paste; the inner surface usually displays traces of scraping, or wheel-finishing on a slow rotational device. The main difference between CGW and CRW is likely to be the degree of oxygen available during the firing process. This group is found in all the contexts at ALM-SC, spanning from the Indus Urban to Post-Urban periods.

Figure 8.5 Technical Groups, ALM-SC. FRW, CRW, FSGW, FRSW, RRW, and RGW (see Section 8.7).

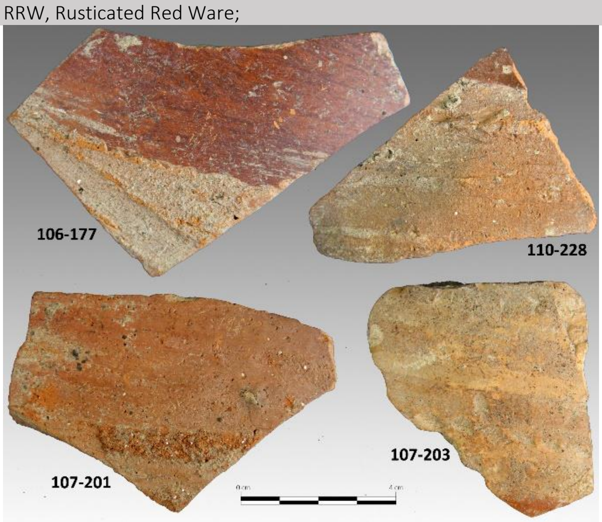
FRW, Fine Red Ware;

CRW, Coarse Red Ware

FSGW, Fine Grey Slip Ware;

FRSW, Fine Red Slipped Ware;

RRW, Rusticated Red Ware;



RGW, Rusticated Grey Ware;

FSGW and FSRW, Fine Slipped Grey Ware and Fine Slipped Red Ware. This technical group is the most common in ALM trench SC in deposits dated to the Indus Urban (ALM period I-B) and Post-Urban (ALM period I-C) period. These vessels are characterised by a very fine ceramic paste, with few small voids visible to the naked eye. The core of the vessels is usually red, the external surface is usually treated with a fine slip, which range from deep red, brownish red to light red, showing a profuse stage of polishing and/or burnishing. Given the colour of sherds, it could be inferred that these vessels were homogeneously fired and cooled in an oxidising atmosphere. Evidence for the use of multiple forming techniques are often visible on the interior and exterior surfaces of these sherds, including possible coiling followed by scraping and partial use of RKE or rotational devices. Fine Slipped Grey Ware (FSGW) group seems to be more frequent in deposits ascribed to the Post-Indus Transition (ALM period II-A), showing a grey core and grey to brown slip.

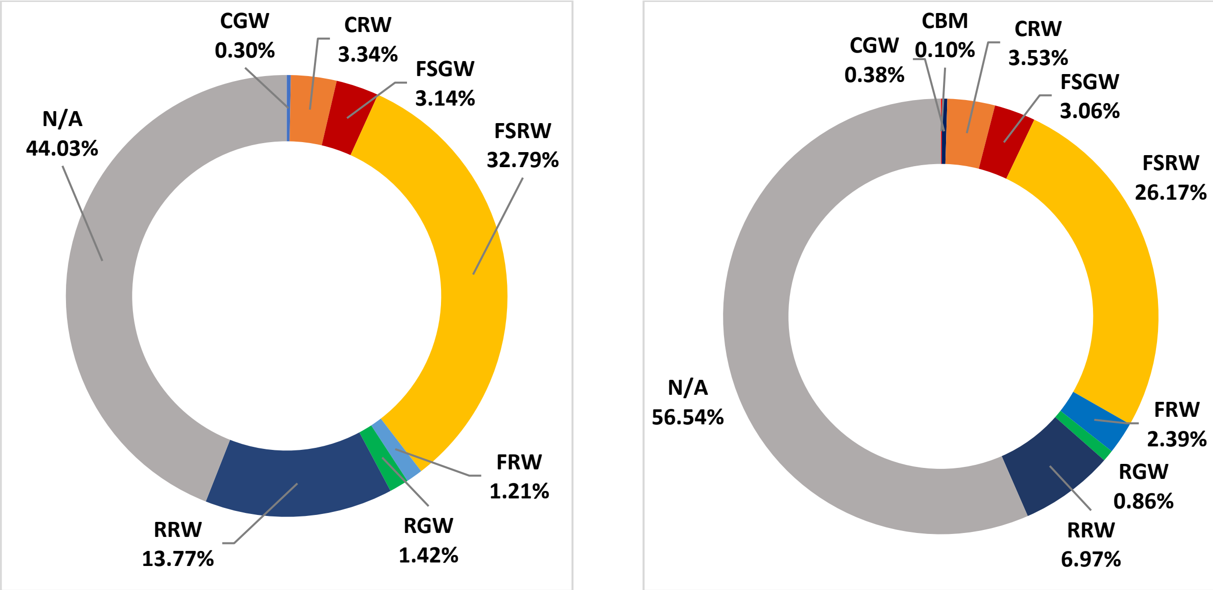
FGW and FRW, Fine Grey Ware and Fine Red Ware. These vessels seem to be more frequent during the Indus Post-Urban period. The material used in their production is a fine clay paste, showing light red to dull-red surfaces and core, likely due to firing in a well-oxidised atmosphere. A rare grey variety of ceramic fragments were also identified. The most significant difference from the other ceramic groups is the lack of visible surface treatments, slip or rustication on both inner and out surfaces.

RGW and RRW, Rusticated Fine Grey Ware and Rusticated Fine Red Ware. The last two groups are found at all phases identified in ALM-SC. The most distinctive characteristic of these vessels is the combined use of two clay pastes. The vessels are generally crafted using a fine clay paste and similar manufacturing techniques to those used for the *FSRW group*; however, the outer surface is covered by a very coarse, micaceous clay slurry or rustication. Macro-traces on the inner surface suggest a combination of forming techniques, possibly coiling followed by the limited use of RKE or wheel-finishing techniques.

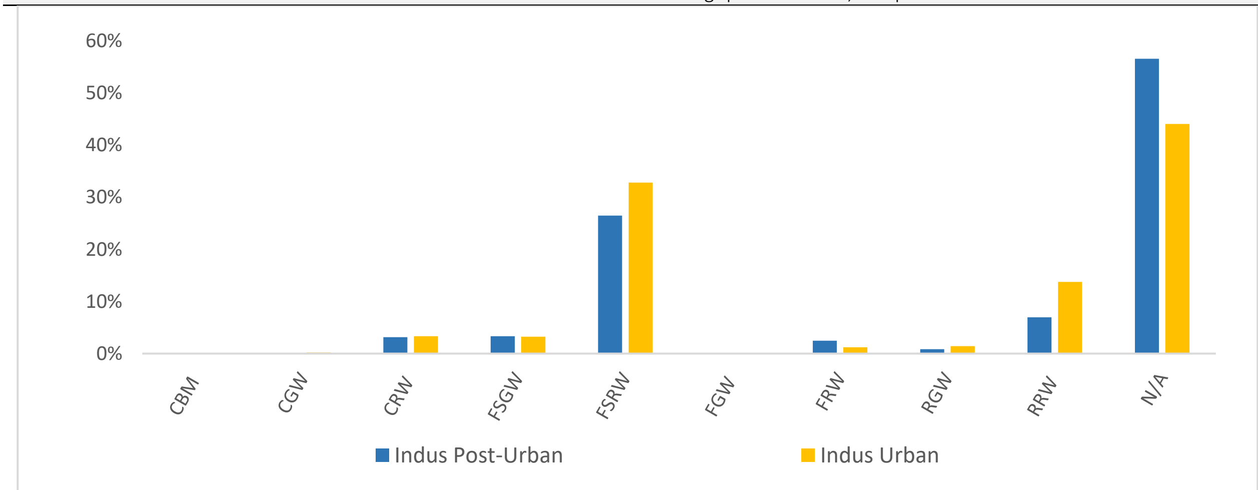
Figure 8.6 Technical Groups, sherd count (Sherds smaller than 4cm^2 with walls thicker than 0.4 cm are listed as N/A) and percentages per period.

PERIOD	CBM	CGW	CRW	FSGW	FSRW	FGW	FRW	RGW	RRW	N/A
Post-Urban Indus	1	1	34	35	277	0	26	9	73	592
Indus Urban Period	0	2	34	32	324	0	12	14	136	435
Sub-Total Sherds	2	3	84	84	655	1	49	23	224	1027

Late Urban period	Indus Post-Urban Period



Indus Urban Period Alamgirpur Trench-SC, comparative chart.



8.8 Petrographic results

The second sorting stage made it possible to identify *techno-petrographic groups*. Considering technical groups and diagnostic sherds, samples were selected to produce ceramic thin-sections. From ALM-SC, 92 thin-sections were produced and studied (see Chapter 3), which provided data concerning raw materials, clay paste preparation and forming techniques. Results concerning technological choices, from raw material selection to the firing and finishing of pottery vessels, are presented in the following sections. Five main petrographic groups, and seven sub-groups (see Table 8.1; Figure 8.7) have been identified according to differences and similarities amongst the fabric components, including: particulate inclusions; size and shape of voids; clay matrix; nature, size and orientation of mineral and rock fragments (see *Tables 8.1 and 8.2, and Figure 8.77*). Details regarding samples and the Petrographic group descriptions are available in *Appendix B*.

8.8.1 Correlations between technical and petrographic groups

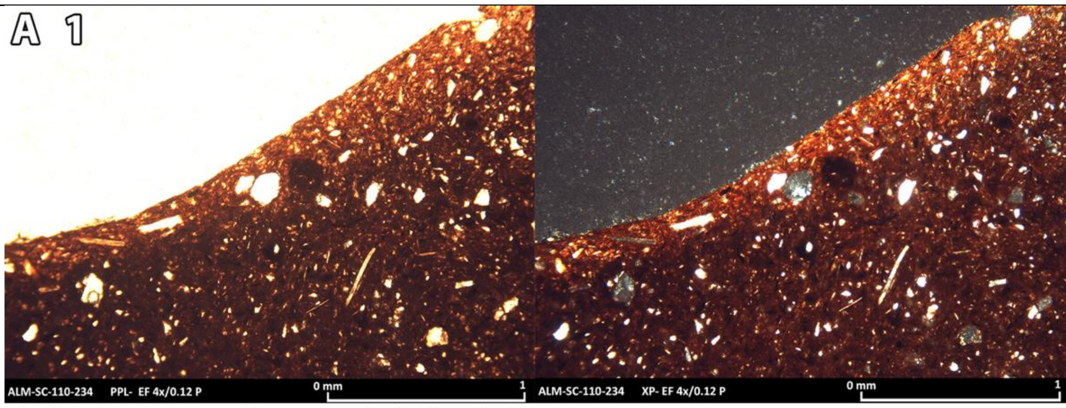
Data from both macroscopic and microscopic analysis provides insight into ceramic recipes and manufacturing processes. Figure 8.6 offers a summary of the correspondence between technical and petrographic groups. In terms of diachronic variability at Alamgirpur, some petrographic and technical groups seem to belong to the Indus Urban and Post-Urban period continuously, such as the Coarse wares (petro-classes ALM-D and ALM-E), Fine slipped Wares (petro-class ALM-A) and Rusticated Wares (see *Figure 8.8*). Synchronically, a diverse combination of technological features was observable. For instance, during the Post-Urban period, the Coarse Ware technical group shows a strong correlation with two petrographic groups, viz. ALM-D and ALM-E. Similarly, Ceramic Building Material (CBM) techno-group seems to correspond to only one distinctive fabric (ALM-C), which is remarkably different from other groups petrographically.

The Fine Wares (FSGW, FSRW, FGW, FRW) and the Rusticated Wares (RGW and RRW) show a combination of slightly different clay pastes and fabrics (TR-A1, A2, and A3). This is not unusual, since the Rusticated Wares, at a macroscopic assessment, present remarkable similarities with the fabrics used for Fine Wares, and the main difference was the application of a coarser slurry. Interestingly, the slurry on the RRW and RGW shows striking resemblances with coarser petro-classes (e.g. ALM-D and ALM-E). Thus, a combination of technological choices was observable. In summary, a part from the distinctive industry of Ceramic Building Materials, the Rusticated Wares seem to combine ceramic recipes from both techno-groups of coarse wares and fine wares.

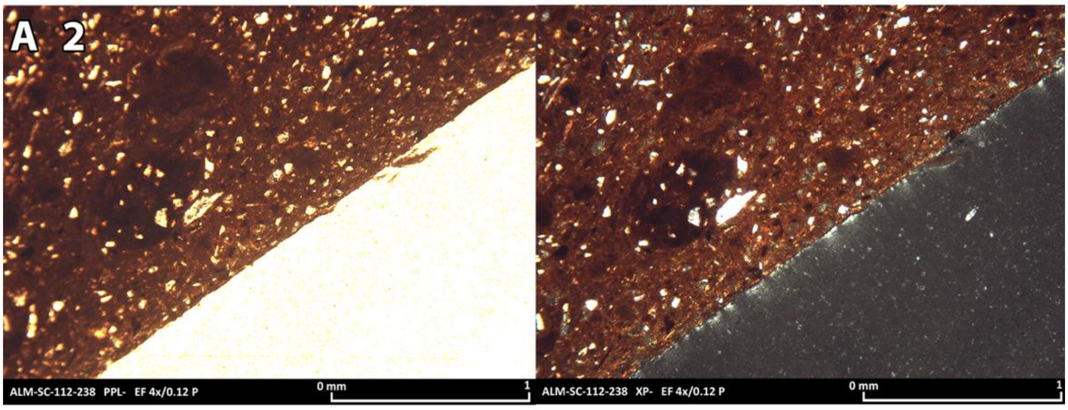
Table 8.1 ALM thin-sections and petrographic groups

Class	Sub-Group	Thin-section no. (TS-A-)
ALM-A	ALM-A1	12, 18, 19, 24, 26, 27, 29, 35, 36, 38, 41, 43, 46, 48, 49, 50, 53, 54, 60, 61, 66, 70, 71, 72, 74, 75, 76, 77, 78, 87, 89, 92, 94, 95, 96, 98, 99, 101
	ALM-A2	23, 34, 42, 45, 51, 55, 56, 79, 88, 93, 105, 109
	ALM-A3	37, 57, 58, 64, 65, 67, 68, 81, 82, 84, 85, 90, 104
ALM-B	ALM-B	22, 62, 63, 97
ALM-C	ALM-C	15, 44
ALM-D	ALM-D	69, 83, 86, 91
ALM-E	ALM-E1	30, 59, 73, 102, 103, 106, 107, 110, 112, 113
	ALM-E2	17, 25, 28, 33, 39, 40, 52, 80, 100, 108, 111

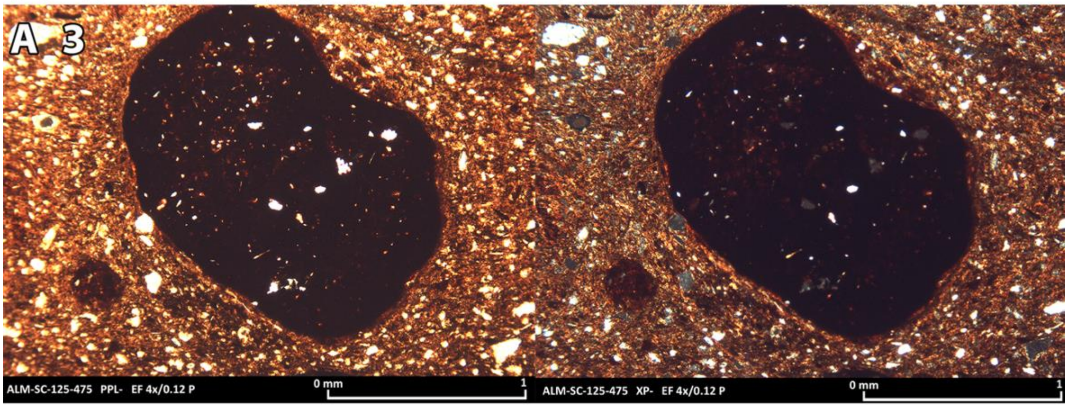
Figure 8.7 ALM SC petrographic fabrics. Photomicrograph of samples belonging to groups A1, A2, A3, B, C, D, E1, and E1. Left PPL and right XP.



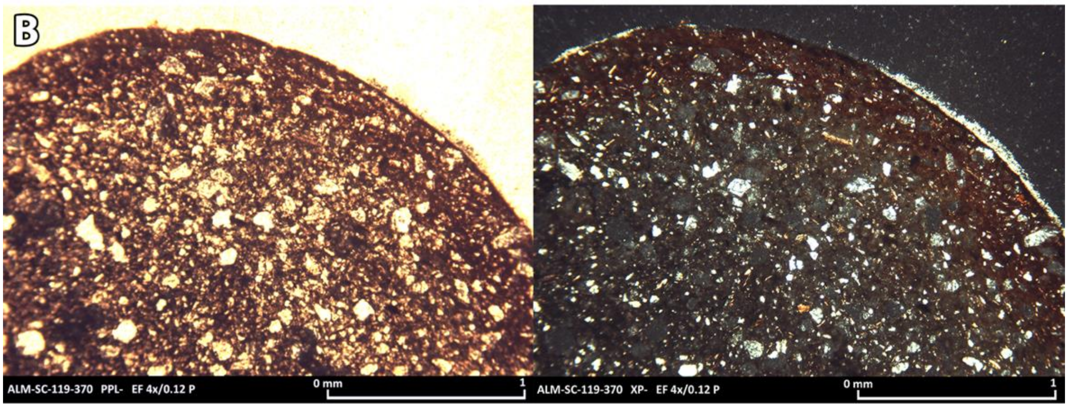
TS-A-53, SHERD ALM-SC-110-234



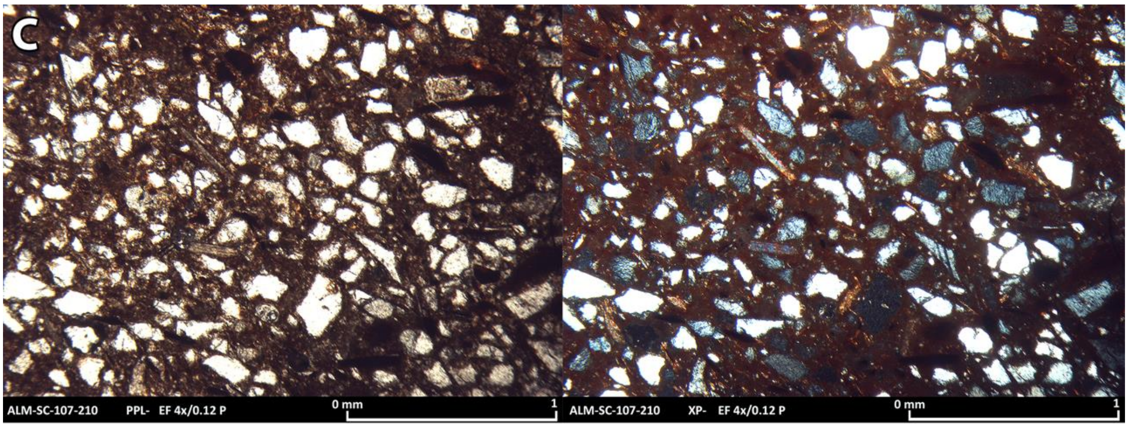
TS-A-55, SHERD ALM-S- 112-238



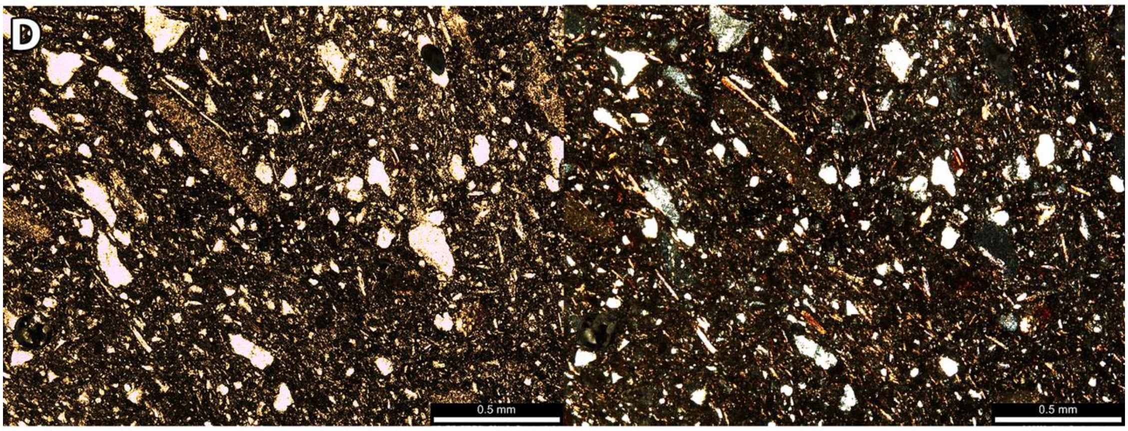
TS-A-65, SHERD ALM-SC-125-475



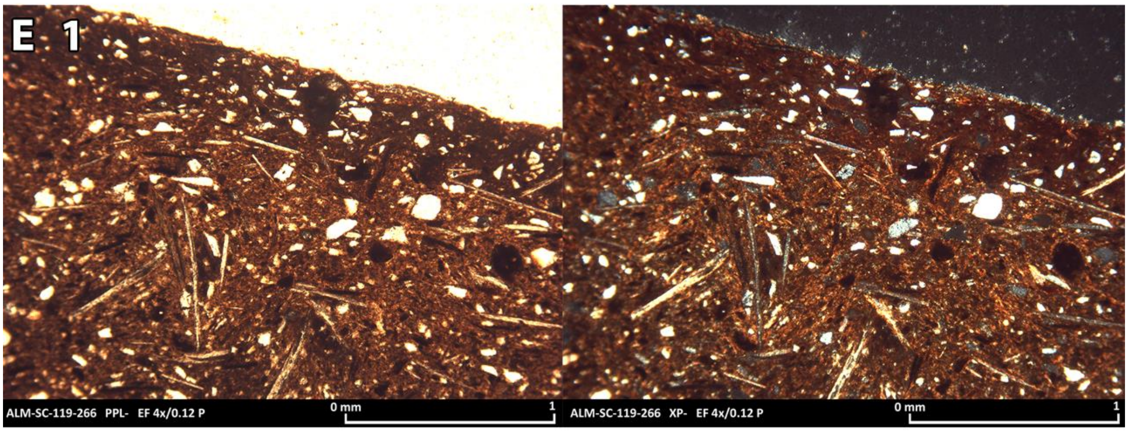
TS-A-63, SHERD ALM-SC-119-370



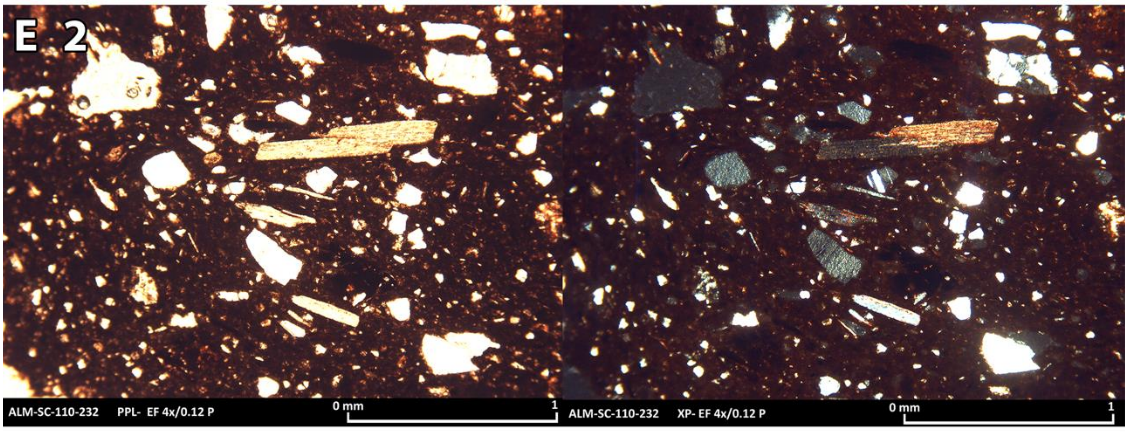
TS-A-44, Sherd ALM-SC-107-210



TS-A-83, Sherd ALM-SC-125-474

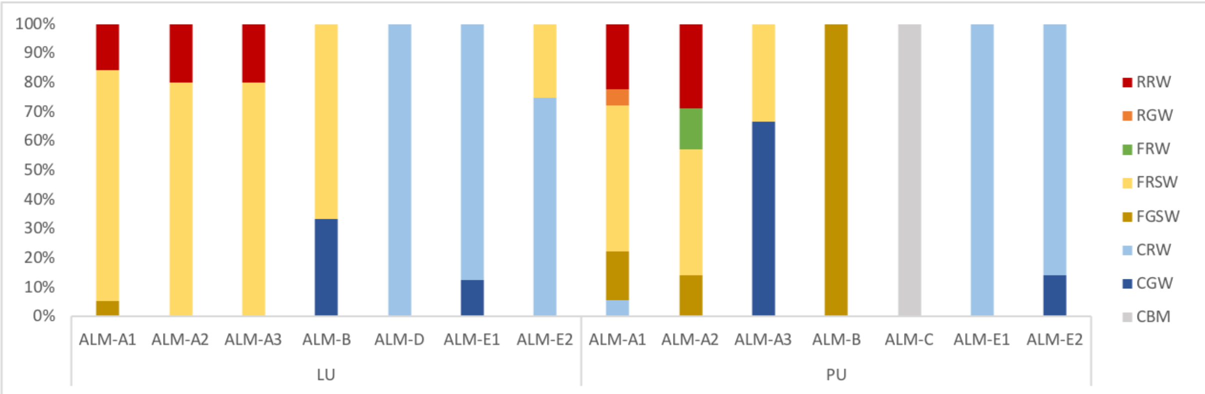


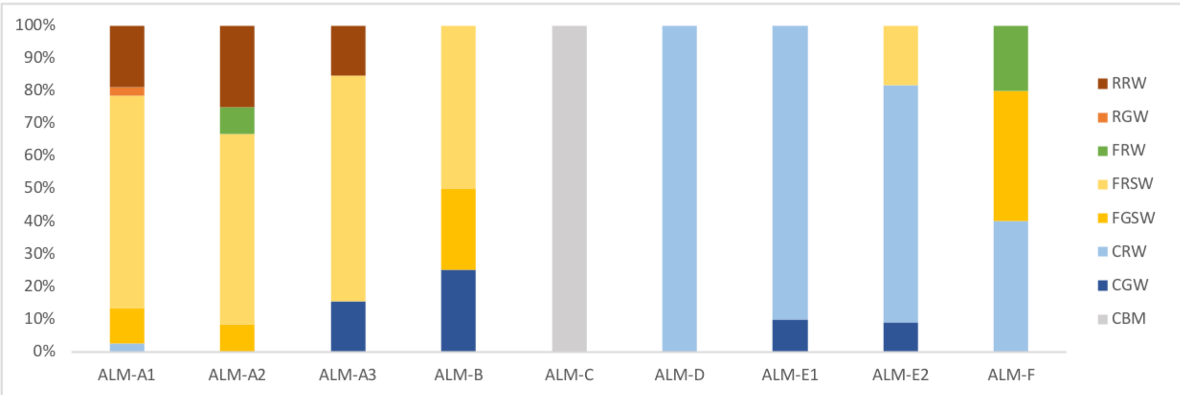
TS-A-59, Sherd ALM-SC-114-266



TS-A-52, Sherd ALM-SC-110-232

Figure 8.8 Comparative diagrams showing correspondences between Technical and Petrographic Groups. From left to right: above, Late Urban and Post Urban phases; below, Post-Indus Period and combined diagram (Urban, Post-Urban and Post-Indus altogether).

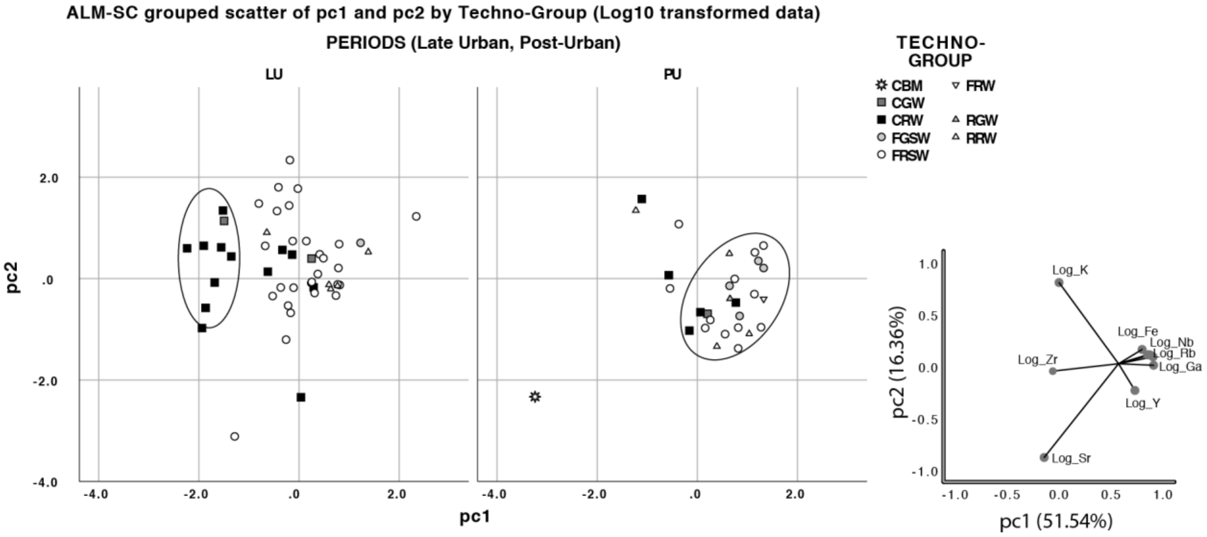


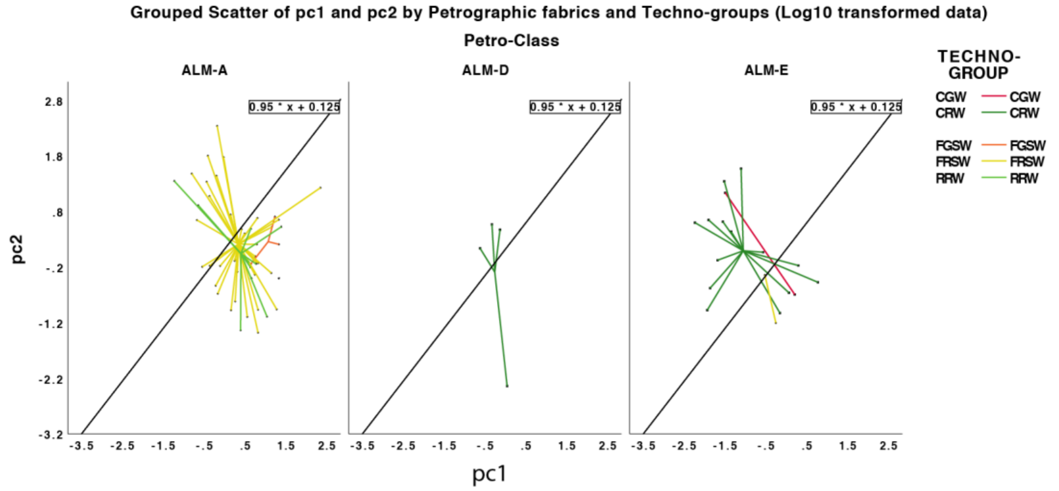


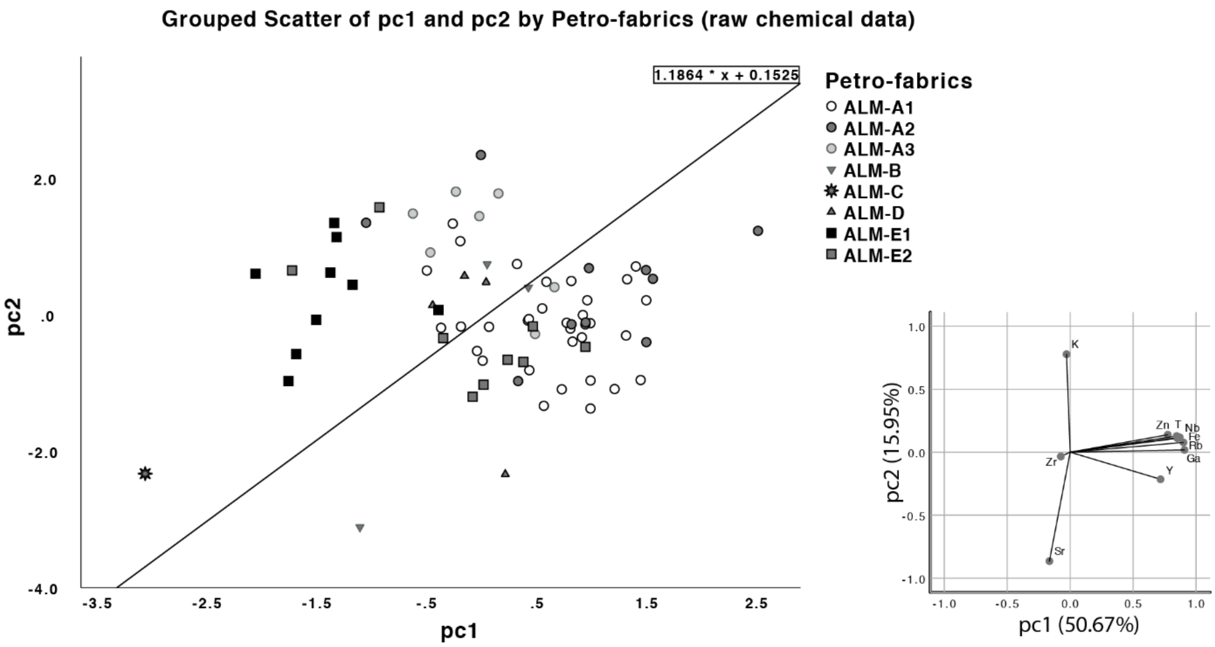
8.9 Geochemical results

Statistical analysis of the chemical data was performed considering the most accurate and meaningful elements (see above Sections 6.12 and 7.12). Details concerning the assessment of the performance of pXRF data calibration can be found in Chapter 4 and Appendix E.

Figure 8.9 *Above and middle*: ALM-SC Log10 transformed data. *Below*: ALM-SC raw chemical data and components load.







8.9.1 PCA, principal component analysis

PCA was performed to produce scatterplot and further investigate trends, possible groups and outliers. K, Sr, T, Fe and Y appeared to be the most significant elements for observing compositional patterning. As shown in Figures 8.8 and 8.9, a few chemical 'trends', rather than clear groups, could be distinguished. The coarse ceramic (petro-fabric ALM-E; techno-groups CRW) samples seem to describe a distinctively separate groups. Fine ceramic samples seem to be closely related compositionally. However, the groups show trends which appear to correlate with the heterogeneity of the techno-petrographic observations, especially petrogroup ALM-A3, which diverges from ALM-A1 and A2 (see Figure 8.8). Overall, most samples appear to be closely related, presenting three main diverging trends. Coarser ceramic building material seem to not belong to any of these groups (CBM-ALM-C).

On one hand the above could be considered an evidence for the use of similar raw material sources, obtained from the surrounding region. To some extent, the apparent close chemical relationship of the sherds seem to suggest an overall similar composition of the fluvial or alluvial clay deposits available in the region and used in the production of ceramics. However, the observed trends suggest the possible use of multiple similar sources, or abundant tempering and modification of raw clay for the production of certain vessels. This will be further discussed below, supporting with petrographic data. The coarser ceramics seem to be consistently different from the average chemical composition of the finer ceramics, which reflects petrographic observations of composition and inclusions: type, grain size and abundancy of minerals identified in thin-sections may explain how they are correlated with the abundance of specific elements.

8.10 Other technological observations

Considering macroscopic observations, identification of technical groups, petrographic and chemical analyses, a partial reconstruction of *chaînes opératoires* for the production of pottery vessels at Alamgirpur was achieved, and shall here be presented.

8.10.1 Data concerning raw material selection and processing

Evidence from thin-section petrographic and geochemical analysis suggest that raw clay used in pottery production during Urban and Post-Urban periods at ALM was dominantly a fluvial non-calcareous clay. Similar raw material appear to have been likely used for the production of vessels ascribed to the finer technical groups, likely being a fluvial clay from sedimentary non-calcareous deposits. Fabric groups show similar features, including the presence of ferruginous nodules and opaque iron, such as fine fragments of ferruginous minerals, a fingerprint of local raw clays. These iron-rich clay pellets tend to resist erosion, and they can be frequent in clay pastes used to manufacture pottery (Albero-Santacreu 2014). This distinctive feature of local clay-rich deposits was observed at the site by Neogi (2014), who documented deposits in close proximity to the site through the analysis of geo-archaeological samples. Such geo-archaeological samples seem to show similar orthic nodules of iron oxide, suggestive of a very wet and humid condition associated with the formation of clay sediments of the palaeo-landscape. The clay paste of the CBM was used as a reference for local unprocessed clay. The clay pastes used in the production of vessels show a remarkably more homogeneous and finer pastes than clays employed for the production of other ceramic materials such as bricks, suggesting different strategies for refining raw materials or the use of different clay sources (see Figure 8.10).

Petrographic samples from Alamgirpur provided evidence of clay processing methods. Potters at the village likely had a specific understanding of local clay deposits, and in some cases raw clay or coarser clay pastes seem to have been valued for the production of specific ceramic materials, likely for functional purposes. Petrographic group ALM-A shows a fine fabric, with fine angular to sub-angular aplastic inclusions, and was mostly used for producing the Fine Ware techno-groups during the Indus Urban and Post-Urban periods. In contrast to the fine, well-levigated clay, which was used for producing of the above mentioned pottery types, little processing was involved in the preparation of clay for ceramic building materials. For instance, petro-fabric ALM-C, identified in the Post-Urban brick ALM-SC-107-210, shows how unprocessed fluvial sand-rich clay may have used at the time in ceramic industries. Thus, clay seems to have been likely used in three different ways at Alamgirpur before moving to the subsequent stages of the *chaîne opératoire (see Figure 8.9)*:

a. As shown in petro-fabric ALM-C, unprocessed clay was likely used in the production of ceramic building materials (CBM).
b. The paste of finer fabrics (petro-fabric ALM-A) shows a homogeneous clay matrix, and very small-grained aplastic inclusions, such as sand-grain quartz, biotite mica

and muscovite mica. Evidence used to suggest the action of levigation are described by Quinn (2013: 156) and Whitbread (1995, Appendix 3).

c. The coarser fabrics (petro-fabrics ALM-D and ALM-E) are characterised by the presence of medium to large-size sub-angular mineral inclusions, mostly quartz, muscovite mica and rare amphibole, possibly suggesting the presence of ground fragments of schist.

Preliminary refining is also reflected in the density and distribution of very small inclusions in the pastes (see Whitbread 1995). Besides large to medium-size aplastic inclusions, all fabric groups show a matrix distinctively characterised by a homogeneous paste and distribution of minerals. Further textural characterisations via point counting (see Quinn 2013) of ceramic thin-sections have the potential to provide a deeper insight into this stage of production, but they have not been attempted.

8.11 Technological considerations

8.11.1 Data concerning forming techniques: coiling and wheel-finishing

Macrosopic analysis and thin-section petrography has provided insight into the manufacturing process of the vessels. A distinctive feature observed in most fabric groups is the presence of relic-coils and coil joins in both the Urban and Post-Urban period samples FSGW/FSRW (mostly in petro-groups ALM-A1 and ALM-A2), FGW and FRW, and Coarse Wares (CRW and CGW, petro-groups TR-B and D). Even though wheel-finishing tend to erase macro-traces or other evidence for primary forming techniques, coils or relic-coils can be identified via macroscopic observations and ceramic petrography by the concentric orientation of elongate inclusions or voids in a vertical thin-section (see Figure 8.11; e.g. Whitbread 1995; Quinn 2013). The use of RKE, rotational devices and wheel-finishing techniques can be inferred by the identification of diagnostic macro-traces on the surface of vessels, mostly the internal surfaces (Roux 1994). As mentioned above (Section 8.7), sherds from ALM-SC seem to show evidence for the use of RKE and wheel finishing techniques.

Figure 8.10 Possible clay paste preparation technology at Alamgirpur. Petrographic Groups (left) and Technical Groups (right).

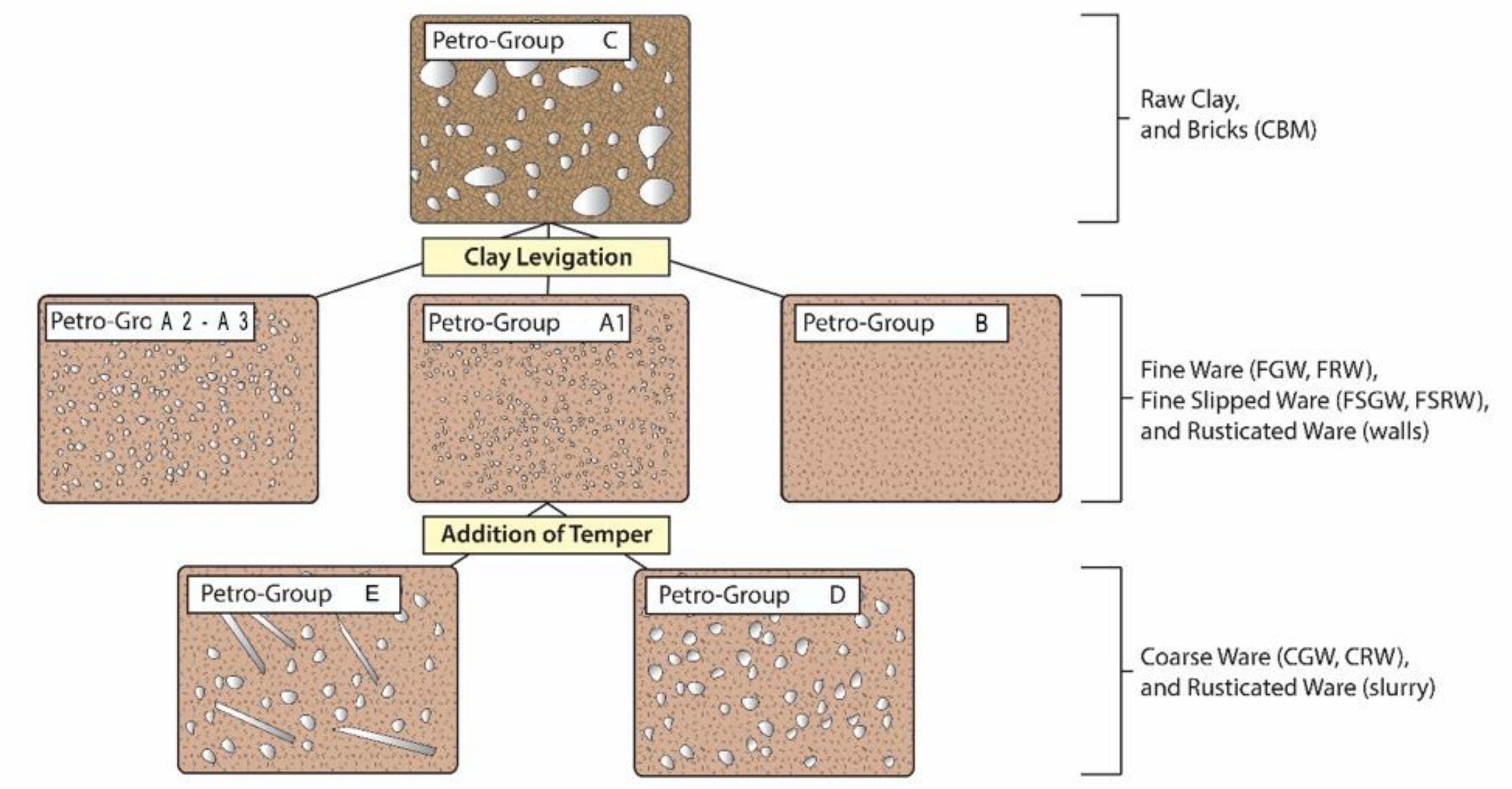
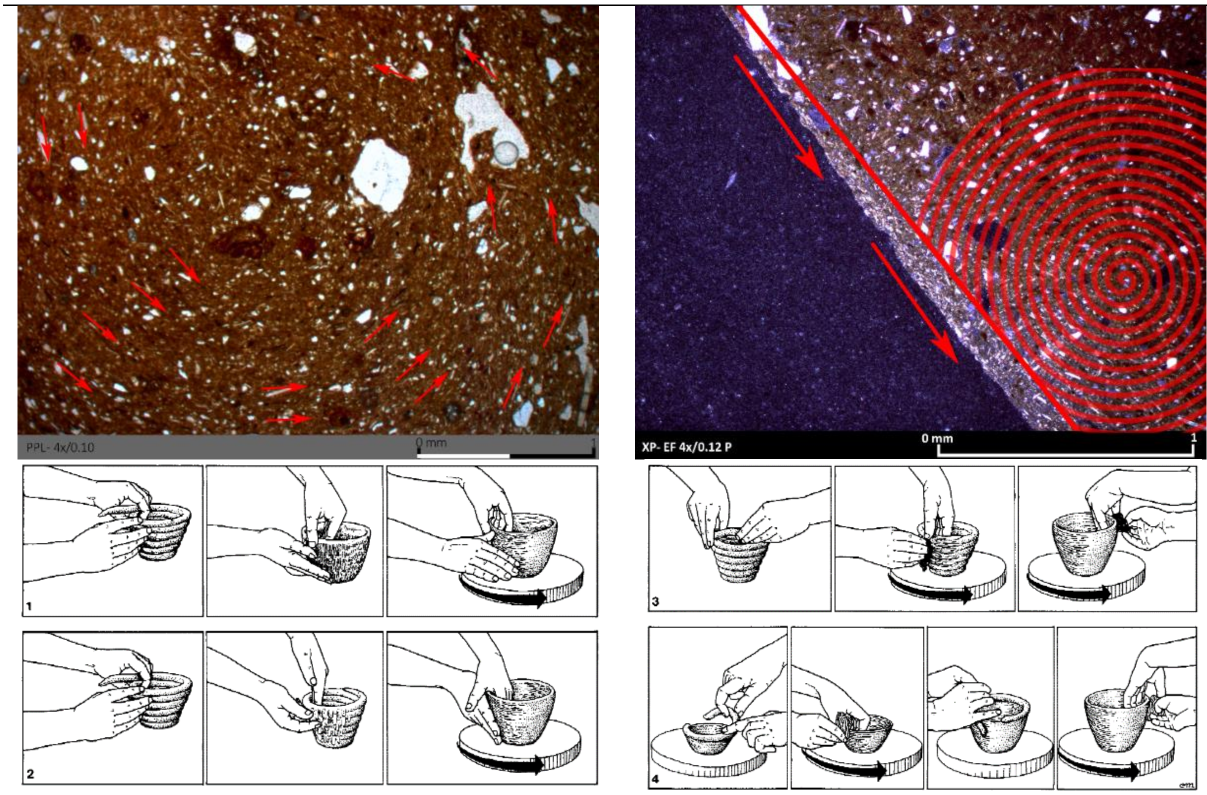


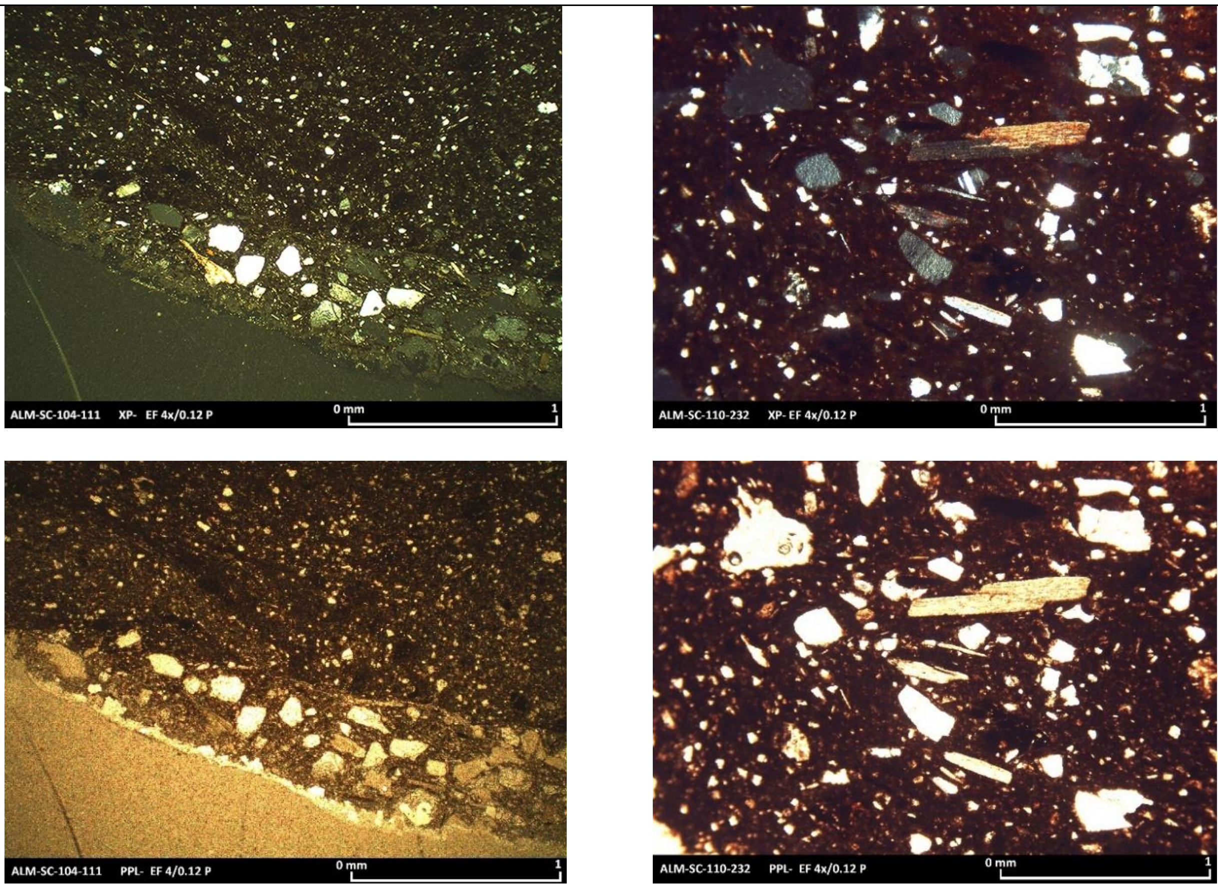
Figure 8.11 The external surface clearly shows a different orientation of aplastic inclusions: Sample ALM-SC-103-81-4x/010-PPL. Manufacturing process: different techniques for coiling and wheel finishing (reproduced from Courty and Roux 1995; Roux and Courty 1998).



8.11.2 Data concerning surface treatments: slips and rustication

The composition of coarse slips on the distinctive wares with applied rustications has already been discussed above (Section 8.8.1), and similarities between the slurry applied to the exterior surface of the Rusticated Ware (e.g. sample 104-111, petro-group A2) and the fabric of Coarse Ware (e.g. sample 110-232, petro-group B) is also presented in Figure 8.12. Significantly, Urban and Post-Urban fine wares seems to show an intermediate finishing stage, after the preliminary forming or fashioning process and before the firing stage. According to microscopic assessment, it seems that the distribution and organisation and direction of aplastic inclusions changes in proximity to the surface. The overall distance between mineral temper is severely reduced, and the orientation of aplastic inclusions in close proximity to the surface changes, becoming parallel to the walls. It thus seems that the surface underwent a process that led to a mechanically induced compaction of the fabric (see Figure 8.11). Such evidence seems to be related to the application of an exterior fine slip, and/or to beating, burnishing or polishing process.

Figure 8.12 Similarities between the slurry applied to the exterior surface of the Rusticated Ware (left, sample 104-111, petro-group A2) and the fabric of Coarse Ware (right, sample 110-232, petro-group B).



8.11.3 Data concerning firing technologies

Firing technologies, particularly the control firing temperatures and conditions, requires specific knowledge and skills to make possible the maintenance and the uniform reproduction of pottery vessels in time, space and under certain environmental and climate circumstances (Sillar and Tite 2000). At first look, from the interior to the exterior surface – and through the core – most slipped and non-slipped red wares at ALM-SC, especially the Fine Ware techno-groups, were uniformly oxidised. This degree of similarity suggests use of a firing structure where abundant air circulation was possible. The rediscovery of kiln fragments lying fused with fragments of ceramics at ALM, as well as possible firing structures or firing places identified during the excavation of Trench XXX (see Figure 8.13; Singh et al. 2013), indicate the local firing of ceramics at the settlement, at least in later periods.

Figure 8.13 Kiln lining and fragments of PGW from a later occupational phase at ALM-YD2.

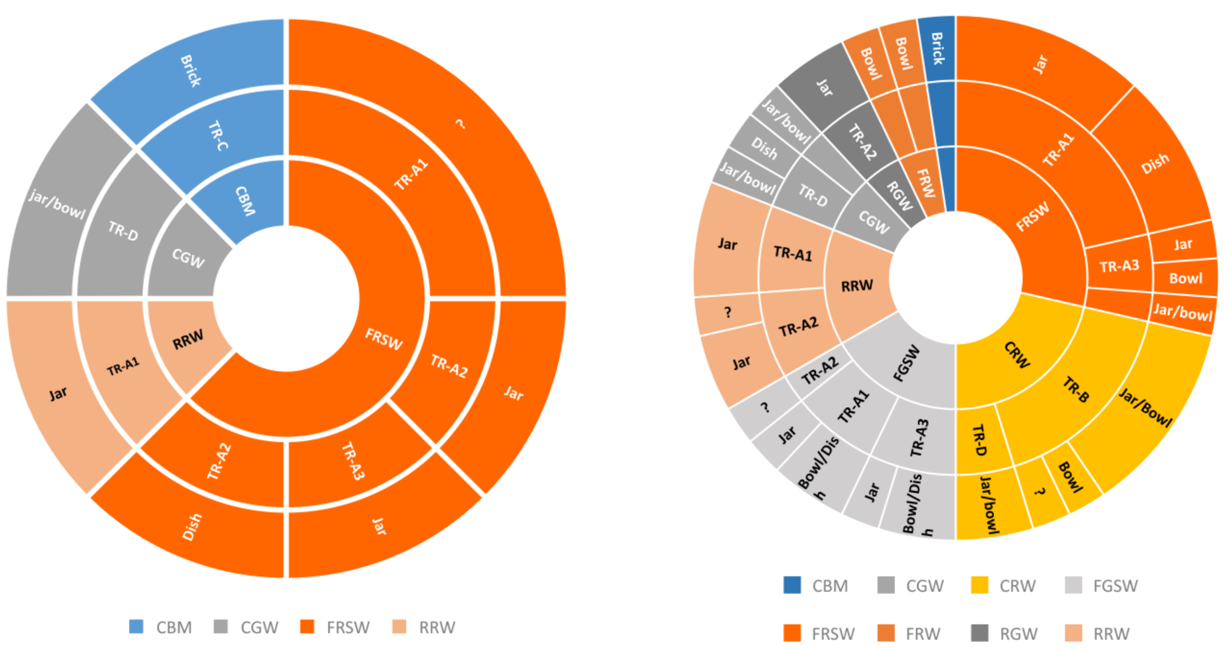
Ceramic petrography can help to identify sherds fired broadly above specific temperatures. Once the minimum temperature/time required to initiate the sintering process is reached, the clay matrix undergoes changes that are visible under optical microscope. The degree of matrix sintering is often correlated to the firing processes: in general, low-fired samples tend to be more optically active and birefringent than high-fired ones (Cultrone et al. 2014). The clay matrix of petro-fabric ALM-A techno-groups show very low optical activity (see Appendix B), well fired ceramics in oxidising atmosphere.

8.12 The identification of ceramic traditions at Alamgirpur

The last stage of analysis combines data obtained from technical groups and petrographic groups with morpho-stylistic observations. This stage is essential for better understanding the functional aspects of ceramics, as well as being able to better identify pottery traditions indicative of variability in levels of social complexity (see Chapter 2). A summary of correspondences detected is here presented. Even though observations on shapes and morphologies are crucial for determining certain aspects of pottery production, given the fragmentary nature of the diagnostic sherds recovered at rural sites such as Alamgirpur, it is difficult to observe substantial correlations between shapes and certain techno-petrographic groups. The comparative diagrams *in Figure 8.14 offer* an overview of the partial relationships between techno-petro groups and vessel forms. Ceramic Building Materials (petro-group ALM-C) have been excluded from this stage of the study. Details about sample are given in Appendix A and B. Drawings of diagnostic sherds have been produced, and are available in Appendix D.

Figure 8.14 Comparative diagrams showing correspondences among technical groups (innermost circle), petrographic groups (middle circle) and vessels' forms (outermost circle) per period.

Indus Urban Period (ALM Period I-B) | Indus Post-Urban Period (ALM Period I-C)



8.12.1 Alamgirpur Coarse Ware

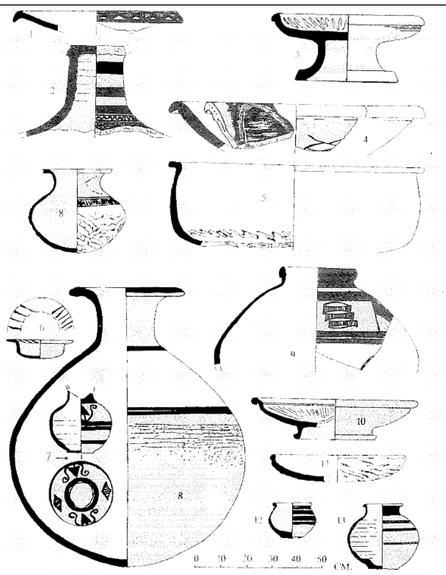
Due to the fragmentary nature of Coarse sherds (techno-groups CGW and CRW) and the lack of diagnostic features, it is not straightforward to carry out a morpho-stylistic and typological assessment of this group of vessels. During the Urban and Post-Urban periods, these ceramics were produced using two coarse pastes (petro-groups ALM-D and ALM-E). Given the porous nature of CGW and CRW vessel walls, along with the presence of the external rustication, these ceramics can be considered as an ideal candidate for a local simple table ware or cooking ware. Considering macroscopic and microscopic observations, these ceramics can be understood as one distinctive pottery tradition, which shows remarkable continuity at the site. Pottery sherds of CGW and CRW were found from the Urban and Post-Urban period deposits, and suggest a distinctive *chaîne opératoire* which occurs concurrently with other ceramic industries. This ceramic tradition is labelled as 'Alamgirpur Coarse Ware'.

8.12.2 The Indus Bara tradition

The study of diagnostic features, vessel forms and painted motifs of FSGW, FSRW, RGW and RRW permitted the assignment of a portion of the fragmentary assemblage to a certain ceramic tradition, which was previously documented at other sites in the Upper

Ganga-Yamuna Doab. Excavation at Ropar (IAR 1953-54; Sharma 1955-56) and Bara (IAR 1954-55), which are both in District Rupnagar, saw the classification of Bara Ware, which is often considered as an eastern regional variety of Indus pottery, differing from ceramics produced in other areas of the Indus zone during the Urban and Post-Urban periods. However, since its identification in 1950s, very few studies on this pottery type have been produced, amongst them the works of Y. D. Sharma (1982; Sharma and Sharma 1982) and Uesugi and Dangi (2017) stood as the most significant (see Section 3.8.3; also Ceccarelli and Petrie in press). What is generally referred to as Bara ware are vessels made of fine clay paste showing small grain size aplastic inclusions. At a macroscopic level, macro-traces suggest that Bara vessels are generally wheel-finished and slipped. The slip provides a deep red to reddish-brown colour when fired in oxidising atmosphere, and shows a characteristic smooth surface. Considering assemblages recovered at Ropar and Bara, and the observations of the material from Alamgirpur described here (see *Figure 8.15*), it seems that the most typical shapes of the Bara tradition include storage jars and dishes, more specifically: globular jars with a long neck and flaring or collared rim, globular carinated jars, and dishes with outflaring rims. Some common shapes identified in Punjab, such as pre-Harappan and classic Harappan pottery types, e.g. carinated dishes with flaring rim, beakers, knobbed lid and lid with out-turned rim, are also found within Bara assemblages (Sharma 1982). However, Bara ware does not appear to include other iconic Urban-period shapes such as wide-mouthed large storage jars, perforated jars, and S-profiled jars.

Figure 8.15 Bara tradition: vessels from Alamgirpur (left), and pottery drawings reproducing Sharma, 1982.



Decoration, painted designs and incised lines are drawn by a blunt-edged object on the smooth pot surface before firing. Black or dark brown painted motifs are mostly geometric, wavy, zigzag, or looped lines and hatched 'net' designs. Vegetal patterns are also found, while the fish seems to be the dominant faunal depiction.

Currently, the origins and development of Bara pottery, and especially its relation with other regional ceramic traditions – such as the classic Harappan pottery types – is still to be explored. Evidence from Farmana and Mitathal seems to suggest a strong connection with the material from those assemblages and classic Harappan pottery shapes (Useugi and Dangi 2017); while ceramic assemblages from Ropar and Bara have been interpreted to be not primarily related to 'that of Harappa' but mostly to the so-called Pre-Harappan (Kalibangān fabrics B, D and F) or Sothi-Siswal ceramics (Sharma 1989) prevalent in north-west India. It is thus possible that Bara ware was a regionally developed Indus ceramic industry.

The dominant pottery tradition at Alamgirpur appears to be a local variety of the Indus Bara tradition. The chronology, shapes and decoration of the Indus Bara ware seems to best match the production of Fine Slipped and Rusticate Ware in Period I-B (Late Phase of the Urban Period; 2135 -1942 BC cal. 95.4%) and Period I-C (Indus Post-Urban period; 1903 - 1749 BC cal. 95.4%). More specifically, the Indus Bara at Alamgirpur includes:

a. ALM period I-B: technical groups FSRW and RRW during the Urban Period, mostly produced using a fine paste (petro-group ALM-A).
b. ALM period I-C: technical groups FSGW, FSRW, RGW and RRW, crafted using three similar fine pastes (petro-group ALM-A) during the Post-Urban period.

Despite its blurred ancestry, Indus Bara pottery can be understood as a regional ceramic production, which developed during a late stage of the Urban period and continued through the Post-Urban period. In view of a certain degree of diachronic changes, Uesugi and Dangi (2017) proposed a provisional division into three major stages of development, which are based on morpho-stylistic and stratigraphic observations, viz. Early Bara (2200-2000 BCE), Middle Bara (2000-1500 BCE) and Late Bara (1500-1300 BCE) stages.

Table 8.2 Correspondence between Technical groups, Petrographic groups, clay pastes, forming, finishing and firing techniques.

Petro-Group	Technical Group	Fine Paste	Coarse Paste	Coiling	RKE and Wheel-Finishing	Mould	Scraping	Rustication/ Slurry	Slipped	Oxidised
C	CBM		x			x				x
B	CGW		x	x			x	x		
B	FGSW	x	x	x	x		x	x	x	x
B	FSRW	x	x	x	x		x	x	x	x
D	CRW		x	x			x	x		x
A3	CGW		x	x	x		x			
A3	RRW	x		x	x		x		x	
A3	FRSW	x		x	x		x		x	x
A2	FRW	x		x	x		x		x	x
A2	FRSW	x		x	x		x		x	x
A2	FGSW	x		x	x		x		x	
A2	RRW	x	x	x	x		x	x		x
A1	FSGW	x		x	x		x	x	x	
A1	FSRW	x		x	x		x	x	x	x
A1	RRW	x		x	x		x		x	x
A1	RGW	x		x	x		x		x	
A1	CRW		x	x			x	x		x

8.12.3 Fine Ware tradition

Two techno-petrographic groups seem not to fit into the above presented picture for traditions at Alamgirpur, i.e. the petrographic group ALM-A3, and the fine non-slipped wares (FGW and FRW). As already mentioned, techno-petro-groups ALM-A1 and ALM-A2 appear to be quite distinctive of Indus Bara vessels. In fact, these petrographic fabrics are identified in Fine Slipped Ware fragments (FSGW, FSRW) as well as rusticated sherds, which are both representative of Bara pottery. This view is also strengthened by observations related to the form and decoration on diagnostic sherds. Nevertheless, the petrographic group ALM-A3 was solely identified in fine wares, predominantly in Fine Grey Ware – either slipped or not – and in none of the rusticated vessels. Similarly, non-slipped Fine Grey Wares (ALM-A3) and Fine Red Ware (ALM-A3 and ALM-A2) do not show characteristic of Indus Bara vessels. This seems to suggest that a restricted, small group of vessels may be part of a third, distinctive ceramic tradition, which is far too fragmentary at ALM-SC.

8.13 Summary

The techno-petrographic and geochemical analyses presented in Chapter 8 indicate that vessels from trench SC at ALM can be divided into five meaningful techno-petrographic groups (Sections 8.7 and 8.8). These groups mostly correspond to five petrographic classes (ALM-A to ALM-E), and show the use of multiple clay paste recipes. The techno-petrographic groups permitted the identification of at least three complex ceramic traditions, which can be used to explore questions concerning social groups, relationships between groups and individuals, and social structures and networks. These results will be further discussed in Chapter 9, and will be compared with data from other sites and from ethnographic observations.

Part Three: Discussion, conclusions and future research

"The method of exposition which philosophers have adopted
leads many to suppose
that they are simply inquirers,
that they have no interest in the conclusions at which they arrive,
and that their primary concern is to follow their premises
to their logical conclusion".

Cohen 1910: 407

Chapter 9. Discussion

The techno-compositional analysis of the ceramic assemblage from LHR I trench EA (Chapter 6), MSD trench I XK2 (Chapter 7) and ALM trench SC (Chapter 8) provides data that make it possible to discuss a variety of rural crafts and technologies at the early stages, peak and decline of urban development in the northwest India. In particular, the techno-compositional approach provides information that can be used to understand ceramic assemblages in order to gain information about social identities, social boundaries and cultural groups, as well as diachronic changes. Here, interpretations of data described in the past four chapters is presented, which combines archaeological data with ethnographic observations. It will follow a chronological 'narrative', that runs from the earliest ceramic tradition at LHR-I, through the late urban assemblages at MSD-I, and then on to the post-urban material at ALM-SC. First, a summary of the variables that can be used to identify socially connected individuals, communities and networks shall be outlined, following the theoretical framework presented in Chapter 2 (see section 9.1 below). Second, synchronic and diachronic similarities and dissimilarities of the identified ceramic *chaînes opératoires* will be discussed by looking at materials from sites excavated in close proximity to a major Indus urban settlement in the region (see sections 9.1 to 9.4). Subsequently, a special emphasis will be put on the variability of ceramic traditions identified at a site distant from the known Indus urban settlement (section 9.5). Finally, data will be used to discuss in a sociological perspective the emerging picture of Indus ceramic landscapes and regional social organisation in a unified view (section 9.6). Eventually, concise answers to the main research question and the three sub-questions presented in Chapter 1 will be provided (section 9.7).

9.1 Variables to socially connected individuals, communities and networks

As mentioned in Chapter 2, this thesis aims to consider ceramic *chaînes opératoires* and compositional data as robust variables for evaluating degrees of social interactions within and between settlements, diachronically and synchronically. A *chaîne opératoire* has been defined as the sequence of actions that transform raw materials into completed products (see Chapter 2; also Creswell 1976: 13). Beyond the identification of distinct ceramic manufacturing techniques, whose variability is theoretically limited, manufacturing sequences and methods, whose combinations are theoretically infinite, tend to be specific (see section 2.3). In other words, combinations of sequences, gestures, and techniques make technological traditions are highly cultural and distinctive of social units, sustained within social boundaries, and thus represent traditions linked through the transmission of a corpus of knowledge and skills (Shennan 2002: 73).

In a diachronic perspective, as mentioned in sections 2.3 and 2.4 of this thesis, the transmission of *chaînes opératoires* involves a number of challenges and limitations. Anthropological studies of techniques and transmission of knowledge show that the reproduction of craft traditions over time needs social learning, or acquiring the corpus of skills and knowledge from a mentor or mentors (O'Brien and Bentley 2011,:317). This is a crucial factor that explains cultural transmission of shared identities, a sense of belonging to a group or to a tradition, and ways of making objects. The mentor is usually found within one's same social unit, social boundary or group (Gosselain 2000; Shennan 2013; Shennan and Steele 1999). Consequently, technological traditions suggest that **individuals sharing the same tradition belong to the same 'community of practice' and likely to the same social unit, i.e., a social unit sharing a corpus of beliefs, knowledge and ways of making** (Lave and Wenger 1991; also see section 2.6). As mentioned in Chapter 2, a learning community, or 'social unit', can range from a family to a caste or sub-caste, from a lineage to a guild, from an ethnic-group to a gender. So forth 'Community of practice' can be seen as a fluid and continuous process, rather than a stationary *status quo*, and explains how traditions are forged, transmitted, sustained, and transformed (Gosselain 2008).

As mentioned in sections 2.5 and 2.6, similarity between manufacturing methods or technological traditions can be seen as part of this phenomenon across time and space. This suggests communities of individuals belonging to the same social unit, who learned and transmitted a tradition within the boundries of determined social interactions. Chronological development and spatial distribution of these communities can be the consequence of historical and sociocultural dynamics, such as movement of people (e.g. through seasonal mobility or matrimonial alliances) and/or population growth. However, dissimilarity in manufacturing techniques within and between settlements suggests different social units in which individuals do not share the same corpus of beliefs, knowledge and practices, and thus are not part of the same social boundaries. Similarity or dissimilarity in craft production, and in ceramic industries more specifically, can thus connect settlements and reveal social units, identities, and networks. Similarity tends to indicate stronger ties, while dissimilarity is usually connected to weaker interrelations, thus offering a glimpse into overall multi-layered social organisations (Hodder 1985; Roux et al. 2017; Stark et al. 2008; Stark 1998).

Moreover, in a synchronic perspective, as outlined in section 2.4 and often as part of social network analysis (Mills 2017), assessing connections between social units requires to ascertain similarities between communities and to examine how individuals or social groups are embedded in and interact with other social units (Borck et al. 2015: 37). The examination of 'embeddedness', interactions, and participation indicates how individuals interrelate with others and how this interrelationship may affect the individuals, their traditions, and their networks (Borck et al. 2015: 37; also see Roux 2019e). As extensively described in section 2.6, *chaînes opératoires* and compositional variability within ceramic assemblages – i.e. heterogeneous or homogeneous recipes and techniques – should permit the identification of multiple coexisting social units within and between settlements, movements of people and/or objects between and within settlements, and whether these suggest interactions (see *social complexity variability*, section 2.4.1)

Ceramic technological traditions are thus robust variables to establish cultural lineages and are linked by historical continuity based on the transmission of knowledge and skills through time (Shennan 2002: 72). *Chaînes opératoires* tend to be transmitted between producers within the same social unit and tend to be more stable and secure evidence, compared to shapes and styles that are likely to change more promptly. The re-discovery of cultural lineages requires the assessment of assemblages of different occupational phases, ideally from the same sites, and a detailed study of *chaînes opératoires* in order to trace socially learned methods of making ceramics over centuries. Similarity and dissimilarity of *chaînes opératoires* of ceramic traditions identified at the three studied settlements shall be discussed below, in a synchronic and diachronic perspective. This will be used to assess qualitatively transmission of knowledge and interactions within and between rural settlements, and to present possible interpretations concerning social units, social complexity, and social structures in the studied region.

9.2 Early Urban synchronic variability, communities and identities at LHR I

The techno-petrographic and geochemical analyses presented in Chapter 6 indicate that vessels from trench EA at LHR I can be divided into seven meaningful techno-petrographic groups (Sections 6.7 and 6.9). These groups mostly correspond to five petrographic class (LHR-A to LHR-E), and show the use of multiple clay paste recipes:

- Vessels-α-(LHR-A and LHR-C)
- Vessels-γ-(LHR-A)
- Vessels-δ-(LHR-A)
- Vessels-ε-(LHR-A)
- Vessels-β-(LHR-D)
- Vessels-ζ-(LHR-B)
- Ceramics-θ-(LHR-E)

The technological practices which characterise the seven identified techno-petrographic groups at LHR I provide possible evidence for: (a) functional categories; and (b) possibly different communities or sub-groups of producers. Certain vessels can be considered as expressions of functional variability of ceramic products at the site, e.g. small subsets of ceramic products such as *Vessels-β*-(LHR-D), *Vessels-γ*-(LHR-A), *Vessels-δ*-(LHR-A), and *Ceramics-θ*-(LHR-E); while the remaining three groups of vessels appear to be more complex and could offer robust evidence for ceramic traditions and groups of producers.

Vessels-β-(LHR-D) and *Vessels-γ*-(LHR-A) are a minor proportion of the corpus, and are restricted to a very limited range of vessels, mainly perforated tall jars (Vessels-β) and black burnished bowls (Vessels-γ), which are very distinctive products within the assemblage. They show distinctive sets of forming and finishing techniques, mostly with very limited use of rotational kinetic energy (RKE, see above Chapter 3.11) or rotational devices, and in particular the black burnished *Vessels-γ* are reduction fired in a characteristic fashion. Petrographic and geochemical observations suggest that these ceramics were likely produced in the same region, the plains of modern Haryana, or even at the same locations, same as the majority of recovered ceramic materials. Given these factors, and considering the restricted variety of morphologies, these ceramics appear to belong to a subset of objects whose function (in the broad meaning of the concept, including socio-cultural or symbolic function) is distinctive, and should be considered as a small subset of products within a broader ceramic tradition, rather than a ceramic tradition *per se*. However, it could also be the case that these *Vessels-β*-(LHR-D), *Vessels-γ*-(LHR-A) may represent exogenous traditions, rarely present at the site, which could have been produced somewhere else, explaining their unique sets of manufacturing techniques and very low frequency In the assemblage.

Similarly, *Vessels-δ*-(LHR-A) and *Ceramics-θ*-(LHR-E), despite being abundant in the ceramic assemblage, represent quite distinctive manufacturing methods and shapes. *Ceramics-θ*-(LHR-E) mostly include Terracotta Cakes and Ceramic Building Material (CBM), while *Vessels-δ*-(LHR-A) are mostly characteristic dark-brown or chocolate slipped small water jars. Despite the fact that the recipes of these ceramics have been tempered in a variety of ways (e.g. LHR-E: *Coarse Phantom Chaff Fabric),* petrographic observations of the clay matrix and geochemical analyses confirm that they were likely produced using clay available in the region, the plains of modern Haryana, or even in close proximity to the same locations as the majority of ceramic materials from Lohari Ragho I. *Vessels-δ*-(LHR-A) and *Ceramics-θ*-(LHR-E) have distinctive sets of forming and finishing techniques, mostly with limited or no use of RKE and rotational devices, and moulded Terracotta cakes and CBM were both manufactured in a specific fashion. Considering the restricted variety of morphologies, it can be suggested that these ceramics belong to a different subset of objects whose function (in the broad meaning of the concept, including socio-cultural or symbolic function) is distinctive, and should be considered as a small subset of products within a broader ceramic tradition, rather than being ceramic traditions *per se*.

The remaining three complex traditions include *Vessels-a*, *Vessels-ε*, and *Vessels-ζ*. Vessels-α-(petro-fabrics LHR-A and LHR-C) make up the majority of the ceramic corpus from trench EA at LHR I. Within this group, various sets of technical actions and surface treatments differentiate sub-groups (e.g. *Vessels-a1, Vessels-a2,* and *Vessels-a3),* including tentative observations on the quality of the final vessels. Typologically, these sub-groups include a variety of open and closed shapes, and show comparable or overlapping morphologies. In this sense, the *Vessels-a* sub-groups do not suggest functional variability of ceramic objects, but more likely indicate different levels of skills and re-elaborations within a single ceramic traditions. Petrographic and geochemical observations confirmed that they were likely produced using similar clay available in the region, the plains of modern Haryana, or even in close proximity to the settlement, like the majority of the recovered ceramic materials.

As mentioned, the *Vessels-α* sub-groups include *Vessels-a1, - a2, and -a3*. Fragments of Vessels-*a4* are particularly rare in the corpus, and thus will not be considered in the discussion in detail. *Vessels-a1* includes lower-quality ceramics, and their production appears to be remarkably less refined when compared to the rest of the ceramic corpus. Several factors could explain the reduced quality of Vessels-α1 bowls and jars, including the involvement of less skilled producers or potters during the manufacturing process (see section 6.7.1). *Vessels-a2* show the use of a more complex combination of technical actions, including an applied rustication to bowls and globular vessels. These vessels also show more care taken with finishing techniques. Both the medium- and higher- quality *Vessels-a2* and *-a3* seem to show a better control over the production phases, though still using the locally available raw materials and clay of the Haryana plain. Importantly, Vessels-*a2* and -*a3* include the highest-quality products of this group.

Vessels-ε-(LHR-A) show the abundant use of RKE and/or rotational devices in the manufacturing process, putting them in a technologically different category of vessels (see section 6.7.5). *Vessels-ε* are high-quality products and share some similar typological forms with the lower quality *Vessels-α*, including bowls and globular jars. However, the morphologies of *Vessels-ε* includes distinctive shapes, such as certain storage jars, dishes, goblets, and vessels with a finer-grained applied rustication. *Vessels-ε* bear evidence for a remarkably advanced control over the production process, though still using the locally available raw materials and clay of the Haryana plain.

Finally, *Vessels-ζ*-(LHR-B), not only show an even more sophisticated set of techniques and final products than all the other techno-petrographic groups identified at LHR-I, but they also seem to suggest the use of different raw materials and sources. These are relatively rare fragments of polished or partially burnished, black painted, bright red slipped vessels, and they may represent an intrusive, exogenous/imported group in the local corpus. Morphologically, *Vessels-ζ* seem to show similarities with techno-group *Vessels-ε*, especially in terms of small- and medium-size jars. Technologically, *Vessels-ζ* could be considered the highest quality products, likely the pinnacle of pottery production seen at LHR I, though perhaps not of the region. Petrographically, this group suggests the use of a finer paste (LHR-B) and possibly a different source of clay, yet showing similarities with the broader alluvial clay identified in the more common petro-class LHR-A. Geochemical data seem to support this interpretation, showing a diverging trend in the chemical variability of this particular compositional group compared to the others.

Thus, it has been possible to split the techno-petrographic groups into two broad meaningful categories, where complex ceramic traditions are characterised by a diverse range of sequences of technical actions and morphologies, which can reveal more information regarding social complexity variability, social interactions, and social organisation (see Chapter 2 and section 9.1; also see below **Error! Reference source not f ound.**).

Table 9.1 Use of techno-petrographic groups for exploring social complexity and functional variability (see Chapter 2).

Social Complexity Variability	Exogenous Tradition	Functional Variability
Vessels-α-(LHR-A and LHR-C) Vessels-ε-(LHR-A)	Vessels-ζ-(LHR-B)	Vessels- β-(LHR-D) Vessels-γ-(LHR-A) Vessels-δ-(LHR-A) Ceramics-θ-(LHR-E)

The picture of social complexity associated to ceramic production emerging from the variability of the assemblage from trench EA at LHR I can be understood through patterns of technological heterogeneity and compositional homogeneity (cf. Roux and Courty 2007, 2013; Roux 2016). The identification of *Vessels-a*-(LHR-A and LHR-C) and *Vessels-ε*-(LHR-A) indicates the presence of a small number of ceramic traditions at the settlement. These ceramic traditions appears to have belonged to producers sharing a specific corpus of technical knowledge and skills but likely belonged to two distinctive social units. Within the *Vessels-a* tradition, a large variety of functional vessels were manufactured, as shown by typological and technological features of bowls and globular *vessels-a2* and *–a3*. The technological variability of the latter groups was higher than with *vessels–a1*, and encompasses a wider array of technical actions, including surface treatments and decorations. This is likely indicative of a certain degree of variability within this ceramic tradition, possibly due to intra-household variability of skills and expertise. Given the stratigraphic position of contexts yielding *Vessels-a*, the producers of these ceramics likely engaged in the most abundant industry at the settlement during its earliest phases of occupation.

Second, the producers of *Vessels-ε* appear to have used a different and more convoluted set of manufacturing techniques, and likely belonged to a different social unit from the above mentioned group of producers. The technical knowledge still shows some similarities to *Vessels-α*, encompassing a wide range of technical actions, including conceptually similar surface treatments (e.g. applied rustications) and certain painted decorations. However, dissimilarity of sequences of manufacturing techniques, morphologies, surface treatments, and decorations indicate that, even though *Vessels-α* and *Vessels-ε* may have had common ancestral origins, they diverged into significantly diverse traditions. Importantly, the producers of *Vessels-α* and *Vessels-ε* were equally using conveniently locally available raw materials, as techno-petrographic observations suggest that were made using similar ingredients and recipes. This pattern will be further discussed in the second part of this chapter, and likely suggests a settlement with high socio-cultural variability (model B2, see Section 2.4) and multiple social components within the sphere of ceramic production (see social complexity variability models B1, B2 and B3 described Chapter 2).

The third ceramic tradition discussed above, the sophisticated black-on-red *Vessels-ζ* seem to be a non-recurrent, rare, exogenous ceramic tradition. This pattern might suggest the circulation of 'imported' containers into the rural settlement. This type of exogenous traditions has not been directly includeed In the discussion concernin sociological variability at the site.

The technological and compositional variability observed at Lohari Ragho I seems to highlight multiple levels of social complexity. On the one hand, likely during the earlier occupational phase at the site, *Vessels-α* seems to suggest the possibility of village-based, domestic production. This was expressed through a range of technical actions, variability of low- to medium-quality products, and rudimentary morphologies, suggesting possible inter-household variability in production and use within the dominant *Vessels-α* industry. The possible presence of less and more experienced potters within this tradition has been already discussed above. On the other hand, the picture appears to become more complex during the subsequent occupational phases, where the manufacture and consumption of *Vessels-ε* and *Vessels-ζ* is observed. Given the broad compositional similarities between *Vessels-α* and *Vessels-ε,* it is likely that producers belonging to both traditions may have settled over time at the settlement. This particular scenario raises questions about the function of this settlement, the possibility of seasonal mobility between settlements and across the landscape, as well as the settlement's connections with other small and large settlements in the region. These latter traditions seem to suggest more standardised productions originating within communities moving in and around the macro-region, the plain of Haryana, with multiple and more advanced experience in pottery-making compared to the producers of *Vessels*-α.

As mentioned above, even though *Vessels-ζ* and *Vessels-ε* appear to be in use concurrently, thus ruling out the possibility of a strict and/or rigid techno-stylistic development over time, the techno-petrographic group *Vessels-a-(*LHR-A and LHR-C) can be considered slightly earlier than the former two groups. The *Vessels-a* tradition appears to be dominant in stratigraphically earlier deposits and at earlier stages of occupation of the settlement, while *Vessels-ζ* and *Vessels-ε* traditions may be considered slightly later. This pattern might suggest a certain degree of technological and stylistic development over time, which will be further explored in the last section of this chapter.

The higher level of sophistication of Vessels-ε and Vessels-ζ may also provide a glimpse into learning mechanisms and social interactions between potters and within communities. The use and reproduction of advanced techniques, as well as better control over the manufacturing process, may point out significant investment of time and resources during the learning process, and perhaps suggest a stronger sense of social boundaries, belonging and identity among the producers of Vessels-ζ and Vessels-ε. Whether the producers of these vessels were trained in a different environment, such as a specialised workshop or an urbanised settlement (e.g. the large-size Indus settlement at Rakhigarhi), cannot be established based on the available data, but these should remain distinct possibilities.

9.3 Early Urban diachronic variability: ceramic landscapes and innovations at LHR I

9.3.1 Raw Materials at LHR I

The material resources used during most of the excavated occupational phases at LHR I trench EA likely reflect the abundant presence of fluvial or alluvial clay available in the palaeoenvironment. Compositionally, most archaeological ceramics seem to plot with clay samples likely from fluvial or alluvial deposits (see Chapters 5 and 6). Vessels-α-(LHR-A), *Vessels-γ*-(LHR-A), *Vessels-δ*-(LHR-A), and *Vessels-ε*-(LHR-A) were likely produced using similar clay sources. Similar alluvial clay may have been also used in the production of

Vessels-β-(LHR-D), *Vessels-ζ*-(LHR-B) and *Ceramics-θ*-(LHR-E), even though the clay pastes were mixed with the addition of plastic or aplastic temper such as *kankar* nodules. Petrographic and geochemical analyses suggest the use of similar clay sources for almost all the recipes, perhaps abundant in the region in close proximity to channels and rivers. Vessels-ζ-(LHR-B) and Ceramics-θ-(LHR-E) are the only groups that show a significantly diverging trend, suggesting different clay processing techniques, tempering or possibly even different clay sources. While these vessels all appear to have been produced locally, it is possible that multiple settlements in close proximity to LHR I were consuming vessels produced also using a few similar clay sources from the area around the settlement.

Significantly, the low compositional variability contrasts to the remarkably high technical variability and technological heterogeneity between the identified techno-groups. The shared knowledge of clay sources or 'clay-scapes', and clay pastes properties in the region implies a certain degree of interaction between various groups of producers, including possible ancestral common origins; whereas the technological heterogeneity seems to indicate a high socio-cultural variability in ceramic production (see Chapter 2).

This indicates that similar resources were used during most occupational phases at the settlement. However, a changing trend is observable during the latest occupational phase (i.e. Early Urban), when more compositional variability is observed. The differences in material resources between the earliest and latest occupational phases are also found on technological and morphological aspects of ceramics.

9.3.2 Ceramic landscapes and technological traditions at LHR I

One of the questions of this thesis encourages the assessment of whether the Indus communities, living at the studied settlement and distributed over the plains of Haryana and sharing some ceramic traditions but made of distinct groups based on the distribution of some techno-petrographic, stylistic and morphological variants, were interacting at the regional scale within an embedded social network. The re-discovery of three distinctive ceramic traditions at LHR I likely suggests the presence of three distinctive communities of practice or social units within and/or around the settlement. Two distinctive dominant traditions, namely *Vessels-a* and *Vessels-ε,* seem to emerge in the Pre-Urban and Early Urban period at LHR I. The technological variability appears to be due to variants of a similar technological tradition, or more likely of two traditions with common ancestral origins (Roux and Courty 2007, 2013) bearing similar technical elements which signal a common origin. They are likely representative of diverging local rural Indus traditions, where it is possible to perceive a broader sense of shared identities, in this case a broad sense of 'Indus-ness' in the ceramic assemblage in terms of morphologies and surface treatments. Moreover, an exogenous 'deluxe Indus' ceramic tradition shows similarity to the classic Indus pottery produced or consumed at large Indus settlements such as Farmana and Rakhigarhi (see Uesugi 2011). In this regard, overall this material expresses a certain phenomenon of amalgamation and sense of connection between sites in the region. Such a phenomenon may occur when cultural groups interact with each other and the subsequent learning networks creating communities of practices, and therefore providing a sense of regional consistency of technological traditions through the borrowing of technological traits (see Roux 2013; also e.g. Livingstone Smith 2001; Gosselain 2008). Individually, the settlement at LHR I presents, on a local scale, a homogenous assemblage consistent with Its own local traditions. This Is coupled with more rare exhaugenous ceramic traditions likely suggesting interactions at the regional scale (following Roux 2019e); this hypothesis will be further explored in the second part of this chapter.

During the Pre-urban and Early Urban periods at LHR I, the three identified overlapping ceramic landscapes seem to point out three distinct social units interacting at or with the settlement at different stages and indicates long-term regional interactions between the communities living on the plains of Haryana. The transitional phase from the Pre-Urban to the Early Urban period seems to be particularly interesting, due to the consolidation of more skilled communities of producers and stronger social ties. It is likely that the ancestral tradition, i.e. the rural domestic *Vessels-a* tradition, was continuously reproduced and sustained at the site or in the region over centuries. This latter witnessed the development of a more refined *Vessels-ε* tradition and the sporadic presence of the exogenous 'deluxe' *Vessels-ζ.*

In other words, during the earliest occupational phase, it is possible to observe a higher overall homogeneity of the assemblage, less sophisticated sequences of actions for the production of vessels, less regular shapes, and limited morphologies. Vessels were formed by coiling and limited use of RKE, and surface treatments appear to be similar to those of the lower-quality vessels of the subsequent phases. Generally speaking, their manufacture reveals a less skilled level of production. Morphological types are simple. During the later phase of occupation, it is possible to observe an overlap of multiple, diverse ceramic traditions, locally consistent within itself and homogenous at the site, with the rare presence exogenous ceramic traditions in the assemblage. In assessing the social variability, only the diverse yet homogenous assemblage at the site have been considered, and the exhogenous… The 'newer' style ceramics of the Early Urban period are characterised by a higher level of skills and overall consistent standardisation of technical actions and morphologies.

In terms of the extent of the three identified ceramic landscapes, similarities can be suggested with contemporaneous ceramic assemblages identified at other Indus settlements, such as:

- LHR Pre-Urban 'rural domestic' tradition: e.g. Grey Ware, Sothi and Girawad, Sothi (Diskhit 1984), Siswal (Bhan S. 1971-72), and Kalibangān;
- LHR Early-Urban 'rural domestic', and 'rural refined' traditions: e.g. Farmana, Masudpur I, and Kalibangān; and
- LHR Early-Urban Indus 'deluxe' tradition (see Appendix D, Plate IX): Farmana, Harappa, and Rakhigarhi (Nath 1998, 1999, 2001).

9.4 Late Urban synchronic variability, communities and identities at MSD I

The techno-petrographic and geochemical analysis of MSD-I, XK2 ceramics has shown that vessels could be mostly divided into seven main techno-petrographic groups (see Chapter 7). Each of the observed techno-groups show certain correlations with distinctive petrographic classes, and suggested the use of a variety of clay paste recipes:

Vessels α - MSD-G	Vessels ζ - MSD-E
Vessels β - MSD-C	Vessels η - MSD-B
Vessels ε - MSD-C/ E/ G	Ceramics θ - MSD-A/ B /D
Vessels δ - MSD-G	

The technological practices which characterise the seven identified techno-petrographic groups at MSD I provide evidence for: (a) functional categories; and (b) possibly different communities or sub-groups of producers. Certain vessels can be considered as expressions of functional variability of ceramic products at the site, e.g. small subsets of ceramic products such as *Vessels β*- MSD-C, *Vessels η*- MSD-B, and *Ceramics- θ*- MSD-A/ -B /-D; while the remaining four groups of vessels appear to be more complex and could offer robust evidence for ceramic traditions and groups of producers. *Vessels* β - MSD-C show a distinctive set of forming and finishing techniques, mostly without the use of RKE or rotational devices. Given its techno-compositional features, and considering the restricted variety of morphologies, it can be suggested that these ceramics belong to a subset of objects whose function (in the broad meaning of the concept, including socio-cultural or symbolic function) is distinctive, and is dissimilar from the rest of the corpus. However, it should not be considered as an entirely independent ceramic tradition, but more likely as a subset of broader ceramic tradition. However, it could also be the case that these Vessels-β may represent exogenous traditions, rarely present at the site, which could have been produced somewhere else, explaining their unique sets of manufacturing techniques and very low frequency In the assemblage.

Similarly, *Vessels* η - MSD-B and *Ceramics* θ - MSD-A/ B /D, despite being abundant in the ceramic assemblage, represent quite distinctive ceramic products. Ceramics- θ - MSD-A/ B /D mostly include Terracotta Cakes and CBM, while Vessels η - MSD-B are mostly chaff tempered bowls. Despite the fact that the pastes of these ceramics have been tempered in a different fashion from the rest of the corpus (e.g. MSD-B*)*, petrographic observations of the clay matrix fine fraction and geochemical analyses suggest that they were likely produced in the same region, the plains of modern Haryana, or even at the same sites, as the majority of recovered ceramic materials. Vessels η - MSD-B and Ceramics- θ - MSD-A/ B /D have distinctive sets of forming and finishing techniques, mostly without the use of RKE and rotational devices, with coarse bowls, moulded Terracotta cakes and CBM being manufactured in a unique fashion. Given these factors, and considering the restricted variety of morphological forms, it can be confidently suggested that these ceramics belong to a subset of objects whose function is distinctive, and different from the majority of ceramics. However, these vessels should also not be considered as being representative of an entirely independent ceramic tradition, but more likely as subsets of broader ceramic tradition.

Overall, Vessels β - MSD-C, Vessels δ - MSD-G, and Vessels ζ - MSD-E are particularly rare in the ceramic corpus, and are restricted to a very limited range of vessels' morphologies, mainly perforated tall jars (vessels-β), jars with applied fish-scale rustication (vessels- δ), and deluxe black-on-red vessels (Vessels ζ). However, the petrographic and geochemical observations confirmed that they were likely produced using raw material largely available in the same macro region (Section 7.8-7.9), the plains of modern Haryana. Given broad compositional similarities of the assemblage, including ceramic building materials, these ceramic products were likely produced at the settlement or in close proximity to the settlement, similar to the majority of recovered ceramic materials.

Given the dissimilarity of recipes, manufacturing techniques and range of morphologies of Vessels α - MSD-G, Vessels ε - MSD-C/ E/ G, Vessels δ - MSD-G, and Vessels ζ - MSD-E, these four groups should be considered as distinctive ceramic traditions – each of them symptomatic of distinctive producers likely associated with distinctive social units or communities of practices. Vessels α - MSD-G and Vessels ε - MSD-C/ E/ G represent the majority of the ceramic corpus at MSD I, XK2. Within these groups, variable sets of technical actions and surface treatments can be used to identify sub-groups of producers, including tentative observations on the quality of the final vessels. Typologically, both these groups include a variety of closed and open shapes and show comparable morphologies. In this sense, the sub-groups do not indicate functional variability of ceramic objects. Petrographic and geochemical observations confirmed that they are likely produced in the same region, the plains of modern Haryana, or even at the same sites, the same as the majority of recovered ceramic materials. Comparative compositional data with assemblages from other sites will be discussed in the last section of this chapter.

The sophisticated black-on-red *Vessels-ζ* seem to be a non-recurrent, rare, exogenous ceramic tradition. This patter might suggest the circulation of 'imported' containers into the rural settlement. This type of exogenous traditions has not been directly includeed In the discussion concernin sociological variability at the site.

Despite being abundant in the corpus, the Vessels α- MSD-G are fragmentary and thus it is difficult to be used to reconstruct full morphologies and the whole sequence of manufacturing techniques. Vessels-*a* show the use of a combination of technical actions and finishing techniques, including the use of an applied rustication to globular jars and bowls, suggesting the use of limited RKE or rotational devices during the finishing forming stage. Stylistically speaking, Vessels-α show limited decorative motifs, mostly painted black bands on lines. Petrographic observations of clay pastes confirm the use of locally available raw materials in the region, and the possible local production of this vessels at MSD village or in its close proximity. These lower-quality ceramics appear to be notably less refined when compared to the rest of the fine ceramics in the corpus. Several factors could explain the reduced quality of bowls-α and jars-α, including the possible presence of less skilled producers or potters.

Vessels ε - MSD-C/ E/ G are the second most abundant ceramic products in the corpus. They show the frequent use of RKE and/or rotational devices in the manufacturing process, putting them in a technologically different category of vessels. Compared to the above mentioned Vessels-*a,* Vessels-ε are medium- and high-quality products, but both traditions share a limited number of similar typologies, including bowls and globular jars. However, a larger variety of morphologies and distinctive shapes make up the typologies of Vessels-ε, such as certain large storage jars, dishes, goblets, flat and disk-based jars, outflaring-rim jars, and a finer-grained applied rustication. Moreover, Vessels ε seem to show a larger variety of decorative patterns, mostly black painted motifs. In general, Vessels-ε show a more advanced control over the production process, still using the locally available raw materials and clay recipe of the Haryana plain.

Finally, *Vessels* ζ - MSD-E not only show a more sophisticated set of techniques and final products than other techno-petrographic groups, but they also seem to suggest the use of compositionally different raw materials and sources. These ceramics are rare fragments of polished, black painted, bright red slipped vessels, and they may represent an intrusive, exogenous/imported group that appears within the local corpus. Morphologically, Vessels-ζ seem to show similarities with techno-group *Vessels*-ε, especially in terms of small- and medium-size jars. Technologically, *Vessels*-ζ could be considered the pinnacle of pottery production in the region. Petrographically, this group suggests the use of a finer paste (MSD-E) and possibly a different source of clay, yet showing similarities with the broader alluvial clay identified in petro-class MSD-G and A. Geochemical analyses seem to support this picture, showing a diverging trend in the variability of this particular compositional group compared to the others.

As mentioned, the technological practices which characterise the seven identified techno-petrographic groups at Masudpur I express different functional categories, as well as different traditions. The above presented observations led to the splitting of the techno-petrographic groups into two broad categories. Due to their distinctive shapes, manufacturing procedures and recipes, certain vessels can tell more about functional variability of certain distinctive ceramic products at the site, e.g. Vessels β - MSD-C, Vessels η - MSD-B, and Ceramics- θ - MSD-A/ B /D. However, four ceramic traditions appear to be more complex and can be considered as robust evidence for producers, or groups of producers, belonging to distinctive lineages, each associated to a corpus of practices, knowledge, skills, and ways of making objects. These complex traditions include Vessels-α – MSD-G, Vessels-ε- MSD-C/ E/ G, Vessels δ - MSD-G, and Vessels-ζ - MSD-E. Consequently, the four identified ceramic traditions can reveal more information regarding social boundaries within which producers learned, sustained and reproduced their practices, and can be used to address aspects of social complexity variability, interactions and stratification at the settlements and within the broader region (see Chapter 2 and section 9.1; also see **Error! Reference source not found.**). This will be further discussed below.

Table 9.2 Use of techno-petrographic groups for exploring social complexity and functional variability at MSD-I, XK2.

Social Complexity Variability	Exogenous Traditions	Functional Variability

Vessels α - MSD-G Vessels ε - MSD-C/ E/ G	Vessels δ - MSD-G Vessels ζ - MSD-E	Vessels β - MSD-C Vessels η - MSD-B Ceramics- θ - MSD-A/ B /D

The picture of social complexity in the realm of ceramic producers that is emerging from the technological variability of the MSD I Trench XK2 assemblage can be understood through its variable degrees of homogeneity and heterogeneity (Roux and Courty 2007, 2013; Roux 2016). *Vessels* α - MSD-G, *Vessels* ε - MSD-C/ E/ G, *Vessels* δ - MSD-G, and *Vessels* ζ - MSD-E suggest the presence of a few technological traditions, that are to some extent linked together by some shared morphologies, technical practices, and the use of one or a small number of clay sources located in the neighbourhoods of the site. This likely reveals a settlement with high socio-cultural variability (model B2, see Section 2.4), and multiple social components in the scope of ceramic producers.

First, the producers of Vessels-α likely had the most abundant production at the site and show significant dissimilarity from the producers of the *Vessels* ε. This dissimilarity has been already highlighted above for each ceramic tradition, in terms of combinations of technical actions, surface treatments and morphologies of ceramic products. A large variety of functional vessels were manufactured, as shown by typological and technological features of bowls and globular vessels-α. The technological variability is high within Vessels–α, suggesting multiple producers at the village, possessing different levels of skills, and thus possible intra-household variability. This tradition encompasses a wide array of technical actions and surface treatments, but limited morphologies and decorations.

Second, the producers of Vessels-ε appear to use a different set or combinations of manufacturing techniques and were potentially self-identifying as a socially or economically different lineage from the above group of Vessels-α producers. The technological variability of this tradition encompass a wide range of technical actions, including a variety of surface treatments and decoration styles. A sense of higher level of skills is here observed when compared to Vessels-α, which seems to suggest a prolonged exposure to the social process of learning, and likely to stronger social ties within this lineage.

The remaining two traditions, *Vessels*-ζ and *Vessels*- δ, are quite rare in the assemblage. Given the limited number of sherds, the highly sophisticated, deluxe black-on-red Vessels-ζ seem to be a non-recurrent, anecdotal, exogenous ceramic tradition. They show, however, strong morphological similarities, and perhaps a certain level of mutual influences, with *Vessels-ε*. This relatedness might suggest the circulation of Vessels-ζ containers into the rural settlement from elsewhere. Finally, the *Vessels-* δ, which show a distinctive fish-scale rustication, do not seem to show significant similarity with any of the above traditions, and might also be a rare exogenous ceramic tradition. Unfortunately, given the small quantity of data available, it is not possible to determine whether this is pottery from a later stage of occupation, or from a different region.

The high level of sophistication of Vessels-ε and Vessels-ζ may also provide a glimpse into the learning mechanisms and social interactions between potters and within communities. The use and reproduction of advanced techniques, as well as better control over the manufacturing process, may point out significant investment of time and resources during the learning process. This may also suggest a stronger sense of social ties within the lineage, and perhaps a stronger sense of belonging and identity among the producers of Vessels-ε.

Observations on morphologies of Vessels-ε tradition also seem to bear some evidence concerning the activities and ways of living of the social unit within which vessels were produced and used. For instance, the presence of storage and large transport jars within this assemblage may point out a certain degree of mobility of goods or people. This hypothesis could explain the production of ceramics by communities moving in and around the macro-region, the plain of Haryana. This may have exposed the moving communities of producers and users to a variety of other more or less advances traditions of pottery-making in the region, some of whom were likely visiting or settling over time at the studied village. These might be part, along with strong social ties among members of this social unit, of the necessary mechanisms that reproduce social identity over time within mobile or nomadic communities in the region (see Petrie et al, 2017: 21; Petrie and Lynam, 2019: 6). This possibility raises a number of questions related to the function of the studied settlement, seasonal mobility between sites and across the landscape, as well as nature of the site's connections with other small and large settlements in the region. Besides the Vessels-ε tradition, whether the producers of the rare, 'deluxe' Vessels-ζ were possibly trained in a different environment, such as a specialised workshop or a urbanised site, this will not be here further discussed.

9.5 Late Urban diachronic variability: ceramic landscapes and innovations at MSD I

9.5.1 Raw Materials at MSD I

As far as composition is concerned, the petrographic and geochemical analyses suggest that potters were mostly collecting raw materials in close proximity to the settlement. It is possible that multiple sites in close proximity to MSD I were consuming vessels produced using a few similar clay sources from the area around the site. Vessels α - MSD-G and Vessels ε - MSD-C/ E/ G, Vessels η - MSD-B and Ceramics-θ-MSD-A/ B /D were mostly produced using one or a few similar clay sources, at times tempered with organic materials (e.g. MSD-B), or with fragments of limestone or calrete-kankar nodules (e.g. MSD-C). Despite these differences, geochemical analysis suggest the use of similar clay sources for almost all the recipes. However, perforated Vessels-β-MSD-C, chaff tempered Vessels-η, and coarse Ceramics-θ-MSD-D/B seem to show a slightly different chemical fingerprint. This is possibly due to the presence of calcrete temper, or possibly a slightly different source of clay, presumably within the region, but possibly one that was more calcareous and similar to the one used for the production of bricks and terracotta cakes. 'Deluxe' Vessels ζ - MSD-E also show a diverging trend, possibly suggesting the use of slightly different raw material sources – either locally available or not. Importantly, the producers of *Vessels-a* and *Vessels-ε* were equally using conveniently locally available raw materials, as techno-petrographic observations suggest the use of similar recipes.

The material resources used during most occupational phases at MSD I (see Chapter 7) reflect the abundant presence of fluvial or alluvial clay available in the local palaeoenvironment. Similar resources were used during most occupational phases seen in trench XK2. However, distinct trends are observable during the two main occupational phases (Early Urban and Late Urban), pointing out possible different sources for the production of CBM, Terracotta cakes, as well as perforated jars and deluxe black-on-red vessels. The differences in material resources between the earliest and latest occupational phases are also found on technological and morphological aspects of ceramics. Conversely, the low compositional variability can be opposed to the significantly high technical variability and technological heterogeneity between techno-groups, as describe in Sections 9.4. The shared knowledge of clay sources, 'clay-scapes', and clay properties in the region may suggest a certain degree of interactions between various groups of producers.

9.5.2 Ceramic landscapes and technological traditions

Similarly to LHR I, one of the issues concerns assessing whether the Indus communities, living at the studied settlement and distributed over the plains of Haryana, sharing some ceramic traditions but made of distinct groups of producers and associated social units based on the distribution of some techno-petrographic, stylistic and morphological variants, were interacting at the regional scale within an embedded social network. The re-discovery of distinctive ceramic traditions at MSD I likely suggests the presence of three distinctive communities of practice and associated social units within and/or around the settlement. As mentioned above, two distinctive dominant traditions, namely *Vessels-a*, *Vessels-ε*, and Vessels-ζ seem to coexist in the Urban period at MSD I.

The lower quality *Vessels-a* tradition suggests variability of skills within this lineage, which appears to have influenced yet been separated from the more dominant *Vessels-ε* tradition. The distinctive combination of technical actions, vessels' forms and stylistic traits of *Vessels-a* was identified in multiple stratigraphic contexts during the Early-Late Urban Transitional phase, likely indicating continuity of use, and perhaps production as well, of this tradition at the settlement for an extended period. As mentioned above, this is indicative of a distinctive lineage of potters, who were likely aware of others communities of producers in the region, yet maintained their own ways of producing objects - which could be read as a form of identity statement. This also suggests the mindful and clear choice to differentiate these ceramic products from other contemporary traditions. Moreover, *Vessels-a* still carry certain ancestral technological and stylistic features seen in Pre-Urban and Early Urban ceramic traditions at LHR I (see Section 9.2 and 9.3), reinforcing the interpretation that conscious efforts and choices were made to sustain an ancient local tradition within the region. This pattern likely suggests the mindful choice not to adopt technological innovations or other ways of making ceramic products. To some extent, this picture reflects a similar situation observed at LHR I, during the latest phase of occupation (see Chapter 6, and Sections 9.2, 9.3).

The higher variability of traditions and technologies of the transitional Early to Late Urban occupational phase seems to go against the more technologically homogeneous Late Urban period. The later ceramics of the Urban period are characterised by a high level of skills, likely pointing out a stronger ties within the associated lineage of producers, and possibly a stronger sense of identity and belonging correlated with higher mobility across the landscape (see Roux and Courty 2005; 2007). Overall, the settlement at MSD I presents, on a local scale, a homogenous assemblage consistent with its own local traditions. This is coupled with more rare exhaugenous ceramic traditions likely suggesting interactions at the regional scale (following Roux 2019e).

Besides the overlap between the *Vessels-a* and *Vessels-ε* traditions, it was possible to observe a third intrusive tradition, a deluxe Indus production. This is not a completely distinct technological traditions and seems to correspond to variants of a similar technological tradition at the rural settlement (Roux and Courty 2007, 2013). At one level, the household production of "rural Indus" tradition, *Vessels-a,* was observed, which provides a weaker sense of 'classic Indus-ness' in the ceramic assemblage in terms of morphologies and surface treatments. The second level is represented by the sophisticated *Vessels-ε* traditions, and the third level is expressed by the "deluxe Indus" tradition. Both the latter ceramic traditions show similarity with ceramics produced or consumed at large Indus settlements such as Farmana or Rakhigarhi. In this regard, this pattern expresses a certain phenomenon of amalgamation and a sense of connection between settlements. Such a phenomenon may occur when groups of producers and their associated social unit interact with each other, especially when learning networks and communities of practices, create and sustain a sense of regional consistency of technological traditions through the borrowing of technological traits of advanced ceramic traditions (e.g. Livingstone Smith 2001; Gosselain 2008). Thus, during most rediscovered occupational phases identified at MSD I trench XK2, the three concurrent ceramic traditions seem to point out that distinct communities of practices, and likely associated distinct social units, have likely inhabited the village and the region, and that long-term interactions may have connected social units within the plains of Haryana.

Overall, *Vessels-a*, *Vessels-ε*, and Vessels-ζ could be considered as being largely contemporaneous at MSD-I, XK2 which seems to discount the possibility of techno-stylistic development over time from one tradition to the other. *Vessels-ε* seem to be the dominant tradition during both main phases of occupations at the site, however, and the Vessels-α tradition appears to be marginally present during the earliest phase of occupation, i.e. Transition from Early to Late Urban phase, and even less frequent during the later phase, i.e. Late Indus Urban phase.

In terms of the extent of the three identified ceramic landscapes, similarities can be suggested with contemporaneous ceramic assemblages:

- **Transition Early-Late Urban (Mature Harappan IIIB):** affinities with Early and Mature Indus ceramics, e.g. Farmana Burial Phase II (e.g. Burial No. 12, 14, No. 21, No. 22, No. 23, No. 29, No. 44, No. 48, No. 50a and 50b, No. 54,); and
- **Late Urban (Mature Harappan IIIC):** affinities with Mature and Late Indus ceramics, e.g. Bara, Late Siswal, Late Harappan, Madina, Bedwa-2, Seman-5 (Dangi 2006b: 31), Farmana, Sanauli, Putti Seman, and Farmana Burial Phase III, (e.g. Burials No. 13, No. 15, No. 16, No. 17, No. 19, No. 33, No. 34, No. 52, No. 66, No. 70), and Harappa Cemetery R-37.

Table 9.3. Simplified summary of identified ceramic traditions, technical groups and petrographic groups from ALM-SC (see Section 8.12).

Ceramic traditions	Associated technical groups	Petrographic groups
Alamgirpur Coarse Ware tradition	CGW and CRW	ALM-D and ALM-E
Indus Bara tradition	FSGW, FSRW, RGW and RRW	ALM-A
Fine Ware tradition	FGW and FRW	ALM-A3 and ALM-A2

9.6 Away from cities: the Indus eastern fringe in the Late Urban period at ALM SC

The techno-petrographic and geochemical analysis of ALM-SC ceramics has shown that vessels could be mostly divided into three main techno-petrographic groups (see Chapter 8). Each of the observed techno-groups show certain correlations with distinctive technical groups and petrographic classes, and suggested the use of a variety of clay paste recipes as well as combinations of manufacturing techniques (see Table 9.3). The technological practices which characterise the three identified techno-petrographic groups at ALM-SC provide evidence for different communities of producers.

The *Indus Bara Tradition* at ALM-SC make up the majority of the ceramic corpus from trench EA at LHR I. This group is characterised by a complex combination of technical actions and surface treatments, and resulted in high quality products, which also bear evidence for a remarkably advanced control over the production process. Typologically, this group include a variety of open and closed shapes, showing a certain level of consistency in terms of reproduction over time, suggesting high levels of skills and within a single ceramic traditions. The morphologies of vessels of the *Indus Bara Tradition* includes distinctive shapes, such as certain globular storage jars with distinctive long necks and outflaring rims, dishes, bowls, and vessels with a finer-grained applied rustication. Petrographic and geochemical observations confirmed that they were likely produced using similar clay available in the region, the plains of the modern Ganga-Yamuna doab, or even in close proximity to the settlement, as the majority of recovered ceramic materials.

The *Alamgirpur Coarse Ware* at ALM-SC make up a minor portion of the ceramic corpus from trench EA at LHR I. This group is characterised by a simpler combination of technical actions and surface treatments compared to the *Indus Bara Tradition*, and is associated with lower quality products. Likely due to the high friability of these ceramics, it was problematic to reconstruct the morphologies of these vessels, which may have included bowls and possibly some closed shapes. Petrographic and geochemical observations confirmed that they were likely produced using distinctive recipes, but the raw clay may have been similar to the clay used in the production of *Indus Bara Tradition,* largely available in the region.

The *Fine Ware* tradition at ALM-SC make is quite rare in the assemblage. This group is characterised by a complex combination of technical actions and limited surface treatments, and resulted in high quality products, which also bear evidence for good control over the production process. Typologically, this group include a small variety of open and closed shapes. Petrographically, this group suggests the use of a finer paste (MSD-E) and possibly a different source of clay, yet showing similarities with the broader alluvial clay identified in the more common and broader petro-class ALM-A. Given the limited number of sherds, the these vessels could be considered as an anecdotal, exogenous ceramic tradition.

The picture of social complexity associated to ceramic production emerging from the variability of the assemblage from ALM-SC can be understood through patterns of technological heterogeneity and compositional homogeneity (cf. Roux and Courty 2007, 2013; Roux 2016). The identification of Alamgirpur Coarse Ware tradition, Indus Bara tradition, and Fine Ware tradition indicates the presence of a small number of ceramic traditions at the settlement. These ceramic traditions appears to belonged to producers sharing a specific corpus of technical knowledge and skills, who likely belonged to three distinctive social units. The producers of the Indus Bara tradition appear to have been the most dominant and characteristic of the Alamgirpur settlement, used a complex combination of manufacturing techniques, and likely belonged to a specific social unit or group. The two other ceramic traditions discussed above, the Alamgirpur Coarse Ware tradition and the Fine Ware tradition, seem to be less recurrent at the site. The poorer quality of products associated with the Alamgirpur Coarse Ware tradition could be likely explained by the presence of the less skilled producers within this lineage, who may have convinently used less time to learn and produce such objects. However, the high quality product of the Fine Ware tradition, likely a non-recurrent, rare, exogenous ceramic tradition, may just be explained by the sporadic movement of goods or people into the village of Alamgirpur. These hypotheses might suggest the circulation of 'imported' containers into the rural settlement, as well as the presence of more or less skilled producers.

In terms of technological observations, at Alamgirpur the identified ceramics mostly were formed using a combination of more of less sofisticated methods. Different forming techniques interlock and seem to have been known, transmitted and used over a long chronological trajectory in the region. Overall, coiling, rotational devices, and RKE finishing techniques seem be frequently emploied. Coiling as a primary forming technique seems to be particularly enduring at the site, and it was likely adopted by generations of potters. Nonetheless, not all ceramic materials underwent such forming process. For instance, the use of the RKE for finishing vessels does not seem to be the sole final forming method at the site. Such is the case of the Coarse Wares (CGW and CRW), which show evidence for preliminary coiling forming methods, but likely underwent a final scraping process with limited to no use of RKE.

In terms of compositional observations, raw materials and provenance of vessels, when looking for clay sources of archaeological ceramics, especially bricks, it is generally accepted that argillaceous materials and temper were collected in close proximity to the site of manufacture (Tite 1999). Such assumption is based on ethnographic observation of ceramic workshops among sedentary communities (Arnold 1985: 32-60). Even though this scenario is not applicable to all cultural contexts, long distance transport of raw clay was probably a rare exception in protohistoric or prehistoric communities (Quinn and Burton 2016). Thus, despite the abundant presence of sedimentary clays surrounding the mound of Alamgirpur, copious in the Ganga-Yamuna doab, knowledge regarding the most suitable clay deposits for the manufacture of ceramic materials was crucial. Considering the consistency of the fine and coarse ware production at the site over time, this vernacular knowledge appears to have been carried through generations at the site. The durability of such a specific knowledge across archaeological periods can be better understood through the notion of *persistent places*, which is 'used to interpret spaces within the territory that are continuously occupied through time, regardless of the cultural changes taking place in them' (Albero-Santacreu 2016: 64).

A clear understanding of the properties of the temper used by local potters could be inferred by the varieties of recipes used for producing not only different types of pottery, but also different portions of a single vessel. In fact, coarse pastes were used for the production of the Coarse Ware (techno-group CRW and CGW), and also for producing a slurry that was applied on the Indus Bara vessels (i.e. metamorphic rustication, technical groups RRW and RGW, see above *Figure 8.15*). The latter group shows a very fine fabric which characterises each vessel; however, the exterior surface was usually roughened by a thick layer of coarse slip, remarkably similar in terms of composition and size of inclusions to the clay paste used for the production of the CGW and CRW.

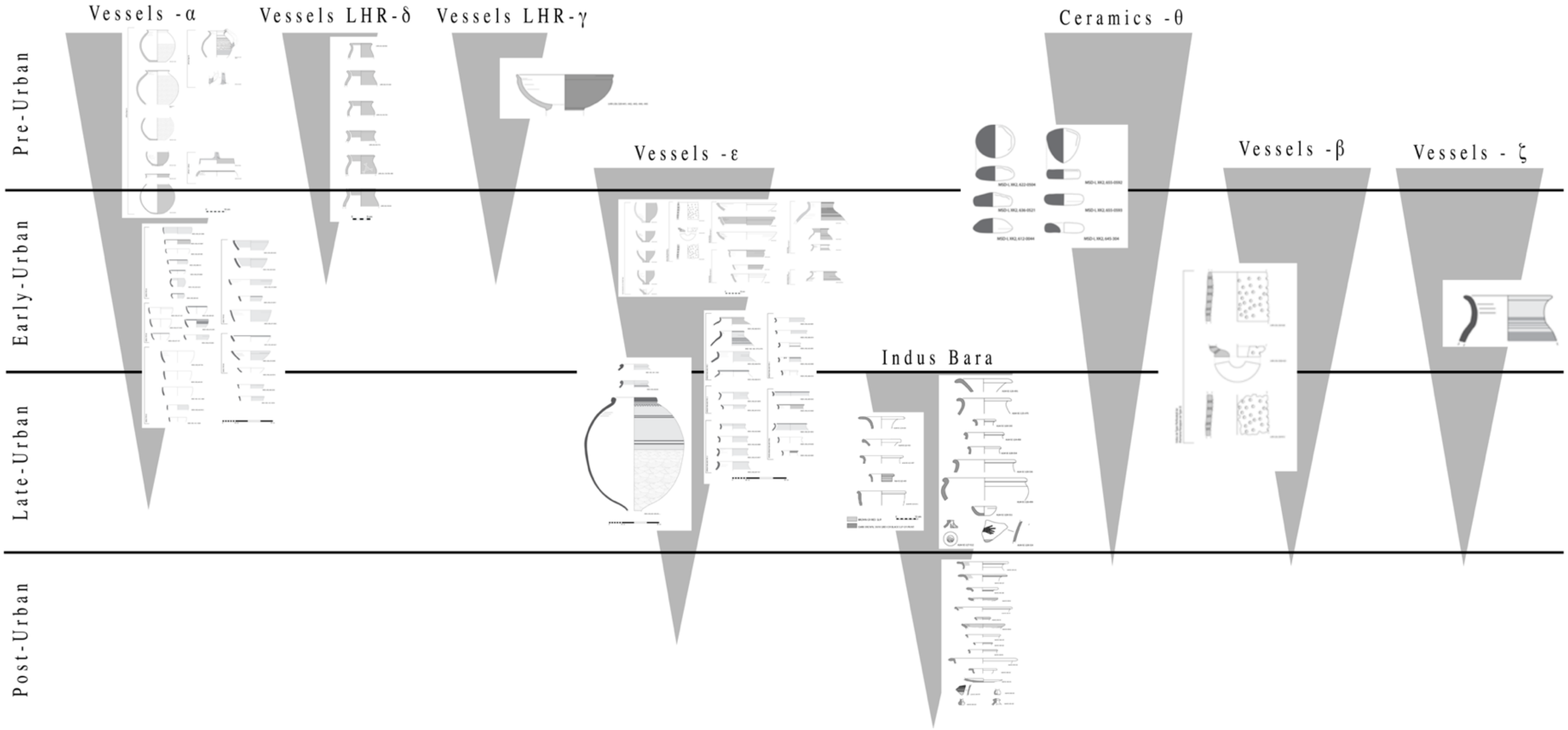
A special note could be presented here concerning the frequent applied rustication observed on vessels at ALM-SC. The use of applied coarse slurry as a surface treatment has already been discussed (see Chapters 6, 7, and 8), including its possible function on storage jars and cooking vessels . Similarly, it is likely that potters at Alamgirpur prepared a coarse paste for forming cooking vessels and designed them to be thermally stress resistant (Braun 1983; Muller et al. 2013, 2016). Thermal shock resistance was probably adequate for coarse tempered ceramics (Alamgirpur Coarse Ware, techno-groups CRW; CRW) when exposed to the temperatures expected for cooking processes (Schiffer et al. 1994; Tite and Kilikoglou 2002; Muller et al. 2013). A possible interpretation is thus related to the necessity to improve the thermal properties of storage vessels and cooking vessels (Rice 1987: 232; Petrie 2010: 82-83). The coarse slip is also believed to keep liquids better preserved from warm climate conditions, and therefore facilitating the storage of cool liquids. As mentioned, a similar technology has been documented at LHR-I and MSD-I, but also at Sheri Khan Tarakai, Bannu basin, Pakistan; Jalipur I in Cholistan (Khan et al 1991: 39); and on cooking vessels from Ravi Phase, Harappa, Punjab, Pakistan (Kenoyer and Meadow 2000). Another possible interpretation is directly connected to the shape of the roughened vessels and the location of the slurry. It is possible that the rustication on globular Indus Bara vessels served a mechanical function, allowing a better grip for moving safely the jars, and also improving the robustness of the vessels, constantly exposed to the friction between the base and the ground. In the latter case, potters might have had to increase the thickness of the whole vessel to obtain a similar result, which would have also resulted in much heavier storage vessels and higher chance of breakage during and after firing; however, the rustication provides a supplementary protection from mechanic damages and better grit at specific portion of the vessels, without undesirable side effects. The mentioned sites of Sheri Khan Tarakai and Jalipur seem to show similarities in ceramic industries, at least concerning surface treatment during very early stages of occupation; nevertheless, such evidence is neither suggestive of direct or indirect transmission of knowledge, nor long distance exchanges or trades. In fact, rough slurry in South Asia, during different chronological periods, have been produced using a large variety of processes and materials (Petrie 2010: 415), and therefore it is only suggestive of a widespread and variable technique for storing and preserving liquids, protecting vessel surfaces against mechanical friction, improving grit and possibly thermal resistance. It is noteworthy to mention that the production of pottery with applied rustication, especially Bara types, seems to be particularly enduring at Alamgirpur, and the essential manufacturing knowledge appears to have been transmitted throughout the whole chronological sequence observed at ALM-SC.

In summary, ceramics from Alamgirpur helped to understand variabilities of ceramic industries at an Indus village-size settlement away from the direct influence of an urban centre (e.g. LHR-I and MSD-I in close proximity to Rakhigarhi). The Indus Bara tradition seems to be the dominant industry here. The sequence of actions associated with these ceramic traditions, as well as knowledge and skills necessary for crafting vessels at Alamgirpur, were consistently transmitted from the Urban period to the Post-Urban Indus occupational phases. On one hand, ceramic recipes and technologies of the Urban period appears continued in subsequent phases; on the other hand, it was also observed the presence of new set of technologies during the Post-Urban period. Similarities and dissimilarities between the traditions identified shall be discussed in the following section.

9.7 A unified view: Indus ceramic landscapes and regional networks

The above presented study of the ceramic assemblages from three sites, which combined macroscopic observations with techno-petrographic and geochemical data, dated from Pre-Urban to the Late Urban periods, suggests the existence of relational links between the Indus rural assemblages and producers. As previously discussed, *Chaînes opératoires* can be presented as robust evidence to socially connect Indus settlements of northwest India and reveal social units and social structures. Rural Indus *chaînes opératoires* can be considered as attributes and indicators of relational structure within societies at villages and at a regional scale, especially considering regular similarities and differences of manufacturing techniques as well as typologies (see Östborn and Gerding 2014 , p. 87, 2014; Roux 2019e). The technological analysis of Indus ceramic assemblages at LHR-I and MSD-I reveals that three similar *chaînes opératoires*, from the clay preparation to the firing, was shared at the regional scale (namely the 'ancestral rural' LHR+MSD *Vessels-a* tradition, the 'refined rural' LHR+MSD *Vessels-ε* tradition, and the 'deluxe' LHR+MSD *Vessels-ζ* tradition).

Figure 9.1 Suggested diachronic development of ceramic traditions indentified at LHR-I and MSD-I. The Indus Bara tradition from ALM-SC is also here presented.

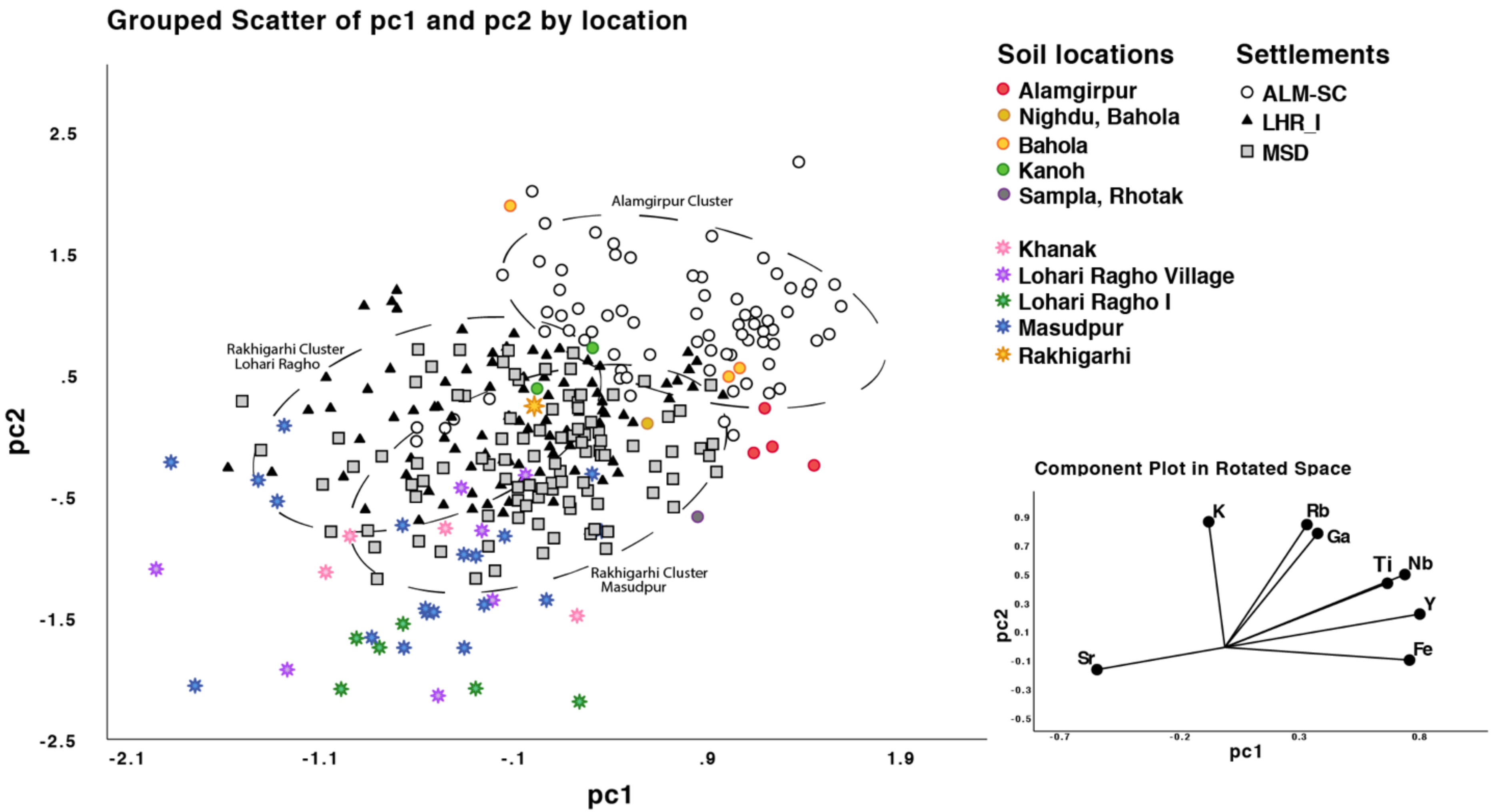


The shared ceramic traditions testify three distinctive social groups, within which they have been reproduced and transmitted. They show significant technological similarities and differences, suggesting intentions of social diversification between the contemporaneous groups, while still influencing each other. Technological boundaries have been maintained over centuries, which also suggest the consistence maintenance of social boundaries through strong social ties within each group, such as possible endogamous marital alliances.

The regional networks of producers and consumers reconstructed here seem to point out a complex picture of communities of practices, within three main ceramic landscapes identified in the area around Rakhigarhi (see Figure 9.1). *Vessels-a*, the ancestral rural tradition, was associated with more sedentary social units or household networks and seems to have been the dominant industry in the Pre-Urban period, developing during the Early Urban period, and gradually contracting during the Late Urban period. This expanding and contracting rural tradition was sustained by producers who were mindful of the existence of several other contemporary ceramic traditions in the region. Yet, they remained consistent within their own technical actions, vessels' morphologies, simpler surface treatments and modest decorations. This could be understood as a statement itself of mindful diversification, deciding not to adopt innovations, other regional techniques, styles or morphologies. Ties of kinship, to varying degrees, may have united the individuals forming this rural social unit of the studied region, explaining the embedded social network.

Variable traits and variants within and between settlements over centuries, may point out the spatial distribution and splitting of social units over time. In order to observe developments and splitting of networks, technical variability, similarities and differences in ceramics between settlement should be considered as evidence for social interactions (see Roux 2019). Given their common traits, the 'refined rural' *Vessels-ε tradition* could be seen as deriving and developing from a common ancestral tradition shared with the *Vessels-a* tradition. *Vessels-ε* seem to dominate the settlements in the Early Urban and Late Urban phases, while overlapping with other regional ceramic industries and likely influencing each other. In terms of morphologies within this rural refined tradition, there is a sense of affinities with classic Indus ceramics in the macro-region (e.g. Farmana and Rakhighari). However, despite similarities, the producers of *Vessels-ε* appear to keep their own identity: whether this is a mindful choice of the community or a lack of possibilities to reach the same level of sophistication as Indus deluxe industries, it will not be further discussed here.

Figure 9.2 Combined grouped scatter of geochemical data presented in Chapter 5, 6, 7 and 8. Two clear clusters emerge, the (Alamgirpur ceramics, and the Rakhigarhi cluster. This latter cluster shows two trends which correlate with the LHR and MSD ceramics. A few soil samples seem to show a match with the compositional fingerprint of ceramics (see details provided in each chapter).



The *Vessels- ε tradition* is found associated with the production of unique shapes, such as transport jars and large storage jars, suggesting tendencies to store, move and exchange within their material record. In this respect, this rural refined tradition could be associated with a sense of mobility or nomadic behaviour, which may have contributed to the establishment of distinctive social mechanisms for the sustainability and reproduction of traditions across the region, but also to a higher degree of regional influences. Given its chronological continuity across occupational phases at the studied settlements, strong technological and social boundaries within this community can be suggested, as well as a strong sense of belonging and identity among the producers of *Vessels-ε*. This tradition appears to have been established already at the early stages of occupation at LHR-I. However, it seems to have consolidate further in subsequent occupational phases at MSD-I, also providing a sense of technological and stylistic development. This tradition seems to show a higher degree of resilience and transformation at LHR-I and MSD-I, possibly associated to a solid network of skilled potters. Social relationships such as endogamous marital allegiances within this group may explain the prolonged transmission of this tradition, also considering the suggested hypothesis of higher mobility across the landscape or nomadic behaviour associated with this industry.

A third tradition, a particularly sophisticated one, was rarely present at the studied Indus villages. The high level of sophistication of Vessels-ζ provided a glimpse into learning mechanisms and social interactions between and among communities. The producers of the 'deluxe' Vessels-ζ were possibly trained in a different environment, where they had the possibility to developed advanced skills and had the time and resources to sustain the productions of sophisticated objects. This may suggest the presence of specialised workshops at certain settlements, such as large-size settlements or dedicated centres of production within the region. However, due to lack of data from specialised workshops or large-size settlements, this hypothesis will not be further discussed here.

In terms of chronological development, the period from the Early-Late Urban transition to the Late Urban phase seems to be particularly interesting, due to the contraction and reduction of production of Vessels-α, possibly a household industry due to its high degree of quality and skills variability, thus likely marking the end of an ancestral household production of ceramics. This tradition was previously found earlier contexts, i.e. Pre-Urban and Early Urban phases, at LHR I (see Chapter 5). The sophisticated Vessels-ε seem to be more resilient, perhaps due to the nature of the strategies and social networks of the groups producing and consuming these vessels, which was also linked to a more skilled community of producers and stronger social ties.

Finally, ceramics from Alamgirpur offered the opportunity to explore the phenomenon of rural stylistic variability almost 150 km away from the Rakhigarhi area, Masudpur and Lohari Ragho. At Alamgirpur ceramic products still bear a flavour of 'Indus-ness', in terms of manufacturing techniques, surface treatments, and decorative styles. Most of the sequence of actions required for producing Indus Bara vessels appear to be similar to the *Vessels-ε* industry, including the surface treatments and painted decorations. However, a significant difference was noticed within morphologies and classes of vessels. These seems to show a distinctive eastern character, bearing morphological similarities with traditions identified at sites such as Bara and Ropar. Even though direct sharing of technical knowledge could not be here suggested within the macro-region, especially between producers at MSD-I and ALM, identity statements and diversification of intersecting social units are clearly present (see Figure 9.2 and 9.3).

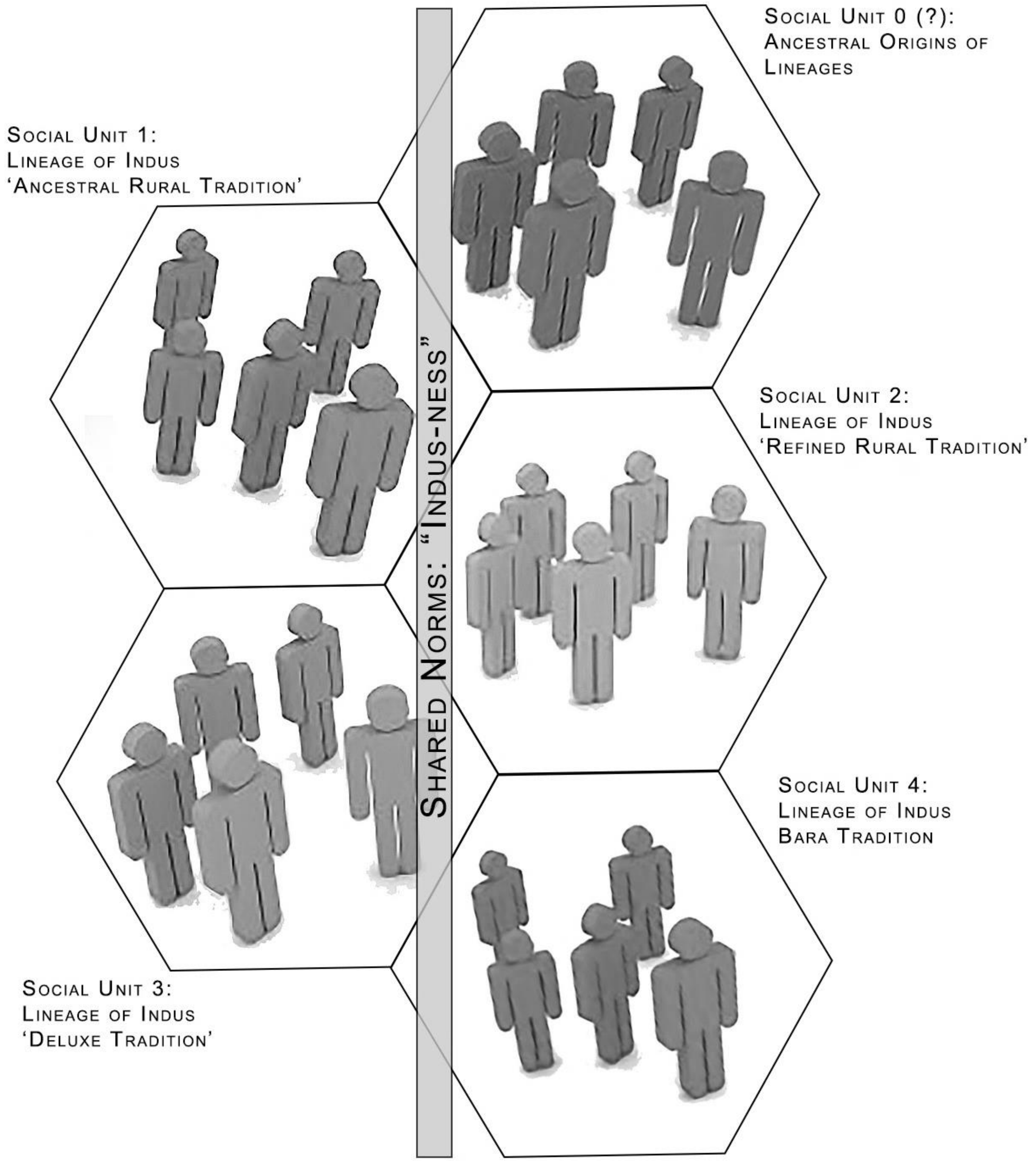
A combination of archaeological, ethnoarchaeological and geoarchaeological observations, and satellite imagery contributed to understand the compositional characterisation of ceramics (see Chapter 5). No similarities between the ancient ceramic traditions and the modern can be found; however, the ethnographic study was particularly useful for identifying clay sources in the region and their properties. Possible locations of clay sources used in the production of ceramics were tentatively suggested per each site (see Chapter 6, 7, and 8), and the broader regional picture becomes clearer when all the compositional data are presented in an integrated fashion. Figure 9.2 shows the statistical analysis of all the available geochemical data. Two clear clusters emerge from the integrated analysis of soil samples and archaeological data, with the eastern ceramics showing a distinctive chemical fingerprint from those recovered in proximity to the urban site of Rakhigarhi. The Alamgirpur cluster shows a good match with local clay samples from alluvial deposits. The Rakhigarhi cluster shows two slightly diverging trends, correlating to the LHR-I and MSD ceramics. This latter cluster shows a good match with local clay samples collected in proximity to the palaeo-channel identified near the settlements of LHR-I and MSD (see Chapter 5, 6 and 7).

Data presented in Figure 9.2 further reinforces the theory of multiple production sites located in different regions, i.e. the area surrounding Rakhigarhi hinterland, the plains of Haryana, and the Alamgirpur hinterland, the Gangetic Hindon sector in the Meerut District. This likely suggests the use of raw materials conveniently collected in proximity to the studied sites. Moreover, the LHR-I and MSD trends within the nearly homogeneous Rakhigarhi cluster may suggest the possible compositional variability of the available clay sources used over time in proximity to the site. Therefore, the above observations contribute to move away from the hypothesis of large scale centralised systems of ceramic production, and well fit a theory of multiple smaller scale industries in different regions.

A special note could be here made about the emergence of shared norms among multiple social units, which form the larger Indus regional network. The presence of multiple, shared synchronic traditions at both LHR-I and MSD-I suggest that distinct social communities inhabited or visited the settlements at a given point in time. This suggests that the broader variability of large social networks living in the region was likely made of multiple distinctive social groups (see Backstrom et al 2006), each of them characterised by strong social ties and mixing population (see Centola and Baronchelli 2015). The network structure that is proposed for the studied region promotes the emergence of shared social norms, and it ensures links between individuals.

Through self-sustained social networks, shared norms and conventions can spontaneously emerge in complex decentralised systems, without centralised control, when there are groups characterised by mixing population and multiple interactions within network structures (e.g. Centola and Baronchelli 2015). Therefore, it is possible to suggest that the shared Indus norms or conventions may have emerged as the result of larger network connectivity, without any centralised control, coordinated leadership, or large-scale management (see Figure 9.3). By analogy with the above mentioned sociological model, through prolonged interactions, without any top-down coordination, it is possible to observe the emergence of shared beliefs and conventions. This would be possible if the social units were intensively interacting, and the boundaries of each group were well defined, yet being fluid and porous. As discussed above, certain specific technical, typological or stylistic similarities within the distinctive traditions and social units could thus be interpreted as a spontaneous effort to maintain a trans-cultural shared corpus of beliefs, as a broader statement of identity and belonging to a larger group – a sense of 'Indus-ness'.

Figure 9.3 Simplified schematic representation of social units and associated lineages of producers. It suggests that shared norms (or a broader shared sense of 'Indus-ness') are sustained and reproduced through decentralised embedded social networks. Here social units and lineages do not replace each other, but coexist and influence each other.



9.8 Answering the research questions

What ceramic technological choices and traditions was the Indus rural context characterised by?

The three dominant ceramic traditions in the Rakhigarhi rural context (i.e. the rural household tradition, the rural refined tradition, and the Indus deluxe industry), and the eastern Indus Bara tradition are here presented as physical manifestations of four porous, fluid social landscapes. Each of these landscapes was sustained by a social unit, including producers, which claimed to be different from other social groups, making their own identity statements, yet being connected via social interactions. A degree of shared knowledge was observed, as well as the effort to sustain their own social boundaries and reproduction within each social unit.

Were rural ceramic industries in the Urban period sustained by a centralised system of production, or by multi-layered self-sustained horizons of traditional practices?

Synchronically, data and results presented in Chapter 6, 7, and 8, as well the above interpretations have shown a complex picture of interlocking systems of production in the studied region. The observed variability at each studied settlement, as well as the perception of a diverse multi-layered system of ceramic landscapes, allowed moving away from 'older' representations of homogeneous ceramic industries within the Indus zone. Each explored ceramic tradition seems to have been self-sustained and strongly connected to their distinctive physical dimensions, e.g. households at villages and their environment, within defined social boundaries. The reconstructed traditions seem likely to have been sustained and reproduced by communities aware of their differences, which have been influenced by broader regional networks to different extents, but kept their own distinctive meaningful features. This complex picture of self-sustained rural traditions, however, neither reinforces nor rejects arguments concerning possible specialised skilled producers at large-size urban settlements, whose production systems may have been influenced by their particular urban social structure.

Did ceramic industries develop or collapse during the Indus early Urban and late Urban periods?

Diachronically, the reconstructed Indus ceramic landscapes seem to have been influenced by broader phenomena affecting the region, but the historical continuity of Indus Civilisation rural traditions seems to have been somehow independent from the socio-political narratives at urban settlements. On one hand, at LHR-I the 'ancestral rural domestic tradition' appears to have been present in the region well before the peak of urban settlements, and its continuity have been perceived until the Late Urban period at MSD-I. On the other hand, the producers associated to the 'rural refined tradition' seem to have been more directly connected to broader narratives and may have more consistently interacted with producers across the region, including at large-size settlements. Similar is the case of the producers of the 'Indus Bara tradition' in the eastern frontier of the Indus zone. Despite the broader connections to a more extensive network of producers, these two latter traditions seem to show a high degree of technological resilience. In fact, their corpus of skills and knowledge was reproduced beyond the eclipse of urban settlements in the Indus zone, and appear to be still vibrant during the Post-Urban period. The mechanisms responsible for the sustainability across centuries of these rural traditions may be correlated to the nature of the relational landscape characterising and connecting rural producers within their social units. In other words, the mechanisms responsible for creating and sustaining the social landscape within which potters crafted their distinctive products may have been also responsible for the continuity of rural industries beyond the so-called 'collapse' of urban settlements. However, it is interesting to note that the rural refined tradition, here associated to community showing more mobile and nomadic lifestyles, seems to have been the most adaptable and resilient in the face of changes happening during the Late Urban period.

Chapter 10. Conclusions and future research

This thesis has successfully employed an holistic approach for the study of a multi-site dataset of archaeological ceramics to explore the complex system of social units, relational landscapes and ceramic traditions characterising the studied region. This was used to explore social dynamics and structure, and to trace evidence for continuity and changes in Bronze Age northwest Indian societies.

The techno-compositional study of LHR I, MSD-I and ALM ceramics has been particularly useful for describing the ceramic corpus in order to identify complex technological traditions, communities of practice and social networks. On the one hand, this approach helped to better characterize occupational phases and related production and consumption of specific ceramic products. This will hopefully have an impact on future reassessment of cultural horizons across sites identified in the region. On the other hand, this approach helped to identify multiple layers of social groups, as well as the interactions at the site and in the wider region of coexisting communities.

The combination of techno-compositional data with morpho-stylistic attributes has helped to identify practices that have functional and socio-cultural values distinctive of each studied phase. There appears to be a greater sense of variability and diversity within assemblages that would have been otherwise interpreted as being excessively homogeneous. A glimpse into the great diversity in technological practices across the plains of Haryana and the Ganga-Yamuna doab has also perceived on both the diachronic and synchronic axis. An increased level of sophistication and skills during the later phase of occupation excavated at LHR I was identified, associated with an increased variability in ceramic traditions. At LHR I communities seem to developed a stronger shared corpus of knowledge, identities and social boundaries, as demonstrated during the later phases of occupation at LHR I.

At MSD from the Transitional Early-Late Urban phase to the Late Urban phase, it was possible to observe a phenomenon of contraction of an ancestral ceramic landscape within the rural context, parallel to the development of more sophisticated regional traditions. At LHR (see Chapter 6), it was presented how the ancestral household production of vessels whiteness the parallel development of a more sophisticated tradition of pottery making. Both traditions seem to have been kept alive at rural settlements, coexisting and likely being associated with overlapping social groups and boundaries. Here it was suggested the existence of at least two social groups, a more permanent group associated with household variability of ceramic production; and a social group associated with possible mobility or nomadic behaviour (Petrie et al, 2017: 21; Petrie and Lynam, 2019: 6) and with the production of more sophisticated vessels partially influenced by broader Indus productions. The latter group was likely exposed to the regional variability of ceramic industries, which included the production of deluxe black-on-red Indus vessels at large scale sites, rarely found at villages. Perhaps the more sophisticated vessels produced by this more mobile group were somehow correlated to the need to sustain stronger social ties. During the Late Urban period, rural refined vessels appear to be more resilient and become the dominant tradition, while the rural ancestral vessels tradition seems to decline. This is somehow a picture diametrically opposed to what was observed from the Pre-Urban to the Early Urban period at Lohari Ragho I.

Away from the urban centre at Rakhighari, the settlement at Alamgirpur provided data concerning a possible derived, later traditions of pottery making. The dominant Indus Bara tradition identified at the settlements show a number of technological similarities, but also compositional, stylistic and morphological difference with traditions identified in the plains of Haryana, which may also suggested possible ancestral common origins. The Indus Bara Tradition seems to be produced during the Late Urban period and during the Post-Urban period, which offered a perception of continuity of the lineage of producers beyond major climatic, environmental, and socio-political transformations.

The observed ceramic landscapes, two rural and possible one deluxe urban industry within the plain of Haryana and one major rural industry at Alamgirpur, could be further explored to understand the function and cultural significance of Indus sites within the region. Moreover, the use of this approach for the study of ceramic assemblages at other sites in the same region and beyond may help to better characterise the phenomenon of seasonal mobility across the landscape and interaction among communities. The network structure that was proposed for the studied region likely promoted the emergence of shared social norms, and it ensured links between individuals. It was suggested that the shared Indus norms or conventions may have emerged as the result of larger network connectivity, without any centralised control, coordinated leadership, or large-scale management (see Figure 9.4). As discussed above, certain specific technical, typological or stylistic similarities within the distinctive traditions and social units could thus be interpreted as a spontaneous effort to maintain a trans-cultural shared corpus of beliefs, as a broader statement of identity and belonging to a larger group – a sense of 'Indus-ness'.

The integrated ethnographic study was particularly useful to better understand the interaction between producers and the landscape, to gain a better perception of variable clay sources in the region, and the explore social structural mechanisms responsible for the continuity and resilience of rural traditions. In particular, the combined data from satellite imagery, geoarchaeology and ethnographic work was valuable to characterise the soil diversity and availability of raw materials. The ethnographic study was also useful to deconstruct theories concerning direct histories and direct continuity from the Bronze Age to contemporary South Asia.

The possible future trajectories would be to use this newly identified traditions to reassess available archives and datasets, and to expand the datasets used in this thesis with samples from other sites and periods. This thesis has found that a range of ceramic technologies, techniques and crafts traditions shaped the social landscapes of complex industries, which were reproduced and transformed across the long trajectory of the Indus social development. Certain degrees of similarity were observed in both synchronic and diachronic perspectives, which contributed to the perception of a broad sense of Indus identity in the rural context. However, beyond the apparent uniformity, the rediscovery of diverse systems of production has made it possible to gain an understanding of multiple groups of pottery producers living in the region through the rise and decline of urbanism in the studied region. This has led to a number of further research questions, for instance: *How did crafting communities of northwest India reorganise themselves after the de-urbanisation of the Indus cities? How did crafting communities adapt and transform after the end of the first urbanism and with the rise of the second phase of urbanism in the region?*

Moving away from linear narratives of homogenous systems of production and yet to be verified assumptions on historical continuity/discontinuity before, during, and after the deurbanisation process of the Indus Civilisation, and making use of a bottom-up approach, post-Indus and Early Historic sites could be used to build up a debate concerning variable technological choices and adaptability in the face of major political and environmental transformations. Results could provide direct insight into the chronological and historical relationship between the *Indus Post-Urban*, or Late Harappan period, and the subsequent phases of occupations in northwest India, e.g. *PGW* and *Early Historic* periods.

Another possible future trajectory could be to integrate more data from urban sites, or from pre-Indus sites. One the one hand, this would help us to better understand the difference between the rural and urban dynamics. On the other hand, this could help clarify the origins and development of the complex systems of ceramic traditions and social units that have been identified during the Indus Early Urban and Urban phases.

Appendix A: Samples

Table A1. Sample list and thin-section (TS-L) numbers from Lohari Ragho I.

TS-L-	Site	Trench	Context	Sherd	Ts Orientation	Photo	Powder Sample
1	LHR-I	EA	508	5	Vertical	Yes	4.5 grams
2	LHR-I	EA	508	7	Vertical	Yes	4.5 grams
3	LHR-I	EA	508	20	Vertical	Yes	4.5 grams
4	LHR-I	EA	508	23	Vertical	Yes	4.5 grams
5	LHR-I	EA	508	30	Vertical	Yes	4.5 grams
6	LHR-I	EA	508	37	Vertical	Yes	4.5 grams
7	LHR-I	EA	508	43	Vertical	Yes	4.5 grams
8	LHR-I	EA	518	49	Vertical	Yes	4.5 grams
9	LHR-I	EA	518	58	Vertical	Yes	4.5 grams
10	LHR-I	EA	518	87	Vertical	Yes	4.5 grams
11	LHR-I	EA	518	88	Vertical	Yes	4.5 grams
12	LHR-I	EA	518	93	Vertical	Yes	4.5 grams
13	LHR-I	EA	518	98	Vertical	Yes	4.5 grams
14	LHR-I	EA	518	102	Vertical	Yes	4.5 grams
15	LHR-I	EA	518	108	Vertical	Yes	4.5 grams
16	LHR-I	EA	518	109	Vertical	Yes	n/a
17	LHR-I	EA	515	214	Vertical	Yes	4.5 grams
18	LHR-I	EA	515	218	Vertical	Yes	4.5 grams
19	LHR-I	EA	515	239	Vertical	Yes	4.5 grams
20	LHR-I	EA	515	240	Vertical	Yes	4.5 grams
21	LHR-I	EA	515	241	Vertical	Yes	4.5 grams
22	LHR-I	EA	515	242	Vertical	Yes	4.5 grams
23	LHR-I	EA	515	245	Vertical	Yes	4.5 grams
24	LHR-I	EA	515	256	Vertical	Yes	4.5 grams
25	LHR-I	EA	515	268	Vertical	Yes	4.5 grams
26	LHR-I	EA	515	283	Vertical	Yes	n/a
27	LHR-I	EA	515	289	Vertical	Yes	4.5 grams
28	LHR-I	EA	515	290	Vertical	Yes	4.5 grams
29	LHR-I	EA	515	291	Vertical	Yes	4.5 grams
30	LHR-I	EA	515	303	Vertical	Yes	4.5 grams
31	LHR-I	EA	515	304	Vertical	Yes	4.5 grams
32	LHR-I	EA	515	313	Vertical	Yes	n/a
33	LHR-I	EA	515	322	Vertical	Yes	4.5 grams
34	LHR-I	EA	515	323	Vertical	Yes	4.5 grams
35	LHR-I	EA	515	327	Vertical	Yes	4.5 grams
36	LHR-I	EA	515	342	Vertical	Yes	4.5 grams
37	LHR-I	EA	515	346	Vertical	Yes	n/a
38	LHR-I	EA	520	359	Vertical	Yes	4.5 grams
39	LHR-I	EA	520	372	Vertical	Yes	4.5 grams
40	LHR-I	EA	520	391	Vertical	Yes	4.5 grams
41	LHR-I	EA	520	400	Vertical	Yes	4.5 grams
42	LHR-I	EA	520	401	Vertical	Yes	4.5 grams
43	LHR-I	EA	520	402	Vertical	Yes	4.5 grams

44	LHR-I	EA	520	407	Vertical	Yes	4.5 grams
45	LHR-I	EA	520	408	Vertical	Yes	4.5 grams
46	LHR-I	EA	520	414	Vertical	Yes	4.5 grams
47	LHR-I	EA	520	422	Vertical	Yes	4.5 grams
48	LHR-I	EA	520	428	Vertical	Yes	4.5 grams
49	LHR-I	EA	520	429	Vertical	Yes	4.5 grams
50	LHR-I	EA	520	433	Vertical	Yes	4.5 grams
51	LHR-I	EA	520	436	Vertical	Yes	4.5 grams
52	LHR-I	EA	520	437	Vertical	Yes	4.5 grams
53	LHR-I	EA	520	440	Vertical	Yes	4.5 grams
54	LHR-I	EA	520	448	Vertical	Yes	4.5 grams
55	LHR-I	EA	520	455	Vertical	Yes	4.5 grams
56	LHR-I	EA	520	458	Vertical	Yes	4.5 grams
57	LHR-I	EA	520	465	Vertical	Yes	4.5 grams
58	LHR-I	EA	520	478	Vertical	Yes	4.5 grams
59	LHR-I	EA	520	482	Vertical	Yes	4.5 grams
60	LHR-I	EA	520	483	Vertical	Yes	4.5 grams
61	LHR-I	EA	520	489	Vertical	Yes	4.5 grams
62	LHR-I	EA	520	494	Vertical	Yes	4.5 grams
63	LHR-I	EA	520	495	Vertical	Yes	4.5 grams
64	LHR-I	EA	520	497	Vertical	Yes	4.5 grams
65	LHR-I	EA	520	499	Vertical	Yes	4.5 grams
66	LHR-I	EA	520	502	Vertical	Yes	4.5 grams
67	LHR-I	EA	520	506	Vertical	Yes	4.5 grams
68	LHR-I	EA	520	532	Vertical	Yes	4.5 grams
69	LHR-I	EA	520	547	Vertical	Yes	4.5 grams
70	LHR-I	EA	520	549	Vertical	Yes	4.5 grams
71	LHR-I	EA	520	550	Vertical	Yes	4.5 grams
72	LHR-I	EA	520	556	Vertical	Yes	4.5 grams
73	LHR-I	EA	520	561	Vertical	Yes	4.5 grams
74	LHR-I	EA	520	565	Vertical	Yes	4.5 grams
75	LHR-I	EA	520	566	Vertical	Yes	4.5 grams
76	LHR-I	EA	520	567	Vertical	Yes	4.5 grams
77	LHR-I	EA	521	574	Vertical	Yes	4.5 grams
78	LHR-I	EA	521	576	Vertical	Yes	4.5 grams
79	LHR-I	EA	521	590	Vertical	Yes	4.5 grams
80	LHR-I	EA	521	592	Vertical	Yes	4.5 grams
81	LHR-I	EA	521	602	Vertical	Yes	4.5 grams
82	LHR-I	EA	521	612	Vertical	Yes	4.5 grams
83	LHR-I	EA	521	619	Vertical	Yes	4.5 grams
84	LHR-I	EA	521	620	Vertical	Yes	4.5 grams
85	LHR-I	EA	521	632	Vertical	Yes	4.5 grams
86	LHR-I	EA	538	674	Vertical	Yes	4.5 grams
87	LHR-I	EA	538	678	Vertical	Yes	4.5 grams
88	LHR-I	EA	553	780	Vertical	Yes	4.5 grams
89	LHR-I	EA	520	809	Vertical	Yes	4.5 grams
90	LHR-I	EA	520	810	Vertical	Yes	4.5 grams

91	LHR-I	EA	520	811	Vertical	Yes	4.5 grams
92	LHR-I	EA	520	812	Vertical	Yes	4.5 grams
93	LHR-I	EA	520	814	Vertical	Yes	4.5 grams
94	LHR-I	EA	520	815	Vertical	Yes	4.5 grams
95	LHR-I	EA	520	816	Vertical	Yes	4.5 grams
96	LHR-I	EA	520	818	Vertical	Yes	4.5 grams
97	LHR-I	EA	520	819	Vertical	Yes	4.5 grams
98	LHR-I	EA	520	821	Vertical	Yes	4.5 grams
99	LHR-I	EA	574	1017	Vertical	Yes	4.5 grams
100	LHR-I	EA	572	1083	Vertical	Yes	4.5 grams

Table A2. Sample list and thin-section numbers (TS-M) from Masudpur I

TS-M	SITE	TRENCH	CONTEXT	SHERD	TS Orient	Powder samples	Petro-Class	Petro-Sub-C
1	MSD-I	XK2	612	3	Vertical	5 to 10 grams	MSD-G	MSD-G1
2	MSD-I	XK2	612	9	Vertical	5 to 10 grams	MSD-G	MSD-G2
3	MSD-I	XK2	612	11	Vertical	5 to 10 grams	MSD-G	MSD-G1
4	MSD-I	XK2	612	12	Vertical	5 to 10 grams	MSD-G	MSD-G1
5	MSD-I	XK2	612	13	Vertical	5 to 10 grams	MSD-C	MSD-C
6	MSD-I	XK2	612	14	Vertical	5 to 10 grams	MSD-G	MSD-G3
7	MSD-I	XK2	612	15	Vertical	5 to 10 grams	MSD-G	MSD-G3
8	MSD-I	XK2	612	16	Vertical	5 to 10 grams	MSD-G	MSD-G2
9	MSD-I	XK2	612	30	Vertical	5 to 10 grams	MSD-G	MSD-G2
10	MSD-I	XK2	612	34	Vertical	5 to 10 grams	MSD-E	MSD-E
11	MSD-I	XK2	612	44	Vertical	5 to 10 grams	MSD-A	MSD-A
12	MSD-I	XK2	612	45	Vertical	5 to 10 grams	MSD-A	MSD-A
13	MSD-I	XK2	612	49	Vertical	5 to 10 grams	MSD-B	MSD-B3
14	MSD-I	XK2	612	52	Vertical	5 to 10 grams	MSD-F	MSD-F
15	MSD-I	XK2	612	57	Vertical	5 to 10 grams	MSD-B	MSD-B2
16	MSD-I	XK2	631	70	Vertical	5 to 10 grams	MSD-C	MSD-C
17	MSD-I	XK2	632	86	Vertical	5 to 10 grams	MSD-G	MSD-G1
18	MSD-I	XK2	632	100	Vertical	5 to 10 grams	MSD-G	MSD-G3
19	MSD-I	XK2	641	160	Vertical	5 to 10 grams	MSD-G	MSD-G3
20	MSD-I	XK2	641	186	Vertical	5 to 10 grams	MSD-A	MSD-A
21	MSD-I	XK2	671	193	Vertical	5 to 10 grams	MSD-G	MSD-G3
22	MSD-I	XK2	671	196	Vertical	5 to 10 grams	MSD-G	MSD-G3
23	MSD-I	XK2	671	199	Vertical	5 to 10 grams	MSD-G	MSD-G3
24	MSD-I	XK2	671	201	Vertical	5 to 10 grams	MSD-G	MSD-G3
25	MSD-I	XK2	671	202	Vertical	5 to 10 grams	MSD-G	MSD-G2
26	MSD-I	XK2	685	231	Vertical	5 to 10 grams	MSD-G	MSD-G3
27	MSD-I	XK2	685	232	Vertical	5 to 10 grams	MSD-G	MSD-G3
28	MSD-I	XK2	685	233	Vertical	5 to 10 grams	MSD-G	MSD-G2
29	MSD-I	XK2	685	234	Vertical	5 to 10 grams	MSD-G	MSD-G3
30	MSD-I	XK2	685	236	Vertical	5 to 10 grams	MSD-G	MSD-G3
31	MSD-I	XK2	685	237	Vertical	5 to 10 grams	MSD-G	MSD-G3
32	MSD-I	XK2	685	238	Vertical	5 to 10 grams	MSD-G	MSD-G3
33	MSD-I	XK2	685	240	Vertical	5 to 10 grams	MSD-G	MSD-G3
34	MSD-I	XK2	685	245	Vertical	5 to 10 grams	MSD-G	MSD-G2

35	MSD-I	XK2	685	270	Vertical	5 to 10 grams	MSD-A	MSD-A
36	MSD-I	XK2	645	293	Vertical	5 to 10 grams	MSD-B	MSD-B3
37	MSD-I	XK2	645	304	Vertical	5 to 10 grams	MSD-A	MSD-A
38	MSD-I	XK2	686	315	Vertical	5 to 10 grams	MSD-G	MSD-G3
39	MSD-I	XK2	686	328	Vertical	5 to 10 grams	MSD-A	MSD-A
40	MSD-I	XK2	688	332	Vertical	5 to 10 grams	MSD-C	MSD-C
41	MSD-I	XK2	692	361	Vertical	5 to 10 grams	MSD-C	MSD-C
42	MSD-I	XK2	692	366	Vertical	5 to 10 grams	MSD-G	MSD-G2
43	MSD-I	XK2	619	383	Vertical	5 to 10 grams	MSD-G	MSD-G1
44	MSD-I	XK2	619	384	Vertical	5 to 10 grams	MSD-G	MSD-G2
45	MSD-I	XK2	619	387	Vertical	5 to 10 grams	MSD-E	MSD-E
46	MSD-I	XK2	619	388	Vertical	5 to 10 grams	MSD-E	MSD-E
47	MSD-I	XK2	619	402	Vertical	5 to 10 grams	MSD-G	MSD-G1
48	MSD-I	XK2	619	405	Vertical	5 to 10 grams	MSD-G	MSD-G1
49	MSD-I	XK2	619	408	Vertical	5 to 10 grams	MSD-G	MSD-G3
50	MSD-I	XK2	619	410	Vertical	5 to 10 grams	MSD-G	MSD-G3
51	MSD-I	XK2	619	420	Vertical	5 to 10 grams	MSD-E	MSD-E
52	MSD-I	XK2	619	421	Vertical	5 to 10 grams	MSD-E	MSD-E
53	MSD-I	XK2	619	423	Vertical	5 to 10 grams	MSD-G	MSD-G1
54	MSD-I	XK2	619	424	Vertical	5 to 10 grams	MSD-G	MSD-G1
55	MSD-I	XK2	619	426	Vertical	5 to 10 grams	MSD-G	MSD-G1
56	MSD-I	XK2	619	427	Vertical	5 to 10 grams	MSD-G	MSD-G1
57	MSD-I	XK2	619	428	Vertical	5 to 10 grams	MSD-G	MSD-G1
58	MSD-I	XK2	619	429	Vertical	5 to 10 grams	MSD-G	MSD-G1
59	MSD-I	XK2	619	430	Vertical	5 to 10 grams	MSD-G	MSD-G1
60	MSD-I	XK2	619	431	Vertical	5 to 10 grams	MSD-G	MSD-G1
61	MSD-I	XK2	619	432	Vertical	5 to 10 grams	MSD-G	MSD-G1
62	MSD-I	XK2	619	433	Vertical	5 to 10 grams	MSD-E	MSD-E
63	MSD-I	XK2	619	436	Vertical	5 to 10 grams	MSD-G	MSD-G2
64	MSD-I	XK2	619	438	Vertical	5 to 10 grams	MSD-G	MSD-G1
65	MSD-I	XK2	619	439	Vertical	5 to 10 grams	MSD-G	MSD-G1
66	MSD-I	XK2	619	446	Vertical	5 to 10 grams	MSD-C	MSD-C
67	MSD-I	XK2	619	461	Vertical	5 to 10 grams	MSD-C	MSD-C
68	MSD-I	XK2	619	462	Vertical	5 to 10 grams	MSD-C	MSD-C
69	MSD-I	XK2	619	465	Vertical	5 to 10 grams	MSD-G	MSD-G3
70	MSD-I	XK2	619	468	Vertical	5 to 10 grams	MSD-G	MSD-G3
71	MSD-I	XK2	619	470	Vertical	5 to 10 grams	MSD-B	MSD-B1
72	MSD-I	XK2	619	471	Vertical	5 to 10 grams	MSD-A	MSD-A
73	MSD-I	XK2	619	472	Vertical	5 to 10 grams	MSD-F	MSD-F
74	MSD-I	XK2	622	493	Vertical	5 to 10 grams	MSD-G	MSD-G2
75	MSD-I	XK2	622	504	Vertical	5 to 10 grams	MSD-A	MSD-A
76	MSD-I	XK2	636	521	Vertical	5 to 10 grams	MSD-A	MSD-A
77	MSD-I	XK2	636	557	Vertical	5 to 10 grams	MSD-A	MSD-A2
78	MSD-I	XK2	655	592	Vertical	5 to 10 grams	MSD-A	MSD-A
79	MSD-I	XK2	655	593	Vertical	5 to 10 grams	MSD-B	MSD-B2
80	MSD-I	XK2	668	627	Vertical	5 to 10 grams	MSD-C	MSD-C
81	MSD-I	XK2	680	637	Vertical	5 to 10 grams	MSD-G	MSD-G2

82	MSD-I	XK2	680	638	Vertical	5 to 10 grams	MSD-G	MSD-G2
83	MSD-I	XK2	680	642	Vertical	5 to 10 grams	MSD-G	MSD-G3
84	MSD-I	XK2	680	653	Vertical	5 to 10 grams	MSD-G	MSD-G3
85	MSD-I	XK2	680	654	Vertical	5 to 10 grams	MSD-G	MSD-G2
86	MSD-I	XK2	680	657	Vertical	5 to 10 grams	MSD-G	MSD-G1
87	MSD-I	XK2	680	658	Vertical	5 to 10 grams	MSD-G	MSD-G2
88	MSD-I	XK2	647	690	Vertical	5 to 10 grams	MSD-B	MSD-B1
89	MSD-I	XK2	647	691	Vertical	5 to 10 grams	MSD-B	MSD-B1
90	MSD-I	XK2	647	693	Vertical	5 to 10 grams	MSD-D	MSD-D
91	MSD-I	XK2	647	694	Vertical	5 to 10 grams	MSD-D	MSD-D
92	MSD-I	XK2	647	695	Vertical	5 to 10 grams	MSD-B	MSD-B1
93	MSD-I	XK2	647	696	Vertical	5 to 10 grams	MSD-B	MSD-B2
94	MSD-I	XK2	646	753	Vertical	5 to 10 grams	MSD-B	MSD-B1
95	MSD-I	XK2	646	772	Vertical	5 to 10 grams	MSD-G	MSD-G3
96	MSD-I	XK2	646	778	Vertical	5 to 10 grams	MSD-G	MSD-G3
97	MSD-I	XK2	646	803	Vertical	5 to 10 grams	MSD-G	MSD-G1
98	MSD-I	XK2	646	838	Vertical	5 to 10 grams	MSD-G	MSD-G2
99	MSD-I	XK2	646	849	Vertical	5 to 10 grams	MSD-G	MSD-G1
100	MSD-I	XK2	646	853	Vertical	5 to 10 grams	MSD-G	MSD-G3

Table A3. Sample list and thin-section numbers (TS-A) from Alamgirpur SC

TS-A	SITE/TRENCH	Context	Sherd N.	TS Orientation	Powder Sample	Petro-Class	Sub-Group
1	ALM/SC	101	1	Vertical	5 grams	ALM-F	ALM-F
2	ALM/SC	101	2	Vertical	5 grams	ALM-F	ALM-F
3	ALM/SC	101	3	Vertical	5 grams	ALM-F	ALM-F
4	ALM/SC	101	6	Vertical	5 grams	ALM-F	ALM-F
5	ALM/SC	101	13	Vertical	5 grams	ALM-F	ALM-F
6	ALM/SC	101	22	Vertical	5 grams	ALM-F	ALM-F
7	ALM/SC	101	24	Vertical	5 grams	ALM-F	ALM-F
8	ALM/SC	101	27	Vertical	5 grams	ALM-F	ALM-F
9	ALM/SC	101	36	Vertical	5 grams	ALM-F	ALM-F
10	ALM/SC	101	37	Vertical	5 grams	ALM-F	ALM-F
11	ALM/SC	101	38	Vertical	5 grams	ALM-F	ALM-F
12	ALM/SC	102	42	Vertical	5 grams	ALM-A	ALM-A1
13	ALM/SC	102	49	Vertical	5 grams	ALM-F	ALM-F
14	ALM/SC	102	55	Vertical	5 grams	ALM-F	ALM-F
15	ALM/SC	102	66	Vertical	5 grams	ALM-C	ALM-C
16	ALM/SC	103	68	Vertical	5 grams	ALM-F	ALM-F
17	ALM/SC	103	69	Vertical	5 grams	ALM-E	ALM-E2
18	ALM/SC	103	70	Vertical	5 grams	ALM-A	ALM-A1
19	ALM/SC	103	81	Vertical	5 grams	ALM-A	ALM-A1
20	ALM/SC	103	86	Vertical	n/a	n/a	n/a
21	ALM/SC	103	90	Vertical	5 grams	ALM-F	ALM-F
22	ALM/SC	104	100	Vertical	5 grams	ALM-B	ALM-B
23	ALM/SC	104	105	Vertical	5 grams	ALM-A	ALM-A2
24	ALM/SC	104	111	Vertical	5 grams	ALM-A	ALM-A1
25	ALM/SC	104	115	Vertical	5 grams	ALM-E	ALM-E2

26	ALM/SC	104	121	Vertical	5 grams	ALM-A	ALM-A1
27	ALM/SC	105	130	Vertical	5 grams	ALM-A	ALM-A1
28	ALM/SC	105	133	Vertical	5 grams	ALM-E	ALM-E2
29	ALM/SC	105	137	Vertical	5 grams	ALM-A	ALM-A1
30	ALM/SC	105	153	Vertical	5 grams	ALM-E	ALM-E1
31	ALM/SC	105	159	Vertical	5 grams	ALM-F	ALM-F
32	ALM/SC	105	172	Vertical	5 grams	ALM-F	ALM-F
33	ALM/SC	106	177	Vertical	5 grams	ALM-E	ALM-E2
34	ALM/SC	106	178	Vertical	5 grams	ALM-A	ALM-A2
35	ALM/SC	106	180	Vertical	5 grams	ALM-A	ALM-A1
36	ALM/SC	106	183	Vertical	5 grams	ALM-A	ALM-A1
37	ALM/SC	106	187	Vertical	5 grams	ALM-A	ALM-A3
38	ALM/SC	106	192	Vertical	5 grams	ALM-A	ALM-A1
39	ALM/SC	107	201	Vertical	5 grams	ALM-E	ALM-E2
40	ALM/SC	107	202	Vertical	5 grams	ALM-E	ALM-E2
41	ALM/SC	107	203	Vertical	5 grams	ALM-A	ALM-A1
42	ALM/SC	107	204	Vertical	5 grams	ALM-A	ALM-A2
43	ALM/SC	107	207	Vertical	5 grams	ALM-A	ALM-A1
43	ALM/SC	107	206	Vertical	n/a	n/a	n/a
44	ALM/SC	107	210	Vertical	5 grams	ALM-C	ALM-C
45	ALM/SC	108	212	Vertical	5 grams	ALM-A	ALM-A2
46	ALM/SC	108	214	Vertical	5 grams	ALM-A	ALM-A1
47	ALM/SC	108	216	Vertical	5 grams	ALM-F	ALM-F
48	ALM/SC	108	221	Vertical	5 grams	ALM-A	ALM-A1
49	ALM/SC	108	222	Vertical	5 grams	ALM-A	ALM-A1
50	ALM/SC	110	228	Vertical	5 grams	ALM-A	ALM-A1
51	ALM/SC	108	224	Vertical	n/a	n/a	n/a
51	ALM/SC	110	229	Vertical	5 grams	ALM-A	ALM-A2
52	ALM/SC	110	232	Vertical	5 grams	ALM-E	ALM-E2
53	ALM/SC	110	234	Vertical	5 grams	ALM-A	ALM-A1
54	ALM/SC	110	235	Vertical	5 grams	ALM-A	ALM-A1
55	ALM/SC	112	238	Vertical	5 grams	ALM-A	ALM-A2
56	ALM/SC	112	242	Vertical	5 grams	ALM-A	ALM-A2
57	ALM/SC	112	250	Vertical	5 grams	ALM-A	ALM-A3
58	ALM/SC	112	251	Vertical	5 grams	ALM-A	ALM-A3
59	ALM/SC	112	249	Vertical	n/a	n/a	n/a
59	ALM/SC	114	266	Vertical	5 grams	ALM-E	ALM-E1
60	ALM/SC	114	268	Vertical	5 grams	ALM-A	ALM-A1
61	ALM/SC	119	361	Vertical	5 grams	ALM-A	ALM-A1
62	ALM/SC	119	364 A	Vertical	5 grams	ALM-B	ALM-B
63	ALM/SC	119	370	Vertical	5 grams	ALM-B	ALM-B
64	ALM/SC	121	394	Vertical	5 grams	ALM-A	ALM-A3
65	ALM/SC	125	475	Vertical	5 grams	ALM-A	ALM-A3
66	ALM/SC	125	481	Vertical	5 grams	ALM-A	ALM-A1
67	ALM/SC	127	507	Vertical	5 grams	ALM-A	ALM-A3
68	ALM/SC	122	397	Vertical	5 grams	ALM-A	ALM-A3
69	ALM/SC	122	399	Vertical	5 grams	ALM-D	ALM-D

70	ALM/SC		400	Vertical	5 grams	ALM-A	ALM-A1
71	ALM/SC	122	402	Vertical	5 grams	ALM-A	ALM-A1
72	ALM/SC		411	Vertical	5 grams	ALM-A	ALM-A1
73	ALM/SC	123	414	Vertical	5 grams	ALM-E	ALM-E1
74	ALM/SC	123	415	Vertical	5 grams	ALM-A	ALM-A1
75	ALM/SC		423	Vertical	5 grams	ALM-A	ALM-A1
76	ALM/SC		446	Vertical	5 grams	ALM-A	ALM-A1
77	ALM/SC	124	450	Vertical	5 grams	ALM-A	ALM-A1
78	ALM/SC		453	Vertical	5 grams	ALM-A	ALM-A1
79	ALM/SC	124	455	Vertical	5 grams	ALM-A	ALM-A2
80	ALM/SC		456	Vertical	5 grams	ALM-E	ALM-E2
81	ALM/SC	125	470	Vertical	5 grams	ALM-A	ALM-A3
82	ALM/SC	125	473	Vertical	5 grams	ALM-A	ALM-A3
83	ALM/SC	125	474	Vertical	5 grams	ALM-D	ALM-D
84	ALM/SC	125	476	Vertical	5 grams	ALM-A	ALM-A3
85	ALM/SC		479	Vertical	5 grams	ALM-A	ALM-A3
86	ALM/SC	125	484	Vertical	5 grams	ALM-D	ALM-D
87	ALM/SC	126	490	Vertical	5 grams	ALM-A	ALM-A1
88	ALM/SC	126	491	Vertical	5 grams	ALM-A	ALM-A2
89	ALM/SC	126	493	Vertical	5 grams	ALM-A	ALM-A1
90	ALM/SC	126	494	Vertical	5 grams	ALM-A	ALM-A3
91	ALM/SC		498	Vertical	5 grams	ALM-D	ALM-D
92	ALM/SC		504	Vertical	5 grams	ALM-A	ALM-A1
93	ALM/SC	127	506	Vertical	5 grams	ALM-A	ALM-A2
94	ALM/SC		517	Vertical	5 grams	ALM-A	ALM-A1
95	ALM/SC	128	521	Vertical	5 grams	ALM-A	ALM-A1
96	ALM/SC	128	524	Vertical	5 grams	ALM-A	ALM-A1
97	ALM/SC	128	526	Vertical	5 grams	ALM-B	ALM-B
98	ALM/SC	128	536	Vertical	5 grams	ALM-A	ALM-A1
99	ALM/SC	128	546	Vertical	5 grams	ALM-A	ALM-A1
100	ALM/SC	128	551	Vertical	5 grams	ALM-E	ALM-E2
101	ALM/SC		553	Vertical	5 grams	ALM-A	ALM-A1
102	ALM/SC		559	Vertical	5 grams	ALM-E	ALM-E1
103	ALM/SC		1342	Vertical	5 grams	ALM-E	ALM-E1
104	ALM/SC	122	1836	Vertical	5 grams	ALM-A	ALM-A3
105	ALM/SC		1867	Vertical	5 grams	ALM-A	ALM-A2
106	ALM/SC	125	1983	Vertical	5 grams	ALM-E	ALM-E1
107	ALM/SC	126	2053	Vertical	5 grams	ALM-E	ALM-E1
108	ALM/SC		2067	Vertical	5 grams	ALM-E	ALM-E2
109	ALM/SC		2078	Vertical	5 grams	ALM-A	ALM-A2
110	ALM/SC		2091	Vertical	5 grams	ALM-E	ALM-E1
111	ALM/SC		2092	Vertical	5 grams	ALM-E	ALM-E2
112	ALM/SC	128	2157	Vertical	5 grams	ALM-E	ALM-E1
113	ALM/SC	128	2241	Vertical	5 grams	ALM-E	ALM-E1

Table A4. Soil samples, including clay rich deposits, sand and rocks (CSR).

Sample No.	Site	Coordinates East	Coordinates North	JRW Samples	Description	Volume (Dry) in ml	Weight (Dry) in g	Volume (wet)	Increased Volume Dry to Wet (%)	Birquette size cm3 (wet)	Briquette size cm3 (dry)	Pre-firing shape	Pre-Firing weight g	Post-Firing (750°C) Weight	Plasticity Score
CSR_01	n/a	na	na	na	na	na	na	na	na	na	na	na	na	na	na
CSR_04	Rakhigarhi	76.107995	29.281949	na	Clay Source nea	250	327	320	0.28	60.066	45.402	Intact	63.352	61.87	2
CSR_05	Lohari Ragho I	76.03687	29.242541	P130	Iron rich nodule	250	270	280	0.12	50.055	36.707	Intact	32.23	30.171	4
CSR_09	Lohari Ragho I	na	na	na	Fragments of m	300	362	320	0.066666667	60.066	56.729	Fragment	15.186	14.816	1
CSR_10	Lohari Ragho I	76.03951	29.24431	P142	Proto-clay, grou	200	180	250	0.25	60.066	53.392	Intact	59.332	57.828	3
CSR_11	Lohari Ragho I	76.03673	29.24567	P134	Alluvial clay, gro	220	222	250	0.136363636	60.066	50.784	Intact	50.81	49.232	4
CSR_12	Lohari Ragho I	76.03673	29.24567	P134	Alluvia clay, Pos	220	222	250	0.136363636	60.066	48.3	Intact	64.135	62.022	4
CSR_13	Lohari Ragho I	76.04105	29.2402	P145	Clay Type LCT 3	180	133	200	0.111111111	60.066	52.64	Intact	59.931	57.991	3
CSR_14	Lohari Ragho I	76.03951	29.24431	P142	LCT 1, mottled	180	174	200	0.111111111	60.066	52.64	Intact	55.66	50.493	3
CSR_15	Lohari Ragho I	76.03722	29.24024	P146	LCT 3, back swa	220	241	250	0.136363636	60.066	52.64	intact	54.16	52.111	4
CSR_16	Khanak	75.867899	28.915325	na	Very good clay	150	200	250	0.666666667	60.066	51.52	intact	63.352	60.996	3
CSR_17	Khanak	na	na	na	Silty deposit. Lit	180	188	200	0.111111111	60.066	48.3	Intact	56.635	55.284	2
CSR_19	Khanak	na	na	na	Yellow clay, goo	220	228	250	0.136363636	60.066	46.06	Intact	45.396	40.288	2
CSR_20	Khanak	na	na	na	Silty Clay, possil	220	235	250	0.136363636	60.066	51.52	Intact	53.993	50.942	2
CSR_22	Khanak	na	na	na	Yellow slip clay	na	na	na	na	60.066	na	na	na	na	na
CSR_23	n/a	na	na	na	na	na	na	na	na	na	na	na	na	na	na
CSR_24	Kanoh	75.765489	29.376597	na	Source of clay b	220	280	250	0.136363636	60.066	50.4	Intact	54.634	51.578	4
CSR_25	Kanoh	75.765489	29.376597	na	Processed clay	180	165	200	0.111111111	60.066	48.96	Intact	46.366	44.178	4
CSR_26	Lohari Ragho	76.056163	29.260721	na	Unprocessed cl	180	200	250	0.388888889	60.066	45.225	Intact	49.996	47.385	4
CSR_27	Lohari Ragho	76.056163	29.260721	na	Processed clay	100	117	150	0.5	60.066	44.22	Fragment	12.093	11.446	4
CSR_28	Lohari Ragho	76.056163	29.260721	na	Unprocessed cl	200	227	240	0.2	60.066	50.048	Intact	46.327	44.015	4
CSR_29	Lohari Ragho	76.05603	29.26505	p170	Clay source nea	120	179	140	0.166666667	60.066	52.64	Intact	61.555	56.348	1
CSR_30	Lohari Ragho	76.03474	29.24657	P152	Clay source fror	200	188	240	0.2	60.066	50.048	Intact	61.072	55.661	3
CSR_34	Lohari Ragho	na	na	p176	Clay from fast r	180	151	200	0.111111111	60.066	45.9	Intact	40.554	39.547	3
CSR_35	Alamgirpur	na	na	na	Grey clay, excel	100	126	110	0.1	60.066	50.784	intact	51.066	47.788	3
CSR_36	Alamgirpur	na	na	na	Grey clay, excel	150	157	180	0.2	60.066	45.9	Fragment	33.708	30.635	4
CSR_37	Alamgirpur	na	na	na	Yellow clay, fou	50	48	60	0.2	60.066	45.225	Fragment	13.528	12.948	3
CSR_38	Alamgirpur	na	na	na	Yellow clay fror	100	91	110	0.1	60.066	51.52	Intact	48.138	46.007	2
CSR_39	Alamgirpur	na	na	na	Processed CSR_	100	84	120	0.2	60.066	47.61	Intact	45.989	43.993	3
CSR_40	Alamgirpur	77.487381	29.005096	na	Processed CSR_	180	170	210	0.166666667	60.066	40.5	Intact	47.833	45.562	4
CSR_41	Alamgirpur	na	na	na	Raw clay, sandy	220	212	230	0.045454545	60.066	51.52	Intact	61.244	58.657	3
CSR_45	Masudpur	na	na	214	na	180	184	200	0.111111111	60.066	48.96	Intact	64.336	58.718	2
CSR_46	Masudpur	75.950973	29.226591	na	Clay used by Po	180	216	200	0.111111111	60.066	46.575	Intact	53.636	51.916	3
CSR_47	Masudpur	75.974641	29.225966	na	Mix of two clay	190	185	200	0.052631579	60.066	45.225	Intact	51.39	49.351	4

CSR_48	Masudpur	76.005814	29.18388	na	Black clay used	180	208	220	0.222222222	60.066	46.8	Intact	49.833	47.395	3
CSR_49	Masudpur	75.950973	29.226591	na	Red clay used b	150	162	180	0.2	60.066	45.9	Intact	54.105	52.172	4
CSR_51	Masudpur	75.99321	29.24641	P206	na	170	126	180	0.058823529	60.066	55.93	Intact	53.251	51.89	1
CSR_52	Masudpur	75.99202	29.2437	P208	Dune/ Channel,	180	175	200	0.111111111	60.066	45.9	Intact	50.17	47.77	3
CSR_53	Masudpur	75.99897	29.24258	P219	Ponding towarc	180	154	200	0.111111111	60.066	45.225	Intact	44.352	40.119	4
CSR_54	Masudpur	75.99834	29.23999	P220	na	170	127	180	0.058823529	60.066	48.96	Intact	42.212	40.594	3
CSR_55	Masudpur	75.9953	29.24482	P250	na	170	127	180	0.058823529	60.066	54.74	Intact	53.708	49.764	1
CSR_56	Masudpur	75.99034	29.2432	P255	na	150	102	160	0.066666667	60.066	44.22	Intact	47.773	45.823	2
CSR_57	Masudpur	75.98984	29.23813	P259	na	180	127	200	0.111111111	60.066	44.55	Intact	47.689	45.618	3
CSR_58	Masudpur	75.98707	29.23658	P263	na	160	171	180	0.125	60.066	54.74	Intact	67.035	62.368	2
CSR_59	Masudpur	75.98852	29.24431	P267	na	160	140	180	0.125	60.066	45.9	Intact	44.964	43.632	3
CSR_60	Masudpur	75.99819	29.24601	P275	na	220	251	250	0.136363636	60.066	48.96	Intact	47.335	45.556	4
CSR_61	Masudpur	75.99953	29.23553	P287	na	200	201	240	0.2	60.066	46.92	Intact	58.398	56.372	3
CSR_62	Masudpur	75.94896	29.20694	P306	Active buried pa	200	205	240	0.2	60.066	46.575	Intact	54.248	48.025	3
CSR_63	Masudpur	75.9482	29.20482	P307	na	160	159	180	0.125	60.066	47.61	Intact	50.318	48.736	3
CSR_64	Masudpur	75.94821	29.20196	P308’	na	200	174	220	0.1	60.066	51.52	Intact	52.708	47.777	2
CSR_65	Masudpur	75.99399	29.23721	P278	Pond sequence	180	221	220	0.222222222	60.066	42.21	Intact	25.188	23.927	4
CSR_66	Bahola	76.78797	29.805748	na	Near excavated	200	211	220	0.1	60.066	47.61	Intact	53.701	48.844	1
CSR_67	Bahola	76.787966	29.805726	na	Near excavated	100	130	120	0.2	60.066	50.784	Intact	59.479	57.875	2
CSR_68	Bahola	76.787685	29.805848	na	Near excavated	200	219	250	0.25	60.066	48.3	Intact	49.011	47.539	2
CSR_69	Bahola	76.789778	29.8084	na	From area betw	250	275	330	0.32	60.066	50.784	Intact	44.187	41.495	3
CSR_70	Bahola	76.774444	29.816342	na	From potter ho	200	279	250	0.25	60.066	50.784	Intact	46.575	43.545	2
CSR_71	Nighdu, Bahola	76.736122	29.84206	na	From Nighdu, li	250	310	350	0.4	60.066	46.92	Fragment	27.687	25.521	4
CSR_72	n/a	na	na	na	na	na	na	na	na	na	na	na	na	na	na
CSR_73	Sampla, Rhotak	76.75414	28.78792	SP3A	Black lake clay,	250	239	350	0.4	60.066	50.784	Intact	45.647	42.619	4

Appendix B: Petrographic classes description

Class	Sub-Group	Thin-section no. (TS-L-)
LHR-A	LHR-A1	8, 14, 17, 27, 28, 29, 32, 37, 38, 40, 42, 45, 54, 56, 58, 59, 60, 62, 64, 65, 66, 76, 77, 78, 81, 83, 85, 86, 91, 93, 94, 96, 97
	LHR-A2	2, 9, 12, 13, 16, 19, 22, 30, 31, 44, 51, 52, 53, 55, 63, 67, 82
	LHR-A3	4, 15, 20, 21, 23, 35, 39, 43, 46, 61, 87, 90, 98
LHR-B	LHR-B	1, 10, 11, 33, 41, 47, 57, 72, 74, 75, 84, 89
LHR-C	LHR-C	6, 24, 25, 26, 34, 79, 80, 88, 99, 100
LHR-D	LHR-D	48, 49, 92
LHR-E	LHR-E1	5, 7, 18, 36, 50, 68, 70
	LHR-E2	3, 69, 71, 73, 95

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-A	MSD-A1	11, 12, 17, 35, 39, 67, 72, 75, 76
	MSD-A2	77
MSD-B	MSD-B1	20, 37, 71, 78, 88, 89, 92, 94
	MSD-B2	93, 79, 15
	MSD-B3	13, 36
MSD-C	MSD-C	4, 5, 68, 98, 40, 28, 41, 66, 16, 67
MSD-D	MSD-D	90, 91
MSD-E	MSD-E	10, 45, 51, 52, 62, 80
MSD-F	MSD-F	14, 73
MSD-G	MSD-G1	65, 58, 86, 59, 64, 61, 84, 46, 1, 53, 30, 57
	MSD-G2	74, 63, 44, 8, 87, 81, 34, 42, 82, 56, 85
	MSD-G3	48, 60, 83, 95, 3, 49, 96, 47, 21, 55, 19, 43, 54, 100, 70, 97, 38, 99, 50, 22, 24, 26, 6, 18, 69, 31, 33, 23, 27, 32, 25, 2, 29, 7, 9

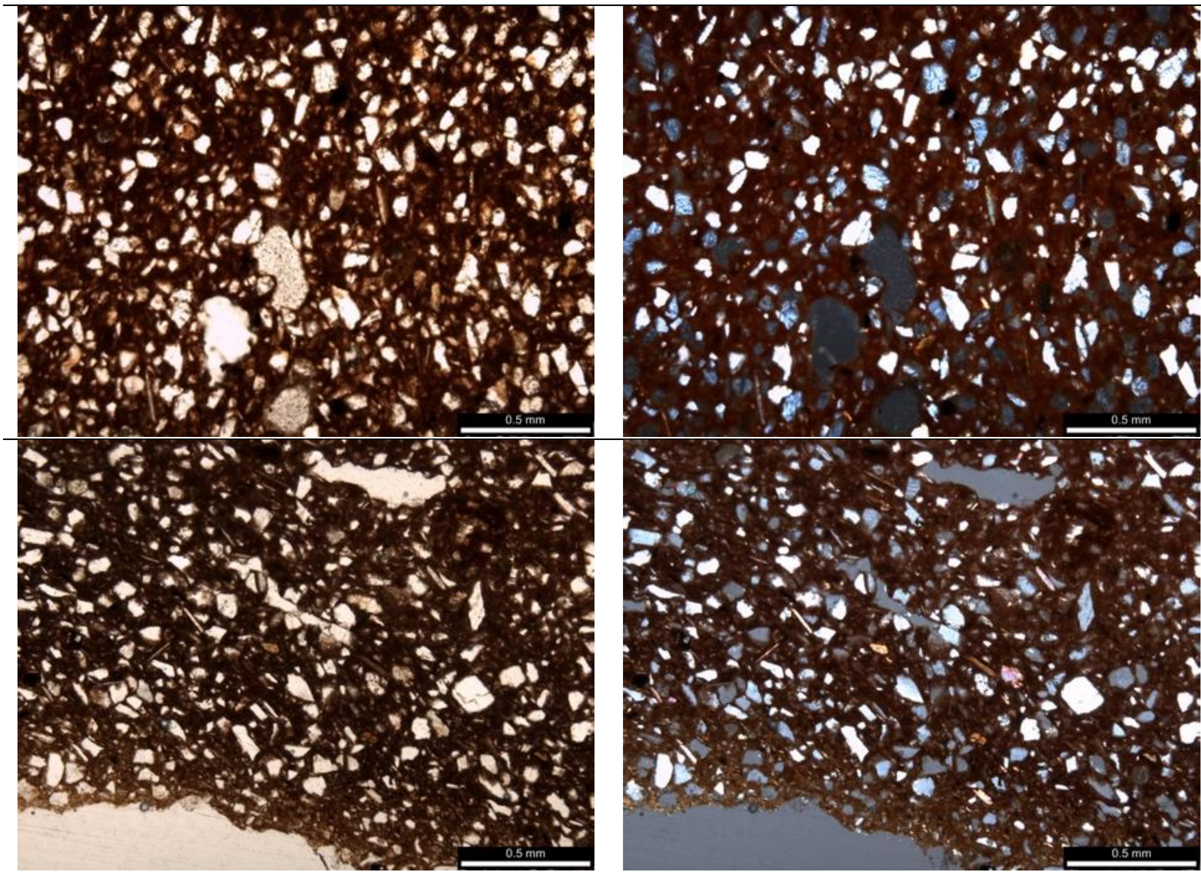
Class	Sub-Group	Thin-section no. (TS-A-)
ALM-A	ALM-A1	12, 18, 19, 24, 26, 27, 29, 35, 36, 38, 41, 43, 46, 48, 49, 50, 53, 54, 60, 61, 66, 70, 71, 72, 74, 75, 76, 77, 78, 87, 89, 92, 94, 95, 96, 98, 99, 101
	ALM-A2	23, 34, 42, 45, 51, 55, 56, 79, 88, 93, 105, 109
	ALM-A3	37, 57, 58, 64, 65, 67, 68, 81, 82, 84, 85, 90, 104
ALM-B	ALM-B	22, 62, 63, 97
ALM-C	ALM-C	15, 44
ALM-D	ALM-D	69, 83, 86, 91
ALM-E	ALM-E1	30, 59, 73, 102, 103, 106, 107, 110, 112, 113
	ALM-E2	17, 25, 28, 33, 39, 40, 52, 80, 100, 108, 111

Class LHR-A: Mica and Quartz Fabric

Class	Sub-Groups	Thin-section no. (TS-L-)
LHR-A	LHR-A1	8, 14, 17, 27, 28, 29, 32, 33, 38, 40, 42, 45, 54, 56, 58, 59, 60, 62, 64, 65, 66, 76, 78, 81, 83, 85, 91, 93, 94, 96
	LHR-A2	2, 6, 9, 12, 16, 19, 22, 30, 44, 51, 53, 55, 63, 67, 72, 82, 31
	LHR-A3	4, 15, 20, 23, 39, 43, 46, 61, 80, 86, 87, 98
		(Exceptions: sherds 520-448, 520-818, 521-576)

Top down: samples 520-811; 518-49; 515-214. Scale bar: 0.5 mm.

PPL XP



Inclusions

25-30%% el. and eq. sa-sr. < 0.18 mm, mode = 0.08 mm. Double spaced or less. Weak to crude- alignment to margins of samples. Unimodal grain size distribution.

dominant: *Quartz;* eq. sa-sr < 1.9 mm, mode = 0.8 mm.

common: Muscovite Mica, el. a-sa < 0.20 mm, mode = 0.15 mm.

few:	*Clinopyroxenes*, eq. sa < 0.15 mm, mode = 0.10 mm. Weathered clinopyroxene, weak pink-green pleochroism.
	Unoptical iron-rich fragments; eq. r-sr < 0.10 mm, mode = 0.08 mm.
rare:	Plagioclase Feldspar
	Polycrystalline quartz;
	Limestone; eq. r-sr. < 0.30 mm, mode: 0.25 mm. Composed of micrite calcite (sherds 515-323; 521-590). Occasional sr. quartz, plagioclase feldspar, mica inclusions, and ferruginous staining.

Voids

15-20% voids. Composed mainly of meso- and macro-elongate voids and meso-vughs. None to very weak alignment parallel to margins of samples.

Matrix

50-60% non-calcareous fabric, Red-brown in PPL and XP (x 40). Homogeneous. Optically non active.

Comments

This homogeneous fabric group is characterised by the presence of mica and quartz inclusions in a non-calcareous red-brown clay with a very low abundance of voids. There is a low abundance of small-sized sub-angular to sub-rounded limestone and *polycrystalline* inclusions and dark iron-rich fragments. These homogeneous inclusions can be understood to have been naturally present in an alluvial fine clay that was used to produce the samples. Weak alignment of the inclusions with the samples' margins, and possible relic coils can be seen in sherds 521-619, 520-814, 508-7 suggesting that the vessels from which the sample came may have been coil built. However, the crude alignment of elongate inclusions and voids in proximity to the margins in samples 515-242, 520-818 and 515-304, may also suggest that they were wheel finished. Samples 520-436 and 515-289 exhibit a thin external layer of dark clay, which represents a slip. Given the colour of the matrix and low to none optical activity, the samples were well-fired in an oxidising atmosphere. This fabric group could be a slightly coarser version of LHR-B group due to the abundance of fine mica and the presence of polycrystalline quartz and Clinopyroxene.

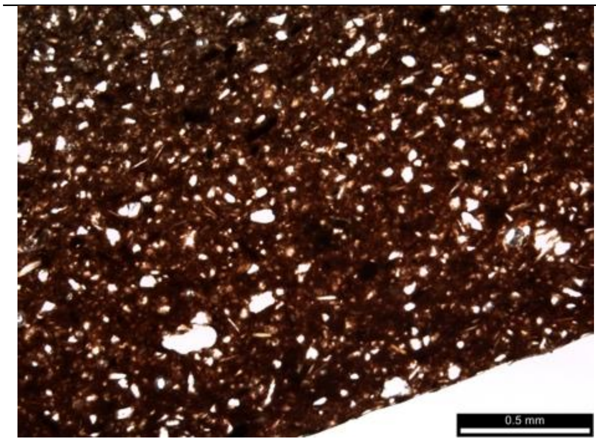
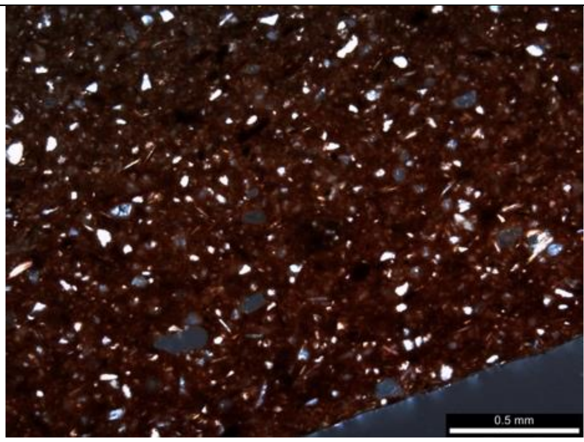
Subgroups:

LHR-A1	See description LHR-A
LHR-A2	Slightly more sparse and larger inclusions
LHR-A3	Slightly more calcareous fabric

Class LHR-B: Fine Mica and Quartz Fabric

Class	Sub-Group	Thin-section no. (TS-L-)
LHR-B	LHR-B	1, 10, 11, 21, 37, 41, 47, 57, 74, 75, 84, 89

Samlple 520-400. Scale bar: 0.5 mm.

PPL	XP
	

Inclusions

15-20% el. and eq. sa-sr. < 0.20 mm, mode = 0.08 mm. Double spaced or more. Weak to crude- alignment to margins of samples. Unimodal grain size distribution.

dominant:	*Quartz*; eq. sa-sr < 0.1 mm, mode = 0.09 mm.
common:	*Muscovite Mica*; el. a-sa < 0.20 mm, mode = 0.15 mm.
few:	*Polycrystalline quartz*; eq. sr-sa. eq. r-sr < 0.10 mm, mode = 0.09 mm.
	Unoptical iron-rich fragments; eq. r-sr < 0.10 mm, mode = 0.07 mm.
rare:	*Clinopyroxene*; eq. sa < 0.1 mm, mode = 0.08 mm. Weathered clinopyroxen, weak pink-green pleochroism.
	Plagioclase Feldspar; el and eq. sa-sr. < 0.15 mm, mode 0.07 mm.

Matrix

70% Non-calcareous fabric, Red-brown in PPL and XP (x 40). Homogeneous. Optically non active.

Void

10-15% voids. Composed mainly of small meso- and macro-elongate voids and meso-vughs. None to very weak alignment parallel to margins of samples.

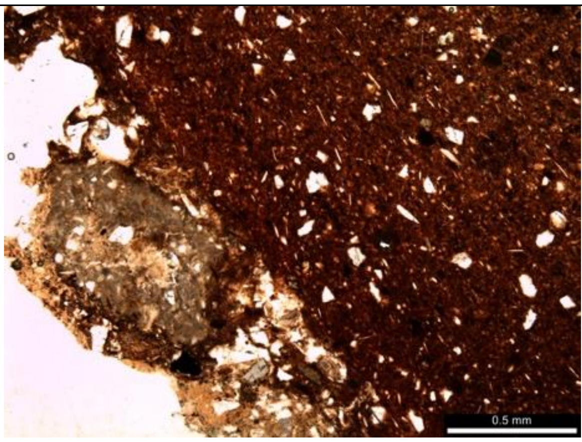
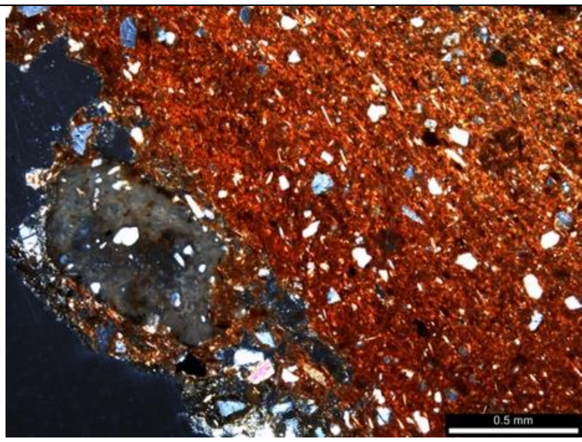
Comments

This homogeneous fabric group is characterised by the presence of very fine mica and quartz inclusions in a non-calcareous red-brown clay with a very low abundance of voids. There is a low abundance of small-sized sub-angular to sub-rounded *polycrystalline* inclusions and dark iron-rich fragments. These homogeneous small inclusions can be understood to have been naturally present in an alluvial fine clay that was used to produce the samples. Weak alignment of the inclusions with the samples' margins, and possible relic coils can be seen in sherd 508-5, 520-565, 518-87, 520-401, 521-620, suggesting that the vessels from which the sample came may have been coil built. However, the crude alignment of elongate inclusions and voids in proximity to the margins in samples 508-5, 521-629 and 518-87, may also suggest that they were wheel finished. Samples 518-87 and 520-400 exhibit a thin external layer of dark clay, which represents a slip. Given the colour of the matrix and low to none optical activity, the samples were well-fired in an oxidising atmosphere. This fabric group could be a very fine version of LHR-A group due to the abundance of fine mica and the presence of polycrystalline quartz and clinopyroxene.

Class LHR-C: Lime-kankar Fabric

Class	Sub-Group	Thin-section no. (TS-L-)
LHR-C	LHR-C	24, 25, 26, 34, 79, 88, 90, 100

Sample 515-323. Scale bar: 0.5 mm.

PPL	XP
	

<u>Inclusions</u>

20-25%% eq. sa-sr. < 1.00 mm, mode = 0.15 mm. Double spaced or more in fine fraction; single spaced coarse fraction. None to crude- alignment to margins of samples. Bimodal grain size distribution.

Coarse fraction: < 1.00 mm.

few: *Limestone*; eq. r-sr. < 1.00 mm, mode: 0.85 mm. Composed of micrite calcite (sherds 515-323; 521-590). Occasional sr. quartz, plagioclase feldspar, mica inclusions, and ferruginous staining.

Fine fraction: < 0.30 mm.

predominant-dom: *Quartz*; eq. sa < 0.25 mm, mode = 0.15 mm. Straight or undulose extinction.

common: *Muscovite Mica*; el. a-sa < 0.2 mm, mode = 0.15 mm.

few: *Unoptical iron-rich fragments*; eq. r-sr < 0.15 mm, mode = 0.10 mm.

rare: *Clinopyroxene*; eq. sa < 0.1 mm, mode = 0.09 mm. Weathered clinopyroxene, weak pink-green pleochroism.

Polycrystalline quartz; eq. sr-sa. < 0.15 mm

very rare: *Epidote*; eq. sr. Size , 0.15 mm

Matrix

60-70% non-calcareous. Red-brown in PPL and deep red-brown in XP (x40). Homogeneous. Optically non active.

Void

10-15% voids. Composed mainly of small vesicles and vughs. None to very weak alignment parallel to margins of samples.

Comments

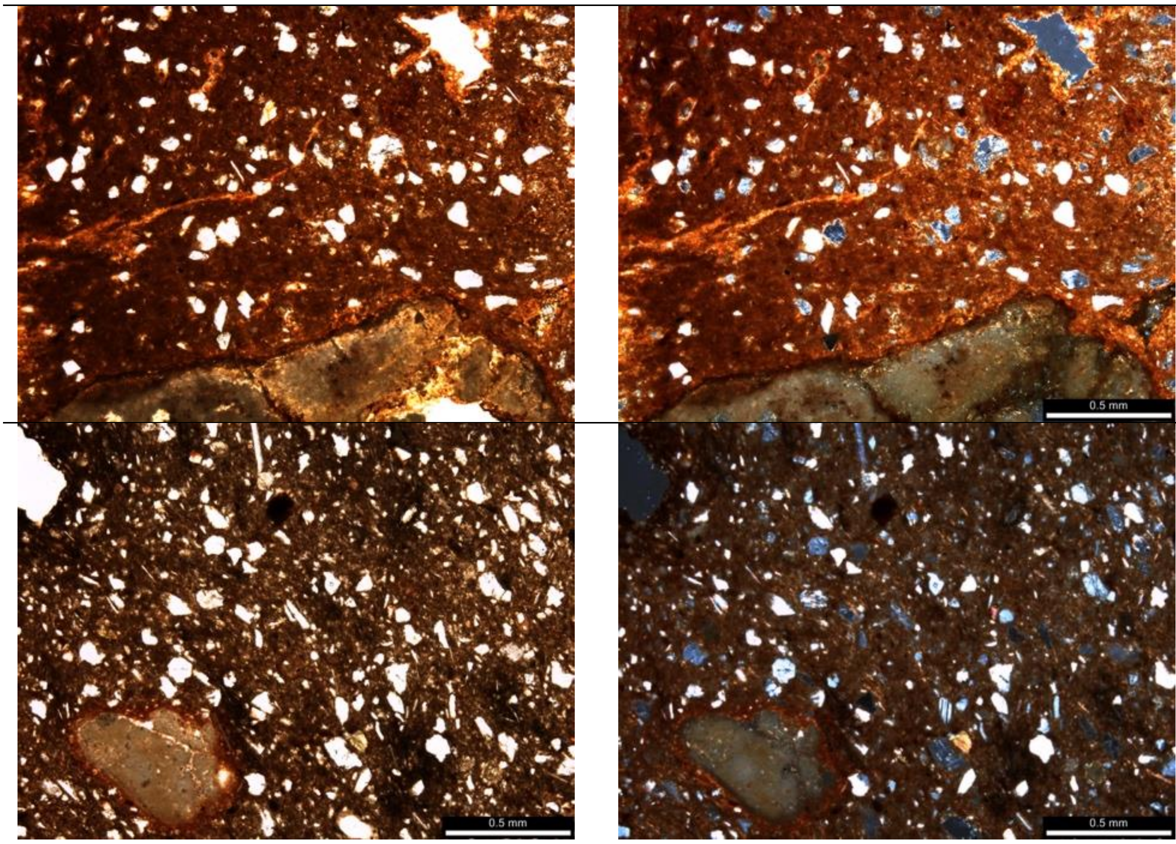
This fabric group is characterised by a combination of two distinctive recipes, both characterised by a non-calcareous clay with single to double spaced or sparse inclusions. There is a clear distinction in terms of the grain distribution and spacing of the inclusions within each thin-sections, depending on the area of the each thin-section. In particular, the area of thin-sections closer to the outer surface of the ceramic sherds shows remarkable difference from the rest of each thin-section. In fact, the outer layer seems to show coarser inclusions that are remarkably different from the rest of each sample. A description follows: (1) The coarse fraction characterise the outer layer of each thin-section. It shows large fragments of calcrete or limestone, which are remarkably larger than the fine fraction. The nature of the calcrete, composed of micritic calcite, might be related to nodules of kankar in the region. This have been likely added as temper in a non-calcareous red clay paste containing quartz, mica, and rare plagioclase feldspar, polycrystalline quartz and pyroxene. (2) The finer fraction characterises the rest of each samples, core and inner areas. This is dominated by small quartz and mica, and by the presence of polycrystalline quartz, often found associated with iron-rich fragments and clinopyroxen. The two clay paste recipes show similarities with other fabric classes: the (1) coarse recipe shows similarities with Class LHR-D: the second one, or (2) the fine one, with class LHR-B. The combined use of two distinctive clay paste recipes manufacturing Indus vessels has also been observed in other thin-sections from neighbouring regions (see ALM fabric classes below). The source of clay was probably an alluvial or fluvial deposit. Inclusions and voids show week to none alignment to margin, and the presence of few relic coils was observed (e.g. sherd 521-592). This seems to suggest that samples may show evidence for the use of coils manufacturing techniques. The low to none optical activity of samples' matrix suggests firing methods at reasonably high temperature in an oxidising atmosphere.

Class LHR-D: Limestone Fabric

Class	Sub-Group	Thin-section no. (TS-L-)
LHR-D	LHR-D	31, 48, 49, 92

Top down: 520-428; 520-429. Scale bar: 0.5 mm.

PPL XP



<u>Inclusions</u>

25-30%% eq. sa-sr. < 2.50 mm, mode = 0.15 mm. Double spaced or more. None to crude-alignment to margins of samples. Bimodal grain size distribution.

Coarse fraction: < 2.50– 2.00 mm.

few: *Limestone*; eq. r-sr. < 2.50 mm, mode: 2.0 mm. Composed of micrite calcite (sherds 520-492; 520-428). Occasional ferruginous staining.

Fine fraction: < 0.30 mm.

predominant-dom: *Quartz*; eq. sa < 0.2 mm, mode = 0.1 mm. Straight or undulose extinction.

common:	*Muscovite Mica*; el. a-sa < 0.30 mm, mode = 0.2 mm.
	TFs; eq and sa. < 0.30 mm, , mode = 0.25 mm. Red-brown to dark red-brown. Low to almost neutral optical density. Diffuse to merging boundaries. Concordant. Composed of optically active red clay with angular quartz, polycrystalline quartz, opaques, and mica. Clay pellets (520-812) or swirls (sherd 520-428).
few:	*Unoptical iron-rich fragments*; eq. r-sr < 0.2 mm, mode = 015 mm.
rare:	*Clinopyroxene*; eq. sa < 0.2 mm, mode = 0.15 mm. Weathered clinopyroxene, weak pink-green pleochroism.
	Plagioclase Feldspar; el and eq. sa-sr. < 0.2 mm, mode 0.15 mm.
	Polycrystalline quartz; eq. sr-sa. < 0.15 mm
very rare:	*Epidote*; eq. sr. Size , 0.1 mm

Matrix

60% non-calcareous. Red-brown in PPL and deep red-brown in XP (x40). Non-homogeneous. Low optical activity to optically non active.

Void

10-15% voids. Composed mainly of elongate vesicles and vughs. None to very weak alignment parallel to margins of samples.

Comments

This fine fabric group is characterised by a non-homogeneous, non-calcareous clay with double spaced or sparse inclusions. There is a good degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions. The coarse fraction shows large fragments of limestone, which are remarkably larger than the fine fraction. The nature of the limestone, composed of micritic calcite, might be related to nodules of calcrete or kankar in the region. This might have been either added as temper, or naturally occurring in a non-calcareous red clay paste containing quartz, mica, and rare plagioclase feldspar, polycrystalline quartz and pyroxene. The source of clay was probably an alluvial or fluvial deposit. No samples show evidence for the use of coils, wheel-coiling, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding can be considered. Some samples show frequent clay pellets in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage. The low to none optical activity of samples' matrix suggests firing methods at reasonably high temperature in an oxidising atmosphere.

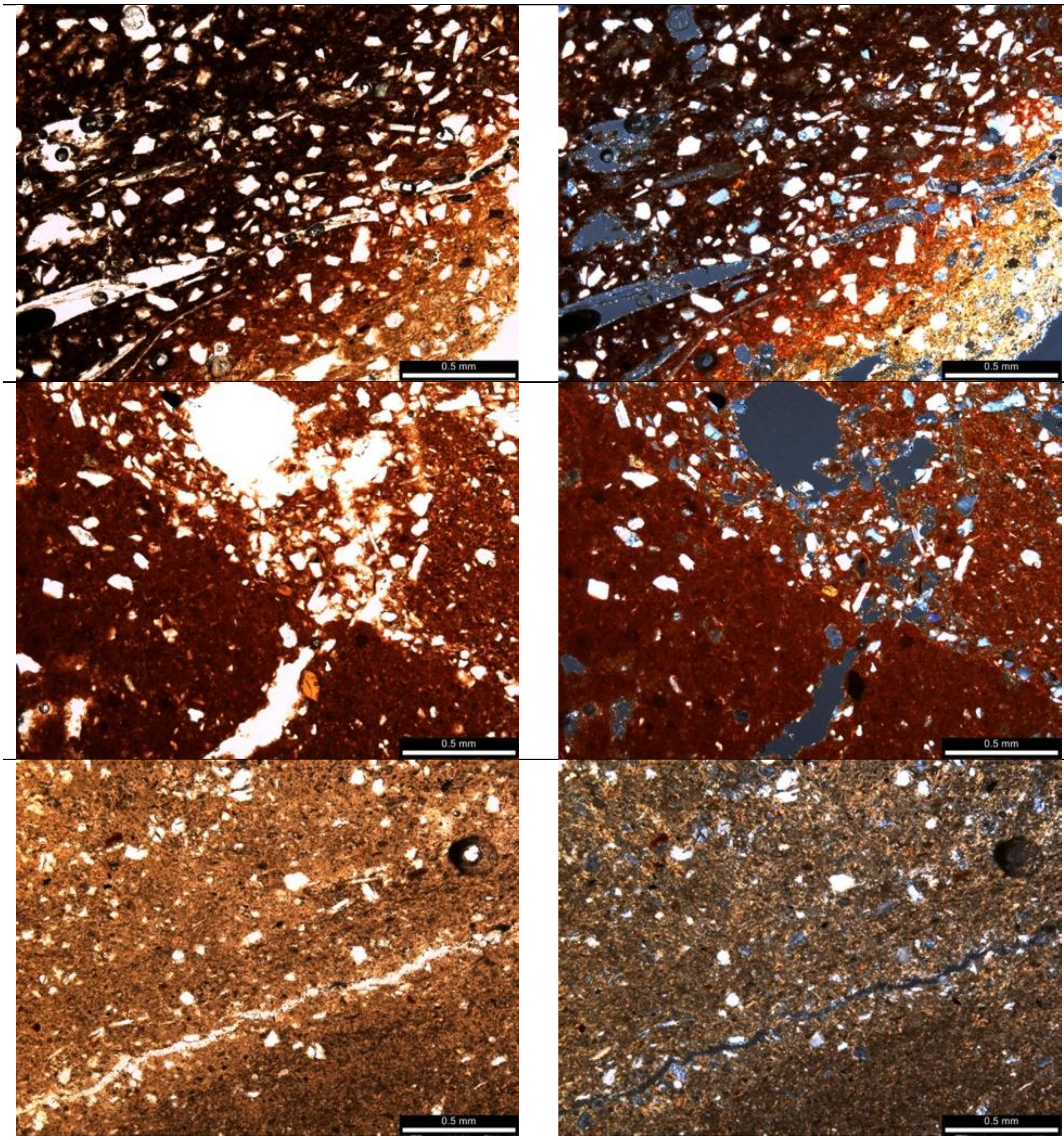
Class LHR-E: Coarse Phantom Chaff Fabric.

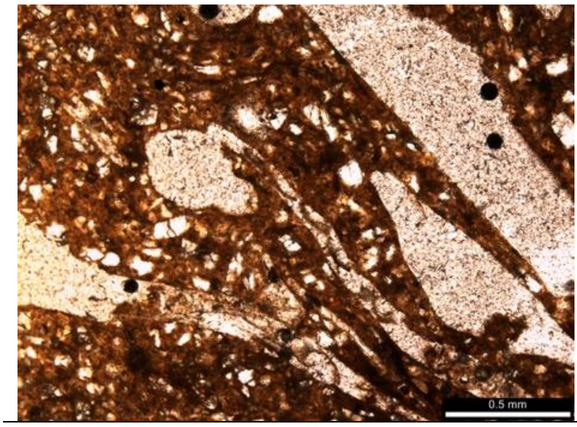
Samples

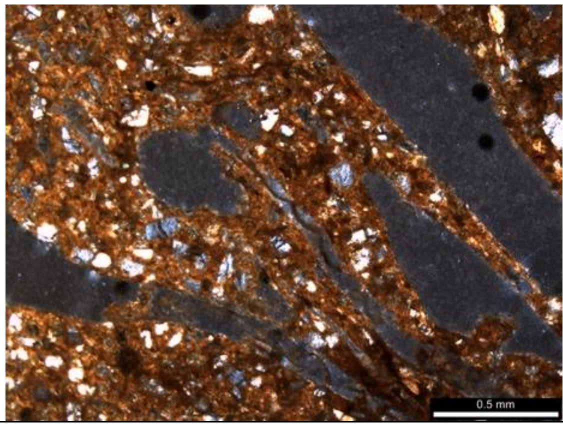
Class	Sub-Group	Thin-section no. (TS-L-)
LHR-E	LHR-E1	5, 7, 13, 18, 36, 50, 68, 70
	LHR-E2	3, 69, 71, 73, 95

Top down: Sub-group LHR-E1: 515-323; Sub-group LHR-E2: Scale bar: 0.5 mm.

PPL	XP







Inclusions

20-25%% eq. sa-sr. < 0.30 mm, mode = 0.15 mm. Double spaced or less. None to crude-alignment to margins of samples. Unimodal grain size distribution.

predominant-dom: *Quartz*; eq. sa < 0.2 mm, mode = 0.15 mm. Straight or undulose extinction.

common: *Muscovite Mica*; el. a-sa < 0.30 mm, mode = 0.20 mm. Possibly related to pyroxene inclusions.

common-few: *Plagioclase Feldspar*;

few: *Polycrystalline quartz*; eq. sr-sa. <

Unoptical iron-rich fragments; eq. r-sr < 3.0 mm, mode = 2.5 mm.

rare: Clinopyroxene:

Matrix

50% non-calcareous. Red-brown in PPL and deep red-brown in XP (x40). Non-homogeneous. Optically non active. This group includes some samples (sub-class LHR-E2) showing a clay matrix to some extent more calcareous (e.g. samples TS-L 3, 69, 71, 73, 95).

Void

25-30% voids. Composed mainly of elongate voids, channels and planar voids. None to very weak alignment parallel to margins of samples.

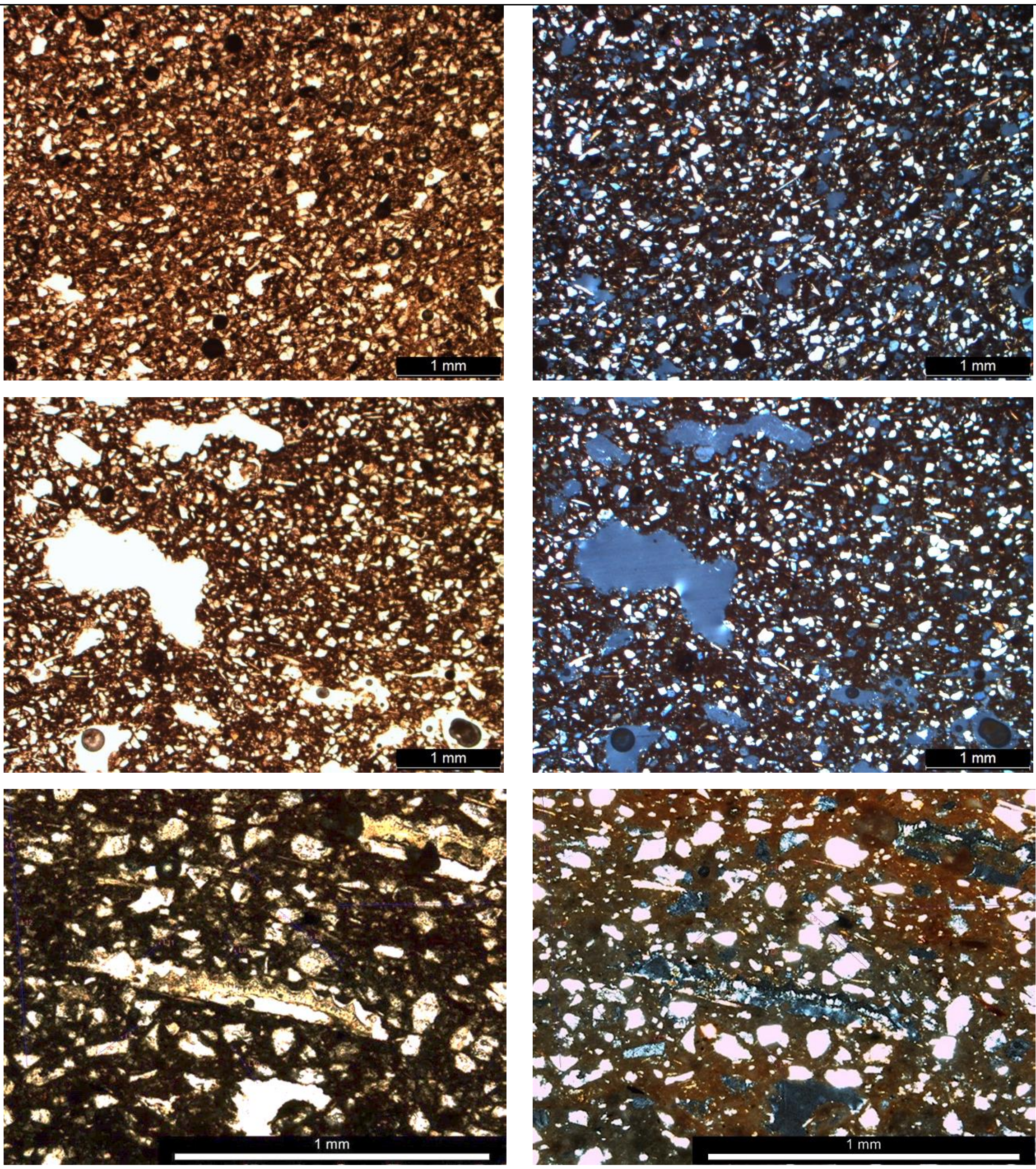
Comments

This coarse fabric group is characterised by the dominant presence of elongate voids in a non-homogeneous clay matrix, generally non-calcareous. There is a certain degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions (e.g. sample X - coarse, sample Y - fine). However, the samples do not subdivide easily into different textural subgroups. Given the presence of phantoms of coarse vegetal inclusions, all samples appear to have been produced by the addition of a quantity of organic material, possibly chaff, to a non-calcareous red clay containing quartz, mica, plagioclase feldspar, polycrystalline quartz and rare clinopyroxene. The source of the clay was probably an alluvial or fluvial deposit. No samples show evidence for the use of coils, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding can be considered. Some samples show frequent clay pellets in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage. The optical activity of samples' matrix suggests firing methods which range from reasonably high-fired to low-fired in an oxidising atmosphere; though some were not entirely oxidised during firing process and may be partially reduced. The use of open-air firing structures could be here suggested to explain the non-homogeneous. This group includes some samples (sub-class LHR-E2) showing a clay matrix to some extent more calcareous (e.g. samples TS-L 3, 69, 71, 73, 95).

Class MSD-A: Coarse Iron-Rich Organic Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-A	MSD-A1	11, 12, 17, 35, 39, 67, 72, 75, 76
	MSD-A2	77

Top down: samples TS-M-11, 12, 77. PPL left column, XP right column, scale bar 1mm.



Inclusions

35-40%% eq. sa-sr. < 0.25 mm, mode = 0.15 mm. Single spaced or less. No alignment to margins of samples. Unimodal grain size distribution.

predominant- dom:	*Quartz*; eq. sa < 0.23 mm, mode = 0.12 mm. Straight or undulose extinction.
common:	*Muscovite Mica*; el. a-sa < 0.25 mm, mode = 0.20 mm.
	Unoptical iron-rich fragments; eq. r-sr < 0.25 mm, mode = 0.2 mm. Very rare fragments in certain samples (e.g. TS-M-77) are particularly large, e.g. eq. r-sr < 0.92.
common-few:	*Brown amphibole*; el. sa-sr < 0.2 mm, mode = 0.18 mm.
few to rare:	*Polycrystalline quartz*; eq. sr-sa.
	Epidote group minerals.
rare:	*Plagioclase Feldspar*.

Matrix

35-45% non-calcareous. Red-brown in PPL and deep red-brown in XP (x40). Homogeneous. Optically low to non- active.

Void

20-25% voids. Composed mainly of elongate voids, channels and planar voids. None to very weak alignment parallel to margins of samples. Rare voids are remarkably larger that the average size.

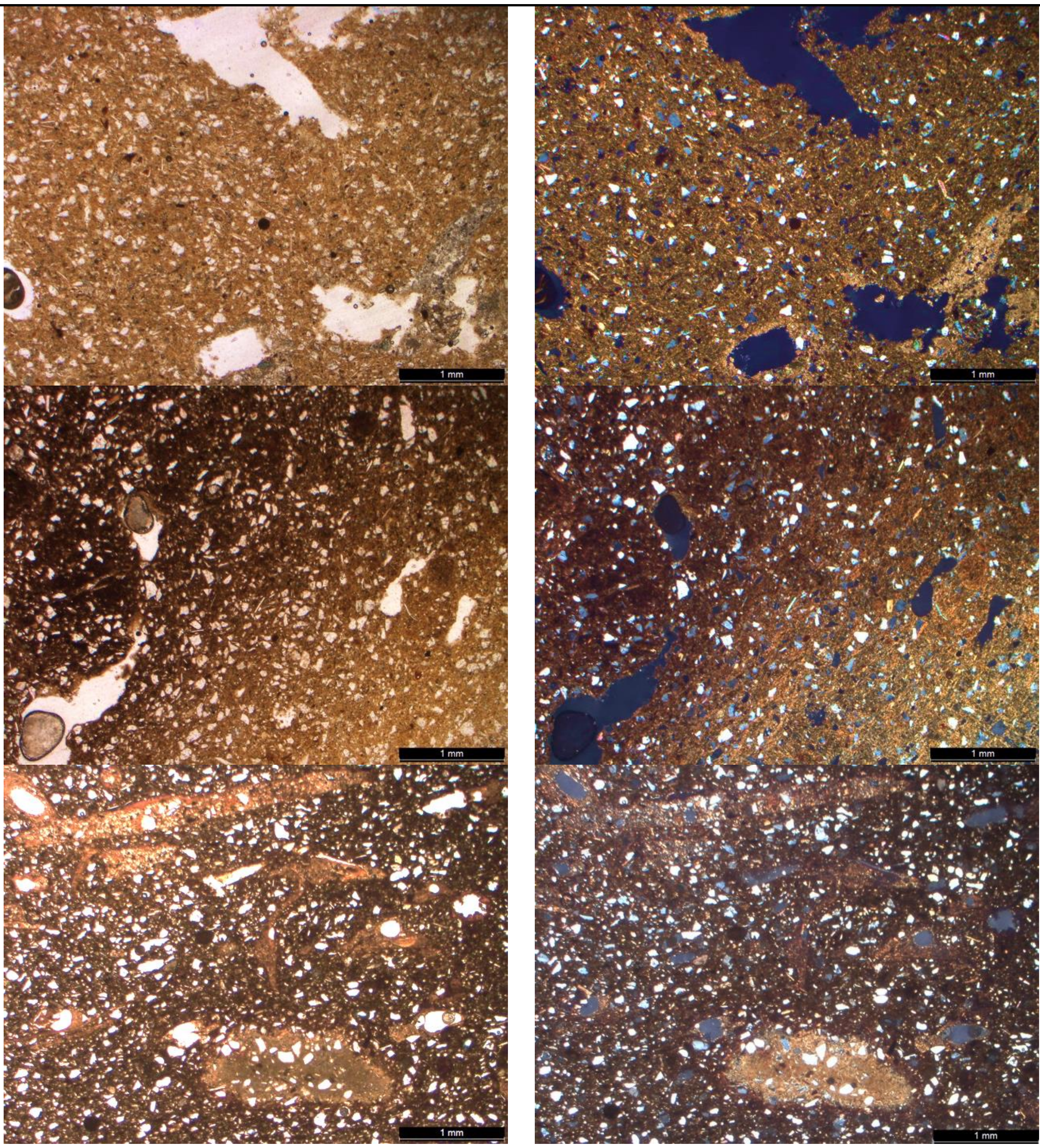
Comments

This coarse fabric group is characterised by the dominant presence of elongate voids in homogeneous clay matrix, mostly non-calcareous. There is a certain degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions, mostly single spaced distance between inclusions . Given the presence of phantoms of coarse vegetal inclusions, samples of these ceramic materials appear to have been produced by the addition of a quantity of organic material, possibly chaff, to a non-calcareous clay containing quartz, mica, brown amphibole, epidote group minerals and iron-rich fragments. The source of the clay was probably an alluvial or fluvial deposit. No samples show alignment of inclusions or void suggestive of the use of coils, or wheel-throwing manufacturing techniques. The possibility of slab building technique and moulding can be considered. Some samples show frequent clay pellets or distinctive clay domains in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage. The low optical activity (XP) and colour (PPL and XP) of samples' matrix suggests firing methods at reasonably high temperatures in an oxidising atmosphere; though some were not entirely oxidised during firing process and may be partially reduced. The use of open-air firing structures could be here suggested to explain the non-homogeneous firing. This group includes some samples. TS-M-77 of subgroup MSD-A2, seems to show crushed shells or fossils.

Class MSD-B: Coarse Calcareous Organic Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-B	MSD-B1	20, 37, 71, 78, 88, 89, 92, 94
	MSD-B2	93, 79, 15
	MSD-B3	13, 36

Top-down: samples TS-M-20, 93, 13. PPL left column, XP right column, scale bar 1mm.



Inclusions

20-25%% eq. sa-sr. < 0.50 mm, mode = 0.20 mm. Double spaced or less. None to crude-alignment to margins of samples. Unimodal grain size distribution.

predominant-dom: *Quartz*; eq. sa < 0.25 mm, mode = 0.15 mm. Straight or undulose extinction.

common: *Muscovite Mica*; el. a-sa < 0.25 mm, mode = 0.20 mm.

few: *Polycrystalline quartz*; eq. sr-sa. < 0.20 mm.

Green amphibole; eq. sr-sa. < 0.10.

rare: *Unoptical iron-rich fragments*; eq. r-sr < 0.30 mm, mode = 0.20 mm.

Clinopyroxene.

Plagioclase Feldspar and possible *Serpentine* and *bones fragments*.

Matrix

60% calcareous. Yellowish-brown in PPL and yellowish-brown in XP (x40). Non-homogeneous. Low optical activity to optically non active. This group shows a calcium carbonate rich clay matrix more than other fabric classes.

Void

25-30% voids. Composed mainly of elongate voids, channels and planar voids. None to very weak alignment parallel to margins of samples.

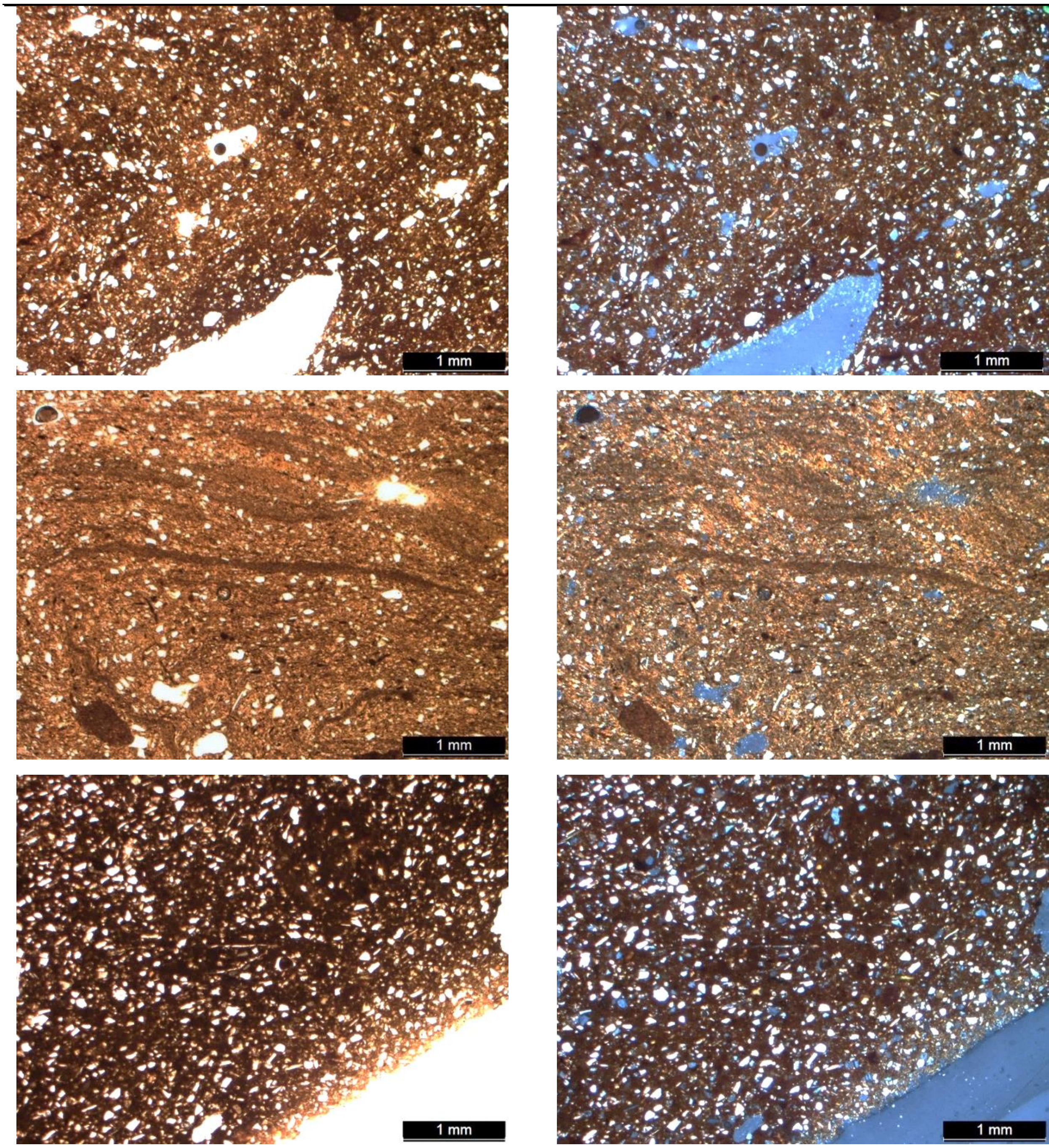
Comments

This coarse fabric group is characterised by a remarkably more calcareous clay matrix and the presence of large voids in a non-homogeneous clay matrix,. There is a certain degree of variation within the fabric group in terms of the grain distribution and spacing of the inclusions. Given the presence of voids likely caused by burnt vegetal inclusions, samples appear to have been produced by the addition of a quantity of organic material, possibly chaff, to a calcium carbonate rich clay paste, quartz, mica, green amphibole, and polycrystalline quartz. The rare presence of clinopyroxene, serpentine and bone fragments was also observed. The source of the clay was probably an alluvial or fluvial deposit. No samples show evidence for the use of coils, or wheel-throwing manufacturing techniques, such as relic-coils or suggestive alignment of inclusions or voids. The possibility of slab building technique and moulding can be considered. Some samples show frequent clay pellets in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage. The optical activity of samples’ matrix suggests firing methods which range from reasonably high-fired to low-fired in an oxidising atmosphere; though some were not entirely oxidised during firing process and may be partially reduced. The use of open-air firing structures could be here suggested to explain the non-homogeneous.

Class MSD-C: Medium-Fine Calcareous Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-C	MSD-C	4, 5, 40, 28, 41, 66, 16, 67, 68, 98

Top-down: samples TS-M-66, 67, 68. PPL left column, XP right column, scale bar 1mm.



Inclusions

20-25%% eq. sa-sr. < 0.30 mm, mode = 0.15 mm. Double spaced or more. Crude to weak alignment to margins of samples. Unimodal grain size distribution.

predominant-dom:	*Quartz*; eq. sa < 0.30 mm, mode = 0.15 mm. Straight or undulose extinction.
common:	*Muscovite Mica*; el. a-sa < 0.35 mm, mode = 0.20 mm.
few:	*Polycrystalline quartz*; eq. sr-sa. < 0.15 mm
	Brown amphibole; eq. sr-sa. < 0.10
	Green amphibole; eq. sr-sa. < 0.10
	TCF, textural concentration features; eq. <2.0 mm, mode 0.5 mm; sharp to merging boundaries; neutral optical density; mostly concordant with matrix. Probably clay pellets.
rare:	*Unoptical iron-rich fragments*; eq. r-sr < 0.30 mm, mode = 0.20 mm.
	plagioclase feldspar,

Matrix

60% calcareous. Yellowish-brown in PPL and yellowish-brown in XP (x40). Heterogenous to almost homogeneous mixing. Low optical activity to optically non active. This group shows a calcium carbonate rich clay matrix.

Void

15-20% voids. Composed mainly of medium to large size voids, including elongate voids, channels and planar voids. Weak alignment parallel to margins of samples.

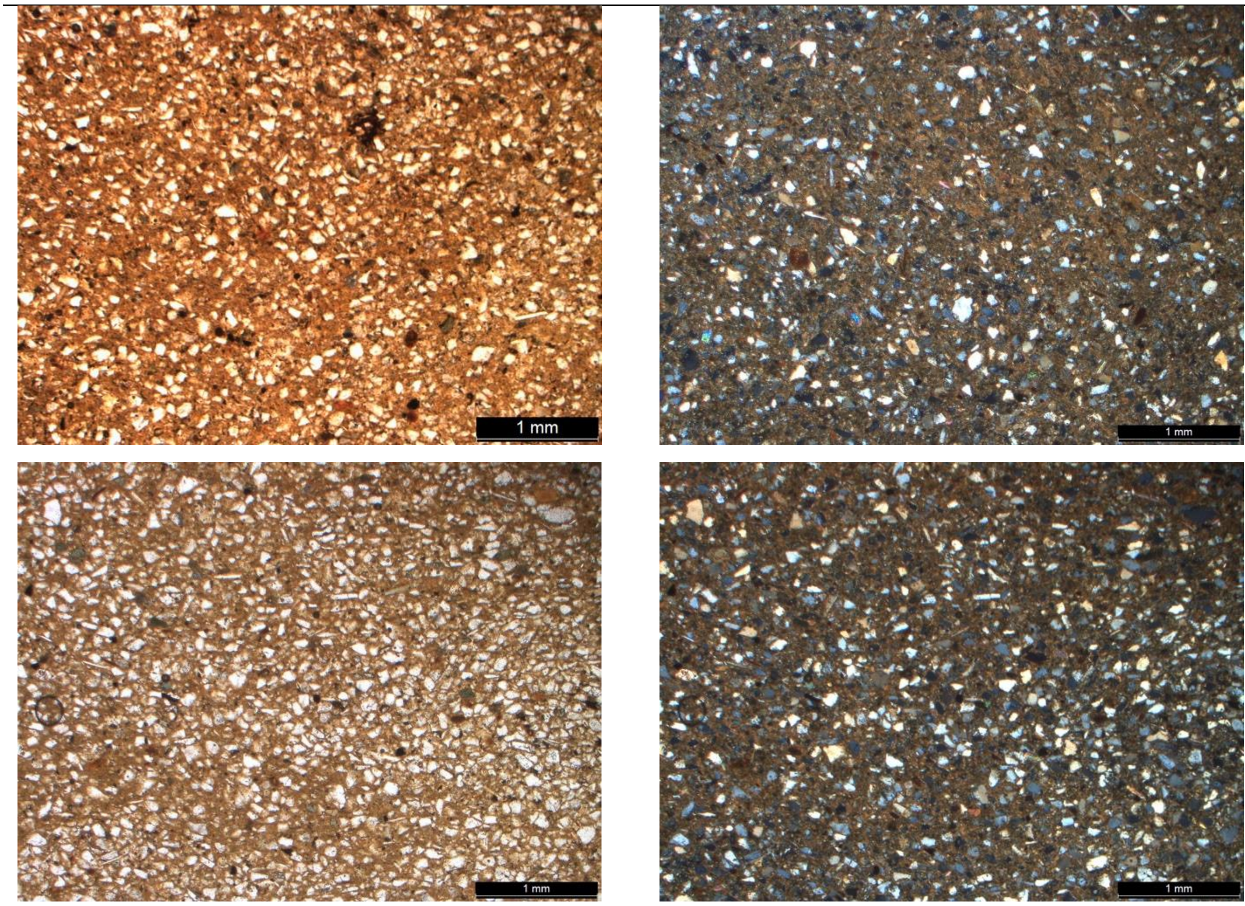
Comments

This fabric group is characterised by a calcareous clay matrix, the presence of medium to fine grained size inclusions, and small to large voids in a homogeneous clay matrix. This clay paste seems more homogenous than other calcaresous fabrics, such as MSD-A and MSD-B. The presence of voids likely caused by burnt vegetal inclusions, samples appear to have been produced by the addition of a quantity of organic material, possibly chaff, to a calcium carbonate rich clay paste, quartz, mica, green amphibole, and polycrystalline quartz. Unlike MSD-B, no serpentine and bone fragments was observed. The source of the clay was probably an alluvial or fluvial deposit. Samples show a weak alignment to the margin of the sections, and possible evidence for the use of coils, such as relic-coils or suggestive alignment of inclusions or voids. The possibility of coil technique, and slab building technique could be considered. Some samples show frequent TCF or clay pellets in the paste, possibly due to rough mixing or processing of clay, or to the addition of dry clay to the paste during the production stage. The optical activity of samples' matrix suggests firing methods reasonably high-fired to low-fired in an oxidising atmosphere. The use of open-air firing structures could be here suggested to explain the non-homogeneous firing.

Class MSD-D: Fine Calcareous Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-D	MSD-D	90, 91

Top-down: samples TS-M-90-91. PPL left column, XP right column, scale bar 1mm.



Inclusions

25-30%% eq. sa-sr. < 0.20 mm, mode = 0.15 mm. Single spaced or more. Crude to weak alignment to margins of samples. Unimodal grain size distribution.

predominant-dom:	*Quartz*; eq. sa < 0.20 mm, mode = 0.15 mm. Straight or undulose extinction.
common:	*Muscovite Mica*; el. a-sa < 0.20 mm, mode = 0.15 mm.
	Green amphibole; eq. sr-sa. < 0.10.
few:	*Polycrystalline quartz*; eq. sr-sa. < 0.15 mm.
	Brown amphibole; eq. sr-sa. < 0.10.

rare: *Unoptical iron-rich fragments*; eq. r-sr < 0.30 mm, mode = 0.20 mm.
Plagioclase Feldspar.

Matrix

60% calcareous. Yellowish-brown in PPL and yellowish-brown in XP (x40). Homogeneous. Low optical activity to optically non active. This group shows a calcium carbonate rich clay matrix.

Void

20-25% voids. Composed mainly of medium to large size voids, including elongate voids, channels and planar voids. Weak alignment parallel to margins of samples.

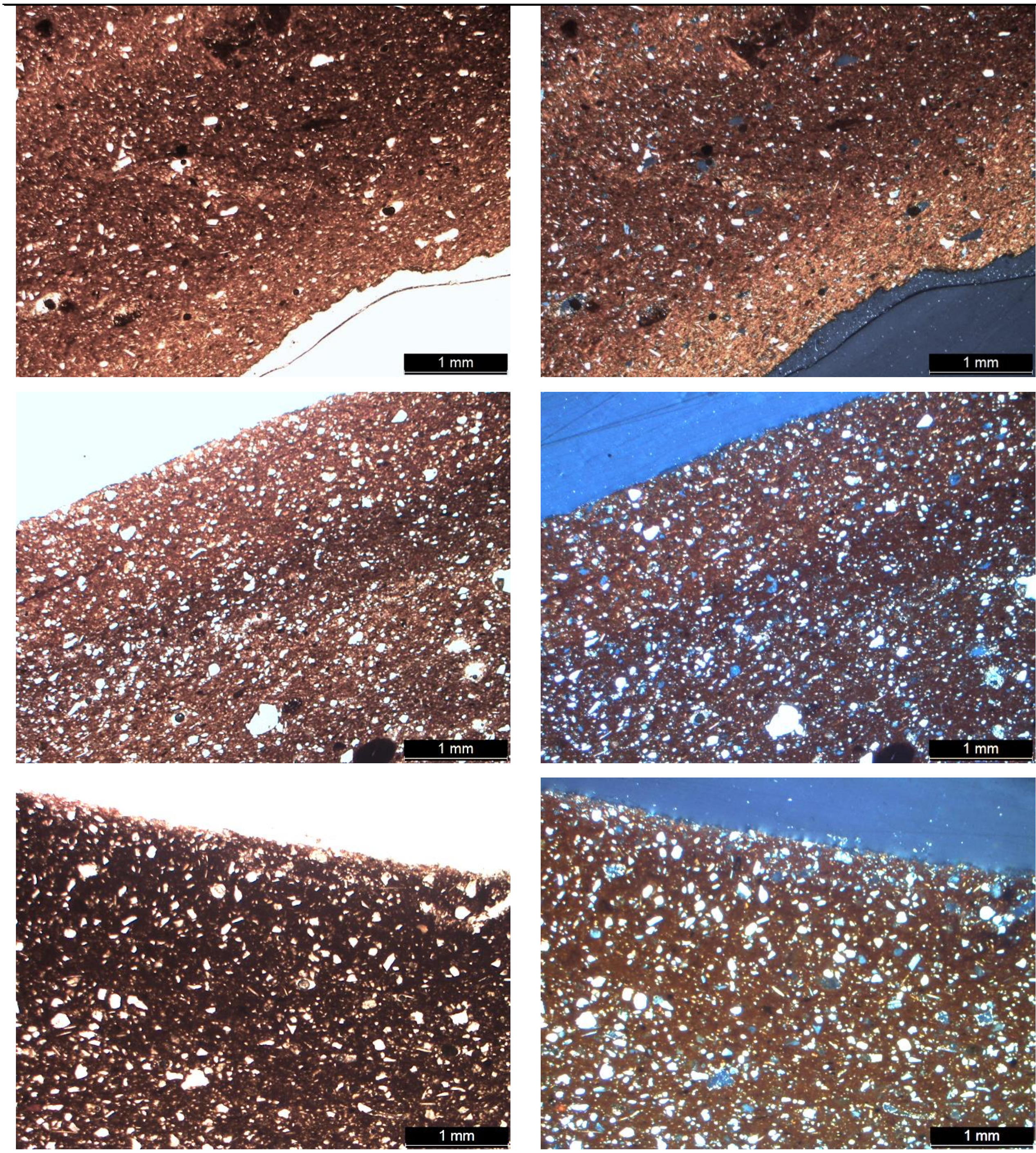
Comments

This fabric group is characterised by a calcareous clay matrix, the presence of fine grained size inclusions, and rare small voids in a homogeneous clay matrix. Unlike MSD-B, no serpentine and bone fragments was observed. The source of the clay was probably an alluvial or fluvial deposit. Samples show a weak alignment to the margin of the sections, and possible evidence for the use of coils, such as relic-coils or suggestive alignment of inclusions or voids. The possibility of coil technique, and slab building technique could be considered. The optical activity of samples' matrix suggests firing methods reasonably high-fired to low-fired in an oxidising atmosphere. The use of open-air firing structures could be here suggested to explain the non-homogeneous firing. Compared to MSD-B and MSD-C, this fabric group shows a remarkably fine and homogenous clay paste.

Class MSD-E: Very Fine Iron-rich Mica and Quartz Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-E	MSD-E	10, 45, 51, 52, 62, 80

Top-down: samples TS-M-10, 45, 62. PPL left column, XP right column, scale bar 1mm.



Inclusions

15-20%% eq. sa-sr. < 0.20 mm, mode = 0.15 mm. Single spaced or less. No alignment to margins of samples. Unimodal grain size distribution.

predominant- dom:	*Quartz*; eq. sa < 0.20 mm, mode = 0.15 mm. Straight or undulose extinction.
common:	*Muscovite Mica*; el. a-sa < 0.20 mm, mode = 0.15 mm.
	Unoptical iron-rich fragments; eq. r-sr < 0.15 mm, mode = 0.15 mm.
few to rare:	*Polycrystalline quartz*; eq. sr-sa.
	Brown amphibole; el. sa-sr
	Epidote group minerals.
Rare:	*Plagioclase Feldspar*.

Matrix

70-75% non-calcareous. Red-brown in PPL and deep red-brown in XP (x40). Homogeneous. Optically low to non- active.

Void

5-10% voids. Composed mainly of planar and subrounded voids. None to very weak alignment parallel to margins of samples. Rare voids are remarkably larger that the average size.

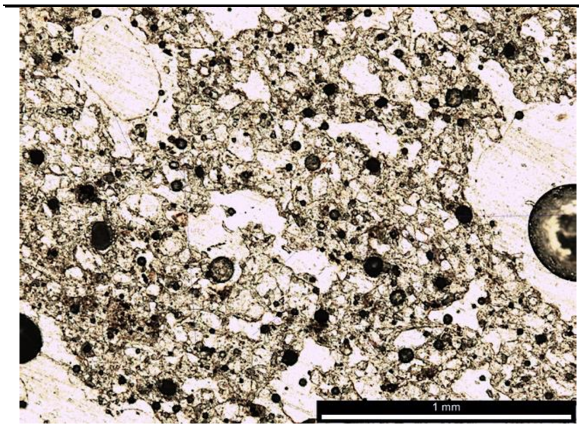
Comments

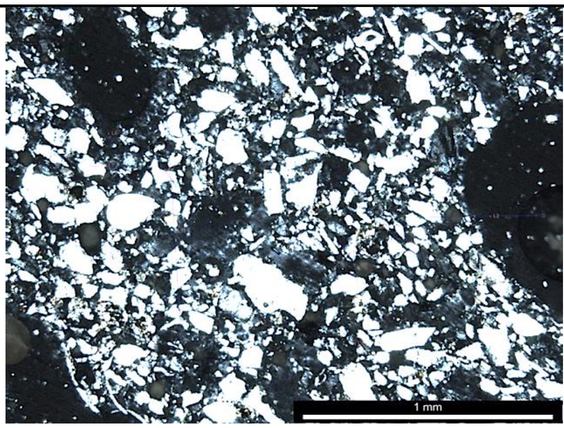
This homogeneous, very fine fabric group is characterised by the presence of very fine mica and quartz inclusions in a mostly non-calcareous red-brown clay with a low presence of voids. The fabric can suggest a mix of non-calcareous and calcarous paste.There is a low abundance of medium-sized rounded dark clay pellets. Possible relic coils can be seen in samples suggesting that the vessels from which the sample came may have been coil built. However, the crude alignment of elongate inclusions and voids in samples may also indicate a certain use of rotatory energy. The samples were well-fired in an oxidising atmosphere. This fabric group, along with group MSD-G, includes the vast majority of ceramic samples

Class MSD-F: Vitrified Fabric Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-F	MSD-F	14, 73

Sample TS-M-14. PPL left column, XP right column, scale bar 1mm.





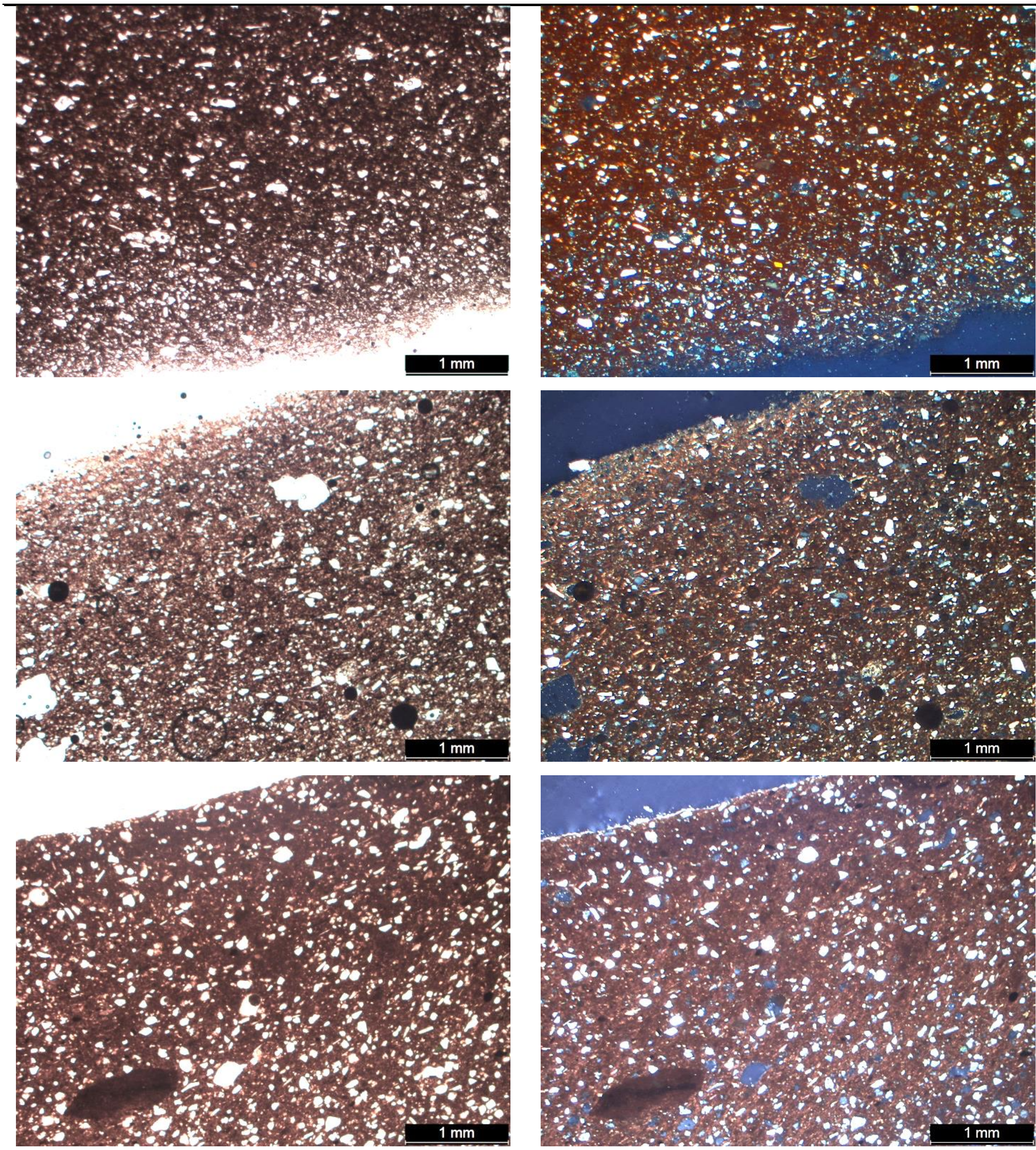
Comments

Siliceous fabric, grey to yellowish grey matric in XP, greyish white to white in PPL. The matrix mostly consists of quartz and very rare mica flakes. At temperatures above 80-900°C clay minerals can start turning isotropic and milky, through a process called vitrification (see Rice 1987:80-110). Clay minerals of the matrix shows an almost completely vitrified appearance.

Class MSD-G: Fine Mica and Quartz Fabric Group

Class	Sub-Group	Thin-section no. (TS-M-)
MSD-G	MSD-G1	65, 58, 86, 59, 64, 61, 84, 46, 1, 53, 30, 57
	MSD-G2	74, 63, 44, 8, 87, 81, 34, 42, 82, 56, 85
	MSD-G3	48, 60, 83, 95, 3, 49, 96, 47, 21, 55, 19, 43, 54, 100, 70, 97, 38, 99, 50, 22, 24, 26, 6, 18, 69, 31, 33, 23, 27, 32, 25, 2, 29, 7, 9

Top-down: samples TS-M-65, 59, 84. PPL left column, XP right column, scale bar 1mm.



Inclusions

15-20 %. eq and el.sa-a. < 0.3 mm. Double-spaced or more. Weakly aligned to margins, especially in proximity of the surface. Mostly unimodal grain size distribution.

predominant-dom:	*Quartz*; eq. sa-a. < 0.20 mm, mode 0.15 mm. Undulose extinction
frequent:	*Muscovite Mica*; el. a.-sa. < 0.20 mm, mode 0.15 mm.
rare:	*Amphibole hornblade; eq. sr.* < 0.15 mm
	Ferrous minerals, unoptical iron-rich fragments < 0.15 mm
	Limestone or calcite inclusions; eq. sr. < 0.20 mm
	TCF, textural concentration features; eq. <2.0 mm, mode 0.5 mm; sharp to merging boundaries; neutral optical density; mostly concordant with matrix. Probably clay pellets.
very rare:	*Plagioclase Feldspar* < 0.10 mm

Matrix

70-75 % mix non-calcareous and calcarous paste. Brown in PPL, red-brown in XP (x50). Homogeneous, but with rare clay pellets in samples and coil-or-swirl. Optically inactive.

Voids

5-10 %. Consisting mainly of meso-channels and meso-vughs, with very rare mega-vughs. Crudely aligned to margins in some samples. Some secondary calcite deposition in voids.

Comments

This homogeneous, fine fabric group is characterised by the presence of fine mica and quartz inclusions in a mostly non-calcareous red-brown clay with a low abundance of voids. The fabric can suggest a mix of non-calcareous and calcarous paste.There is a low abundance of medium-sized rounded dark clay pellets. However, these inclusions appear to have been naturally present in the otherwise fine clay that was used to produce the samples. Possible relic coils can be seen in samples suggesting that the vessels from which the sample came may have been coil built. However, the crude alignment of elongate inclusions and voids in samples may also indicate a certain use of rotatory energy. The samples were moderately well-fired in an oxidising atmosphere. This fabric group, along with group MSD-E, includes the vast majority of ceramic samples. A possible subgroup, MSD-G2 , slightly richer in plagioclase inclusions (TS-M-2, 3, 4, 48, 60, 78) could also be defined.

Class ALM-A: Iron rich micaceous fabric

Subgroup ALM-A1: Fine Iron rich micaceous fabric

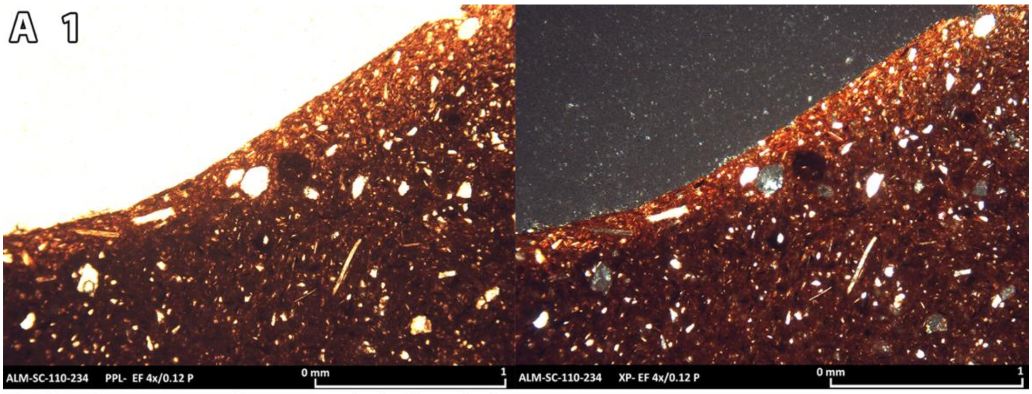
GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-A1	FIRM	361, 394, 475, 481, 507	81, 100, 130, 137, 180, 183, 192, 203, 204, 221, 222, 228, 234, 235, 268	22, 36, 42

Subgroup ALM-A2: Medium-fine Iron rich micaceous fabric

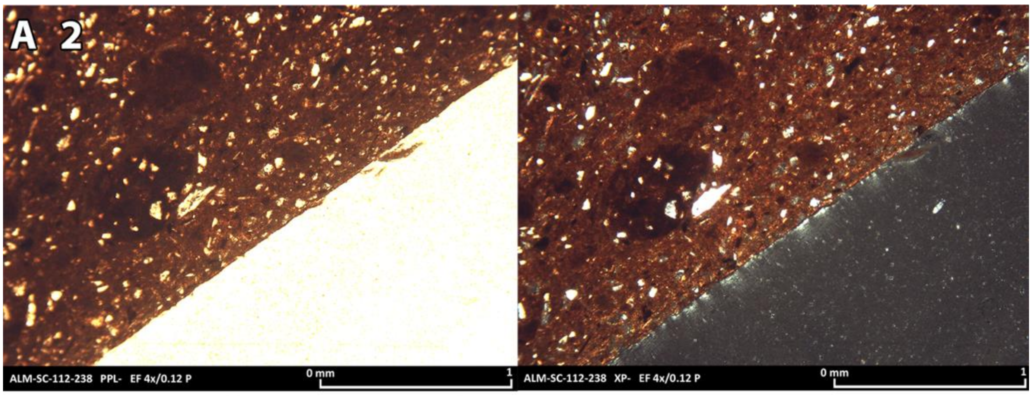
GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-A2	MFIRM	370	68, 111, 121, 177, 183, 202, 214, 201, 238	2, 3, 13, 24

Subgroup ALM-A3: Very fine iron rich clay and quartz fabric

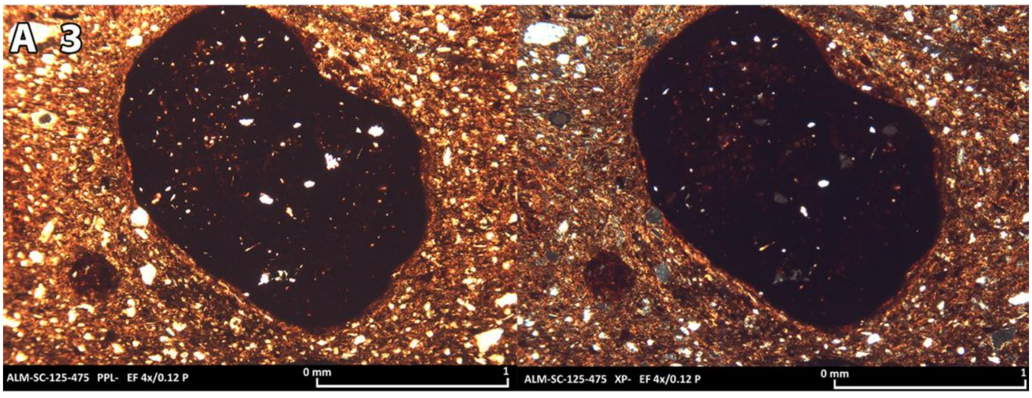
GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-A3	VFIRCQ	n/a	105, 159, 172, 178, 229, 250	1, 27, 55



TS-A-53, Sherd ALM-SC-110-234



TS-A-55, Sherd ALM-S- 112-238



TS-A-65, Sherd ALM-SC-125-475

Inclusions

10-15% eq and el. sa.-sr. < 0.3 mm. Double-spaced or more. Weakly aligned to margins. Unimodal, well-sorted grain size distribution.

dominant:	*Quartz*; 10% eq and el. sa.-sr. < 0.3 mm, mode = 0.25 mm. Composed of well-sorted, equant sub-angular and sub-rounded, non-oriented quartz fragments, which are contained in a fine alluvial iron-rich non calcareous clay matrix.
frequent:	*Muscovite mica*; 5-10% el. and sa. < 0.3 mm, mode = 0.23 mm. Well-sorted, elongated sub-angular, weakly oriented colourless mica flakes. Usually white in PPL and light orange-brown in XP.
common:	*Biotite mica*; 5% el. and sa. < 0.3 mm, mode = 0.25 mm. Well-sorted, elongated sub-angular, weakly oriented colourless mica flakes. Usually dark brown in PPL and reddish-brown in XP.
	Micritic calcite; 5% el. and sa. < 0.3 mm, mode = 0.3 mm. Equant sub-rounded, non-oriented lumps of limestone. Reddish-brown to orange-brown in PPL.
	Ferruginous nodules; 5% el. and sa. < 1 mm, mode = 0.5 mm. Equant sub-rounded, non-oriented iron-rich nodules. Usually dark brown to black in PPL and dark brown to black in XP.
rare:	*Polycrystalline Quartz*; el. and sa.-sr. < 0.3 mm, mode = 0.2.5 mm. Equant sub-rounded, non-oriented polycrystalline quartz fragments.
very rare:	*Amphibole*; eq and sa.-sr. < 0.2 mm, mode = 0.15 mm. Composed of equant sub-rounded, non-oriented amphibole. Usually reddish-brown in PPL and reddish-orange in XP, possibly due to firing alteration.

Matrix

70-75%. A fine alluvial iron-rich non calcareous clay matrix. Golden-brown to yellowish-brown in PPL, red-brown to deep brown in XP (x40). Homogeneous. Little core-margin differentiation. Optically inactive, highly fired clay.

Voids

5-10%. mode = 0.5 mm. Consisting mainly of elongated sub-rounded voids. Moderate alignment of voids to margins of sections.

Subgroup A1 Comments

This fabric is characterised by the presence of fine inclusions. The lack of larger inclusions, along with the lack of evidence for the use of organic inclusions and relatively rare voids, suggest that local clay was very well levigated. The presence of ferruginous nodules is distinctive of this fabric group, along with the homogeneous appearance of the fabric. The non-optical nature of the fabric and the presence of reddish amphibole are suggestive of high firing regime. The source of the clay seems to be alluvial, sedimentary argillaceous deposits. Some samples show secondary calcite deposits on the surface and within the voids. An applied, fine slip is visible in some samples.

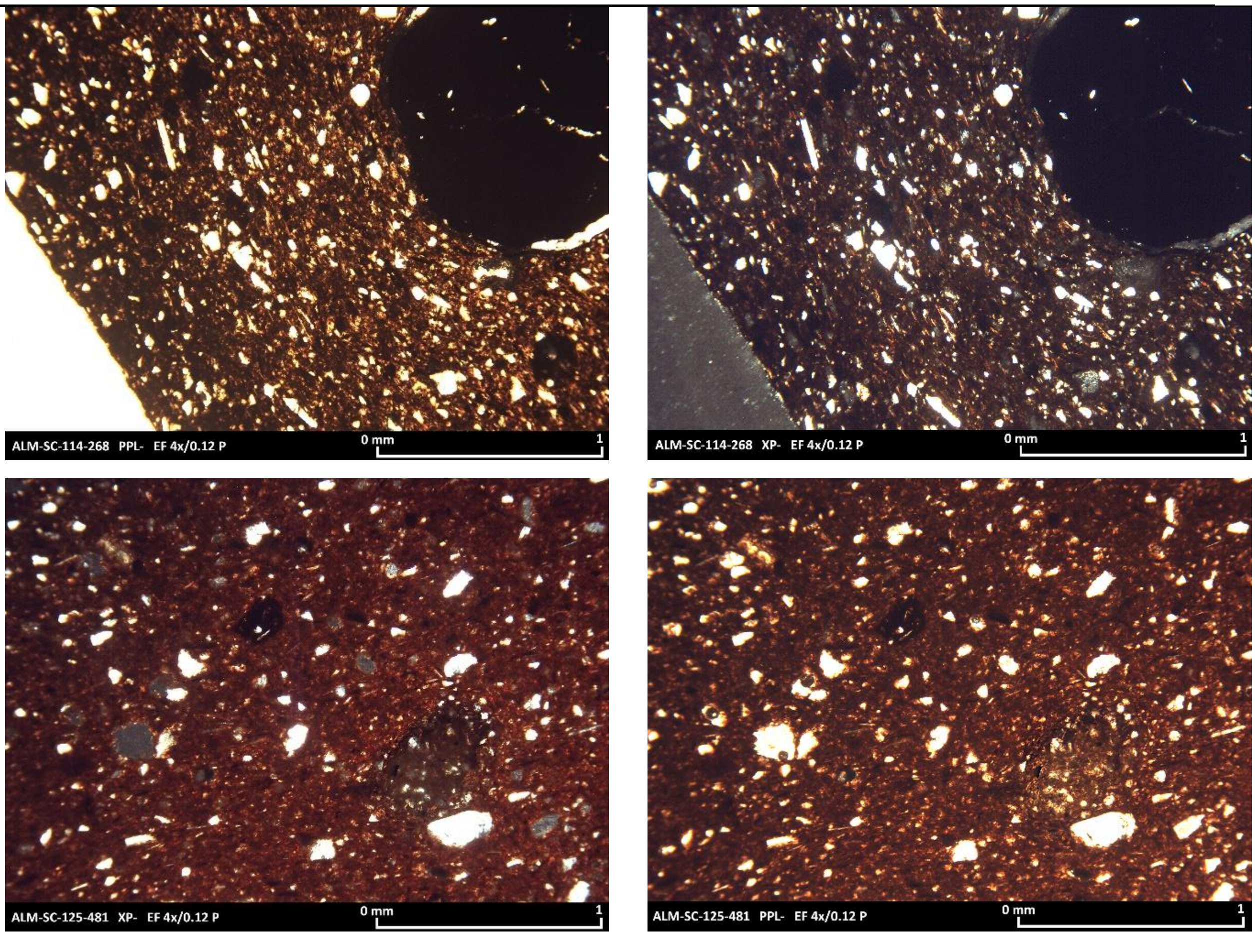
Subgroup A2 Comments

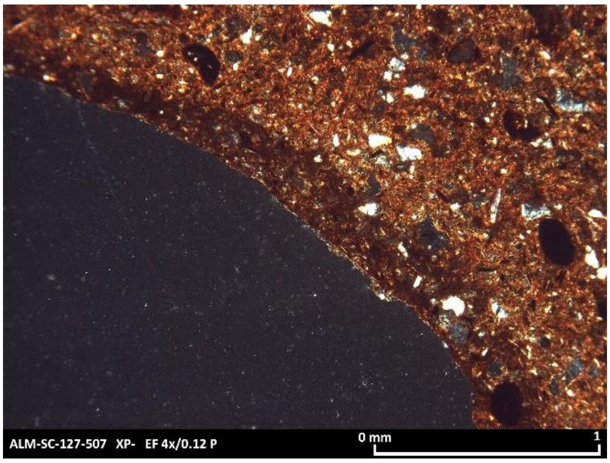
This fabric is characterised by the presence of medium fine inclusions. Besisdes the slightly larger inclusions characterising this group, this fabric shared most elements of A1 (see above). An applied, fine slip is visible in some samples (e.g. ALM-SC-106-183). Sub-**variation:** Sample ALM-SC-104-12. Rare Micritic calcite; Equant sub-rounded, non-oriented lumps of limestone. Micritic calcite is usually reddish-brown to orange-brown in PPL and deep brown to greyish-brown in XP.

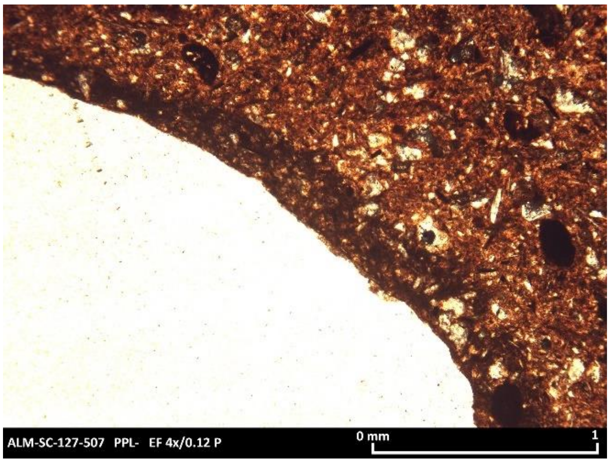
Subgroup A3 Comments

This fabric is characterised by the presence of very fine rare inclusions. This petrographic group can be considered as a finer variety of group 'TR-A1 and Tr-A2'. The lack of larger inclusions, along with the lack of evidence for the use of organic inclusions and relatively rare voids, suggest that local clay was very well levigated. The presence of ferruginous nodules is distinctive of this fabric group, along with the homogeneous appearance of the fabric. The non-optical nature of the fabric and the presence of reddish amphibole are suggestive of high firing regime, under different degrees of oxygen availability. The source of the clay seems to be alluvial, sedimentary argillaceous deposits. Some samples show secondary calcite deposits on the surface and within the voids. An applied, fine slip or self-slip (grey or dark red in colour) is visible in some samples (e.g. ALM-SC-112-250; ALM-SC-102-55).

Other examples: Petrographic Group ALM-A




ALM-SC-127-507 XP- EF 4x/0.12 P
0 mm
1


ALM-SC-127-507 PPL- EF 4x/0.12 P
0 mm
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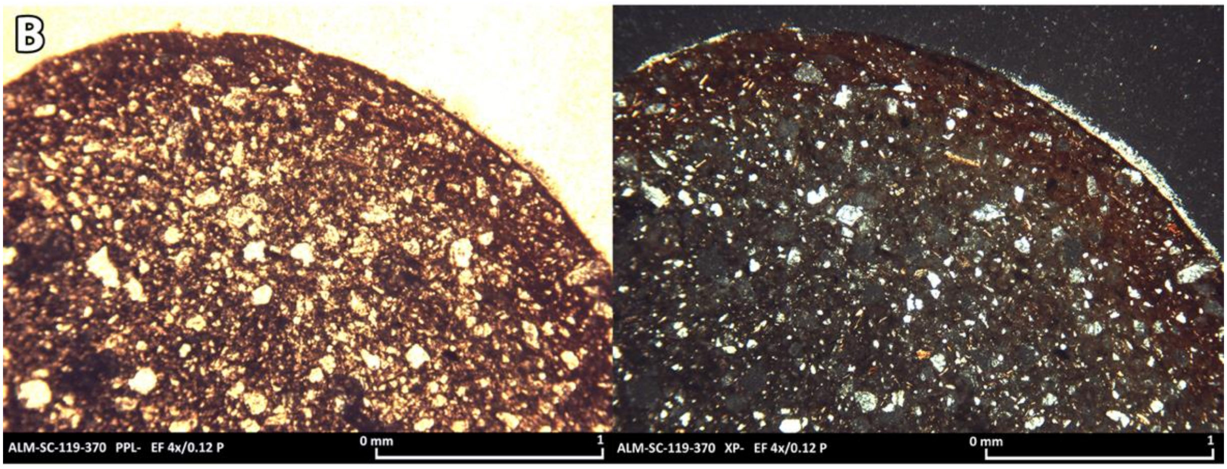
Class ALM-B: Fine Sand-tempered Fabric

Class	Sub-Group	Thin-section no. (TS-A-)
ALM-B	ALM-B	22, 62, 63, 97



TS-A-63, Sherd ALM-SC-119-370

Inclusions

25-30% Eq and el. sa.-sr. < 1.0 mm. Single-spaced or more. Weakly aligned to margins. Unimodal, well-sorted grain size distribution.

dominant:	*Quartz*; eq and sr. < 0.3 mm, mode = 0.2 mm. Composed of well-sorted, equant and sub-rounded, non-oriented quartz fragments.
frequent:	*Muscovite mica*; el. and sa. < 0.3 mm, mode = 0.25 mm. Poorly-sorted, elongated sub-angular, non-oriented colourless mica flakes. Usually white in PPL and light orange-brown in XP.
rare:	*Biotite mica*; el. and sa. < 0.3 mm, mode = 0.25 mm. Elongated sub-angular, non-oriented mica flakes. Usually brown in PPL and reddish-brown in XP.
	Ferruginous nodules; eq. and sr. < 1.0 mm, mode = 0.8 mm. Equant sub-rounded, non-oriented iron-rich nodules. Usually dark brown to black in PPL and dark brown to black in XP.
very rare:	*Amphibole*; eq and sr. < 0.15 mm, mode = 0.1 mm. Equant, sub-rounded, non-oriented amphibole. Usually reddish-brown in PPL and reddish-orange in XP, possibly due to firing alteration.

Iron-rich fragments. el. and sa. < 0.2 mm, mode = 0.15 mm. Equant sub-rounded, non-oriented iron-rich fragments (possibly hematite). Usually dark brown to black in PPL and dark brown to black in XP.

Matrix

60-65%. A fine alluvial iron-rich non calcareous clay matrix. Golden-brown to dark-brown in PPL, greish, dark-brown to reddish brown in XP (x40). Homogeneous matrix. Significant core-margin differentiation in colours. Optically inactive, likely highly fired clay.

Voids

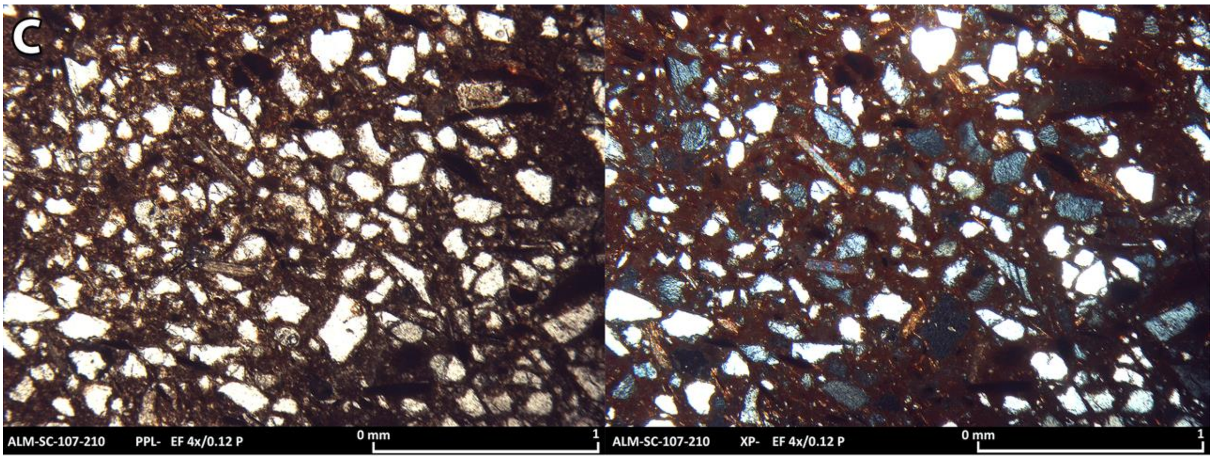
5-10%. mode = 0.5 mm. Consisting mainly of sub-rounded channels and vesicles. Moderate alignment of voids to margins of sections.

Comments

This fabric is characterised by the presence of medium fine inclusions. It is compositionally similar to group ALM-A, but it shows remarkably more abundant and rounded inclusions, as well as different XP and PPL colours, likely due to different firing techniques from ALM-A ceramic pastes. The lack of larger inclusions, along with the lack of evidence for the use of organic inclusions ,and relatively rare voids, suggest that local clay was very well cleansed. The presence of ferruginous nodules is another distinctive features of this fabric group, along with the homogeneous composition. The non-optical nature of the fabric and the presence of reddish amphibole are suggestive of high firing regime. The source of the clay seems to be alluvial, sedimentary argillaceous deposits. An applied, fine slip is visible in some samples. In XP, the core of the section seems grey to grey-ish brown, while the margins and external areas of the sections appear reddish-grey and reddish-brown. This may be due to specific firing and cooling techniques.

Class ALM-C: Coarse Sand-tempered Fabric

GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-C	CSF	n/a	210	66



TS-A-44, Sherd ALM-SC-107-210

Inclusions

20%. Eq. and el. sa-sr. single-spaced to double-spaced. Not aligned to margins of samples. Unimodal, moderately sorted grain size distribution.

- dominant*:* *Quartz*, eq and el. sa-sr. < 0.25 mm, mode = 0.2 mm. Composed of moderately sorted, equant to elongated, randomly oriented quartz fragments. Some are strongly connected with flakes of mica. Possibly related to medium-grade metamorphic rocks.
- frequent*:* *Muscovite Mica*, el. sa. < 1 mm, mode = 0.8 mm. Elongated, poorly-sorted, randomly oriented flakes of Muscovite Mica. White in PPL and high second order birefringence in XP.
- common*:* *Opaque iron*, eq. sa-sr < 0.25 mm. mode = 0.15 mm. Fine fragments of ferromagnesian minerals.
- few*:* *Biotite Mica*, el. sr. < 1 mm, mode = 0.7 mm. Elongated, poorly-sorted flakes of Biotite Mica. Brown to reddish-brown in PPL and high second order birefringence in XP.

  Quartzite, eq. sr. < 0.25 mm, mode = 0.2 mm. Moderately sorted, equant, randomly oriented fragments of quartzite.

Ferrouginous nodules, eq and el sr.-r. < 2 mm, mode = 0.7 mm. Amorphous to well-rounded iron nodule of possible pedogenic origin containing some quartz grains.

rare*:* Plagioclase Feldspar, el. sr. < 0.7, mode: 0.5 mm. Subhedral fragments of Plagioclase Feldspar. Albite twinning and zoning are visible.

Matrix

73%. A fine alluvial iron-rich non calcareous clay matrix. Light-brown to yellowish-brown in PPL, red-brown to deep brown in XP (x40). Possible evidence for clay mixing. Little core-margin differentiation. Optically inactive, highly fired clay. The matrix shows at least two varieties of clays in the samples, especially in close proximity to the edges of the sections. This can be understood as evidence for either clay mixing of calcareous and non-calcarous clays, or for possible percolation of secondary calcite.

Voids

7%. mode = 2 mm. Consisting mainly of amorphous elongated sub-rounded voids. Moderate alignment of voids to margins of sections.

Comments

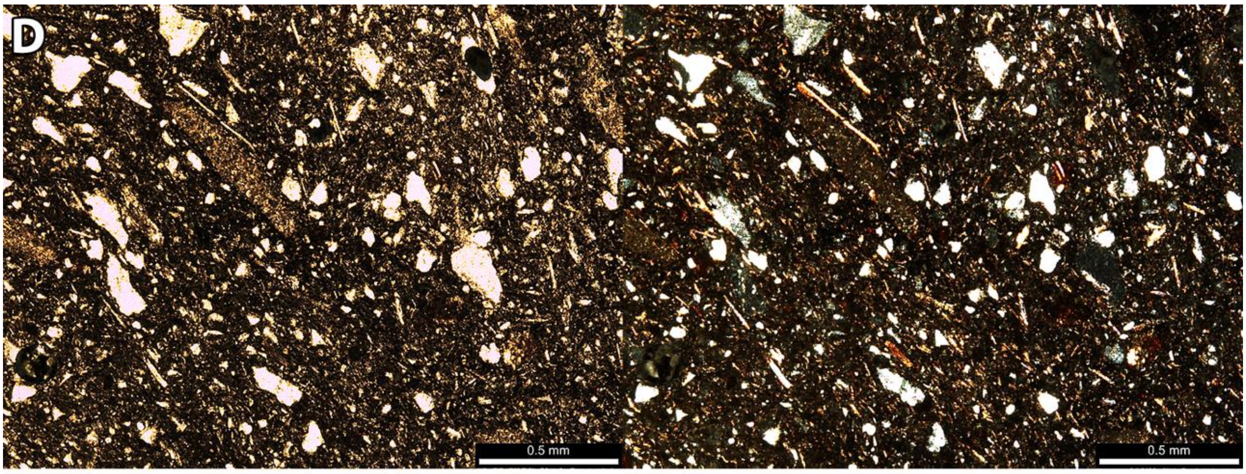
This fabric is characterised by the presence of coarse inclusions, moderately sorted. The uneven distribution of aplastic inclusions in the paste could be a consequence of the addition of temper in a well standardized grain-size and suggests a non-homogeneous, irregular clay paste preparation. The combination of inclusions suggests the presence of medium-grade metamorphic rocks as main source of aplastic inclusions. The presence of ferruginous/ iron nodules, of possible pedogenic origin, is distinctive of this fabric group, which could be used to trace the provenance of raw clay. The non-optical nature of the clay fabric is suggestive of high firing regime. The source of the clay seems to be alluvial, sedimentary argillaceous deposits.

The matrix shows at least two varieties of clays in the samples, especially in close proximity to the edges of the sections. This can be understood as either clay mixing of calcareous and non-calcarous clays, or evidence fo7r possible percolation of secondary calcite. Some samples show secondary calcite deposits also on the surface and within voids.

An applied, coarse rustication is visible on same samples (e.g. ALM 105-153). The applied slurry is coarser (inclusions <30%) than the paste used for producing the body of vessels; nevertheless, similar inclusions are visible. The clay matrix of the slurry looks brighter than the rest of the section, orange-brown in colour. The slurry is applied only on the external surface.

Class ALM-D: Coarse Micaceous Polycrystalline Quartz Fabric

GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-D	CMPQ	364	187, 212, 242, 251	n/a



TS-A-83, Sherd ALM-SC-125-474

Inclusions

15-20% Eq and el. sa.-sr. < 0.5 mm. Double-spaced or more. Weakly aligned to margins. Unimodal, well-sorted grain size distribution.

dominant: *Quartz*; 5-10% eq and el. sa.-sr. < 0.3 mm, mode = 0.2 mm. Composed of poorly-sorted, equant sub-angular and sub-rounded, non-oriented rare quartz fragments, which are contained in a fine alluvial iron-rich non calcareous clay matrix.

frequent: *Muscovite mica*; 5% el. and sa. < 0.2 mm, mode = 0.2 mm. Elongated sub-angular, weakly oriented colourless mica flakes. Usually white in PPL and light orange-brown in XP.

Ferruginous nodules; 5% el. and sa. <0.5 mm, mode = 0.5 mm. Equant sub-rounded, non-oriented iron-rich nodules. Usually dark brown to black in PPL and dark brown to black in XP.

rare: *Biotite mica*; 1% el. and sa. < 0.3 mm, mode = 0.2 mm. Elongated sub-angular, weakly oriented colourless mica flakes. Usually brown to dark brown in PPL and reddish-brown in XP.

Polycrystalline Quartz; el. and sa.-sr. < 0.4 mm, mode = 0.4 mm. Equant sub-rounded, non-oriented polycrystalline fragments.

Matrix

75%. A fine alluvial iron-rich non calcareous clay matrix. Golden-brown to yellowish-brown in PPL, red-brown to deep brown in XP (x40). Ash grey to battleship grey (PPL) when fired in reducing atmosphere. Heterogeneous. Little core-margin differentiation. Optically inactive, highly fired clay.

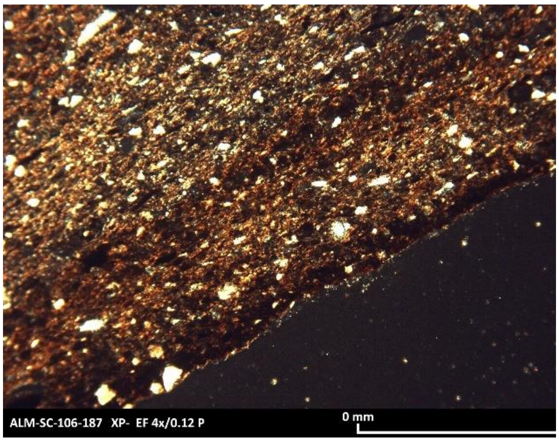
Voids

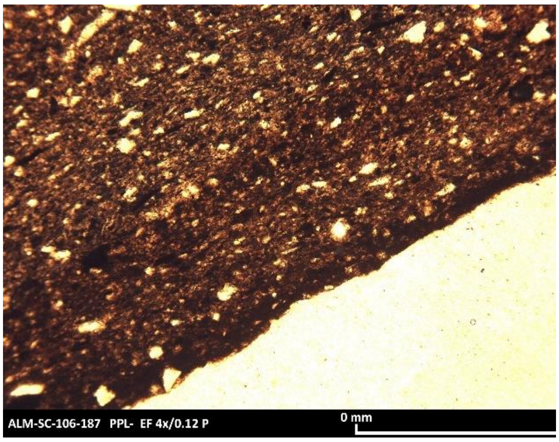
5%. mode = 0.5 mm. Consisting mainly of elongated sub-rounded voids and vesicles. Moderate alignment of voids to margins of sections.

Comments

This fabric is characterised by the presence of medium to fine inclusions. The lack of larger inclusions, along with the lack of evidence for the use of organic inclusions and relatively rare voids, suggest that local clay was very well levigated. Large ferruginous nodules are visible of this fabric group, along with the homogeneous appearance of the fabric. The non-optical nature of the fabric and the presence of reddish amphibole are suggestive of high firing regime, under different degrees of oxygen availability. The source of the clay seems to be alluvial, sedimentary argillaceous deposits. Some samples show secondary calcite deposits on the surface and within the voids. An applied slip is visible in most samples (e.g. ALM-SC-119-364; ALM-SC-112-242; ALM-SC-112-251; ALM-SC-106-187). Another distinctive feature of this fabric group is the clay mixing. Compared (187) to other petrographic groups from Alamgripur, ceramic thin-sections present an irregular mixing of different clay pastes, which are not homogenised. For instance, sample ALM-106-187 shows two types of clay pastes, distinguished by colours and frequency of iron-rich inclusions, which are not homogeneously mixed.

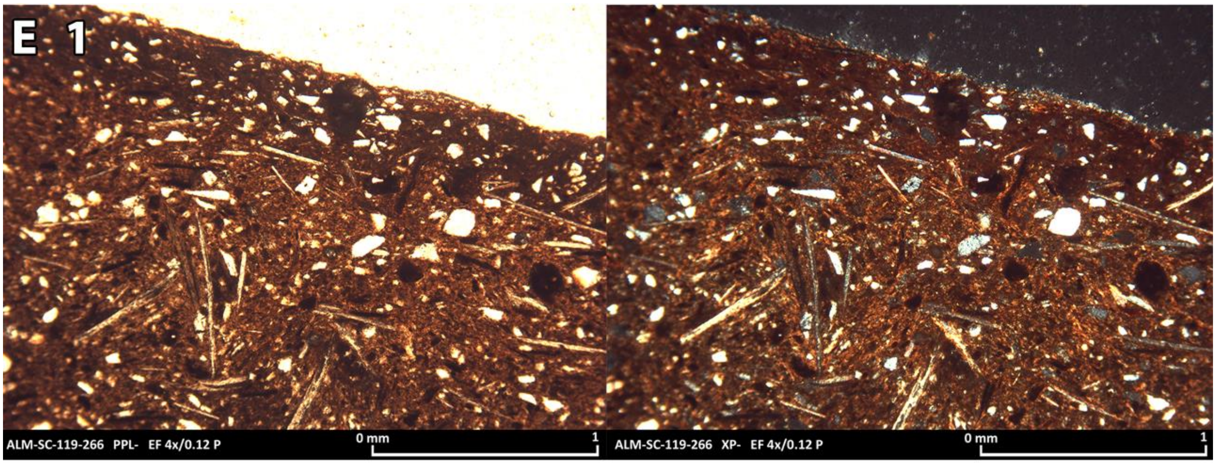
Examples: Petrographic group TR-D



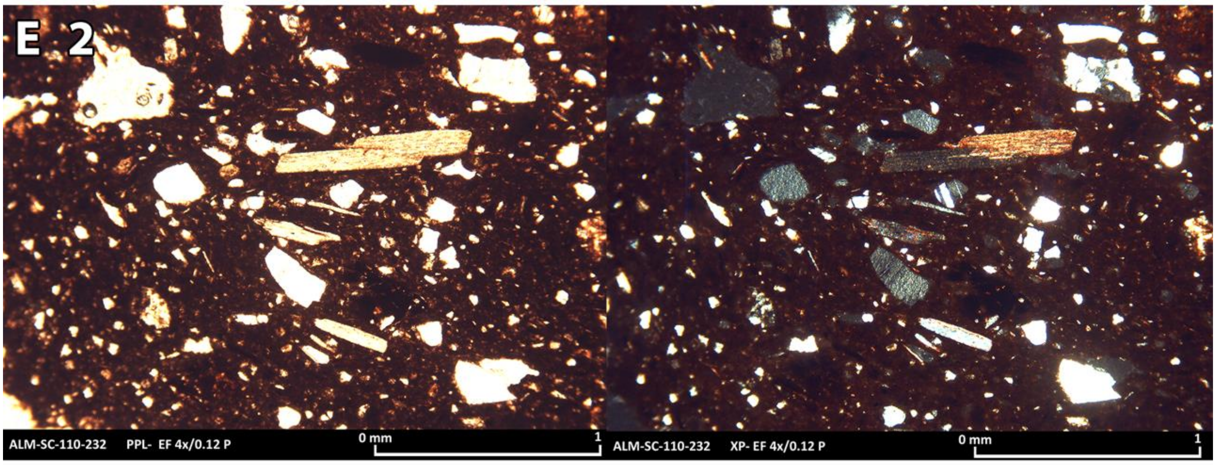


Class ALM-E: Coarse Metamorphic Fabric

GROUP	CODE	INDUS URBAN-PERIOD (sherd numbers)	POST-URBAN (sherd numbers)	POST-INDUS TRANSITION (sherd numbers)
TR-B	CMF	n/a	69, 90, 115, 133, 153, 207, 216, 232, 266	6, 37, 38, 49



TS-A-59, Sherd ALM-SC-114-266



TS-A-52, Sherd ALM-SC-110-232

Inclusions

20%. Eq. and el. sa-sr. single-spaced to double-spaced. Not aligned to margins of samples. Unimodal, moderately sorted grain size distribution.

dominant*:*	*Quartz*, eq and el. sa-sr. < 0.25 mm, mode = 0.2 mm. Composed of moderately sorted, equant to elongated, randomly oriented quartz fragments. Some are strongly connected with flakes of mica. Possibly related to medium-grade metamorphic rocks.
frequent*:*	*Muscovite Mica*, el. sa. < 1 mm, mode = 0.8 mm. Elongated, poorly-sorted, randomly oriented flakes of Muscovite Mica. White in PPL and high second order birefringence in XP.
common*:*	*Opaque iron*, eq. sa-sr < 0.25 mm. mode = 0.15 mm. Fine fragments of ferromagnesian minerals.
few*:*	*Biotite Mica*, el. sr. < 1 mm, mode = 0.7 mm. Elongated, poorly-sorted flakes of Biotite Mica. Brown to reddish-brown in PPL and high second order birefringence in XP.
few*:*	*Quartzite*, eq. sr. < 0.25 mm, mode = 0.2 mm. Moderately sorted, equant, randomly oriented fragments of quartzite.
	Ferrouginous nodules, eq and el sr.-r. < 2 mm, mode = 0.7 mm. Amorphous to well-rounded iron nodule of possible pedogenic origin containing some quartz grains.
rare:	*Plagioclase Feldspar*, el. sr. < 0.7, mode: 0.5 mm. Subhedral fragments of Plagioclase Feldspar. Albite twinning and zoning are visible.

Matrix

73%. A fine alluvial iron-rich non calcareous clay matrix. Light-brown to yellowish-brown in PPL, red-brown to deep brown in XP (x40). Possible evidence for clay mixing. Little core-margin differentiation. Optically inactive, highly fired clay. The matrix shows at least two varieties of clays in the samples, especially in close proximity to the edges of the sections. This can be understood as evidence for either clay mixing of calcareous and non-calcarous clays, or for possible percolation of secondary calcite.

Voids

7%. mode = 2 mm. Consisting mainly of amorphous elongated sub-rounded voids. Moderate alignment of voids to margins of sections.

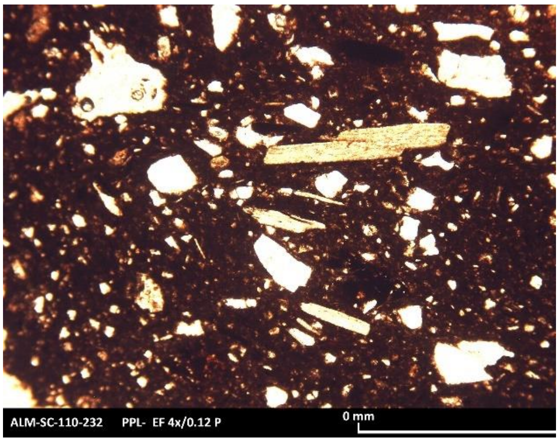
Comments

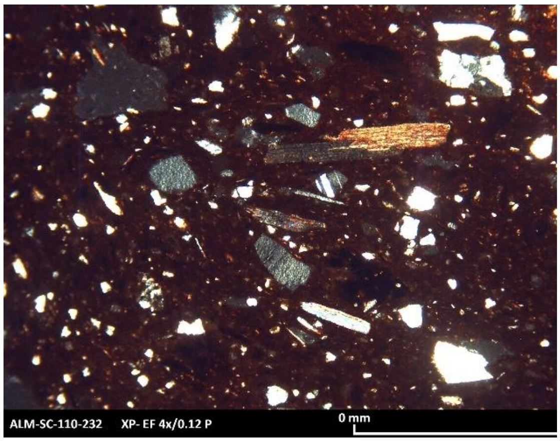
This fabric is characterised by the presence of coarse inclusions, moderately sorted. The uneven distribution of aplastic inclusions in the paste could be a consequence of the addition of temper in a well standardized grain-size and suggests a non-homogeneous, irregular clay paste preparation. The combination of inclusions suggests the presence of medium-grade metamorphic rocks as main source of aplastic inclusions. The presence of ferruginous/ iron nodules, of possible pedogenic origin, is distinctive of this fabric group, which could be used to trace the provenance of raw clay. The non-optical nature of the clay fabric is suggestive of high firing regime. The source of the clay seems to be alluvial, sedimentary argillaceous deposits.

The matrix shows at least two varieties of clays in the samples, especially in close proximity to the edges of the sections. This can be understood as either clay mixing of calcareous and non-calcarous clays, or evidence for possible percolation of secondary calcite. Some samples show secondary calcite deposits also on the surface and within voids.

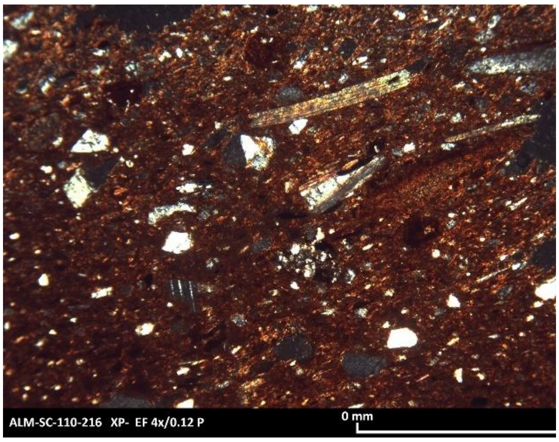
An applied, coarse rustication is visible on same samples (e.g. ALM 105-153). The applied slurry is coarser (inclusions <30%) than the paste used for producing the body of vessels; nevertheless, similar inclusions are visible. The clay matrix of the slurry looks brighter than the rest of the section, orange-brown in colour. The slurry is applied only on the external surface.

Examples: Petrographic group TR-B






ALM-SC-110-216 PPL- EF 4x/0.12 P
0 mm


ALM-SC-110-216 XP- EF 4x/0.12 P
0 mm

Appendix C: Geochemical data

Table C1. Chemical data expressed in parts-per-million (ppm). Samples descriptions is available in Appendices A and B. It shows a 1000 separator (,) and no decimals for ppm.

Sample No.	Site	Type	Context	Fe (ppm)	Ga (ppm)	K (ppm)	Nb (ppm)	Rb (ppm)	Sr (ppm)	Ti (ppm)	Y (ppm)	Zn (ppm)	Zr (ppm)
CSR_01	na	na	na	30,922	10	37,230	9	105	354	3,201	17	79	124
CSR_04	Rakhigarhi	clay	soil	46,166	16	30,062	14	152	151	4,233	25	162	179
CSR_05	Lohari Ragho I	clay	soil	37,180	12	18,833	12	88	141	3,858	27	70	297
CSR_09	Lohari Ragho I	clay	soil	27,743	12	22,999	11	92	179	3,410	24	68	240
CSR_10	Lohari Ragho I	clay	soil	29,474	12	17,163	11	90	169	3,934	25	61	289
CSR_11	Lohari Ragho I	clay	soil	30,591	14	18,498	10	100	147	3,813	22	99	240
CSR_12	Lohari Ragho I	clay	soil	31,681	14	19,683	11	108	135	3,921	21	101	215
CSR_13	Lohari Ragho I	clay	soil	29,936	13	16,938	10	91	176	3,492	21	66	240
CSR_14	Lohari Ragho I	clay	soil	30,808	10	19,826	9	98	1,324	3,501	15	78	214
CSR_15	Lohari Ragho	clay	soil	35,940	14	20,300	13	110	172	4,040	23	90	225
CSR_16	Khanak	clay	soil	34,285	15	23,847	12	133	124	3,750	24	91	208
CSR_17	Khanak	clay	soil	35,655	13	22,840	13	116	135	4,427	30	86	264
CSR_19	Khanak	clay	soil	36,580	13	27,515	13	128	174	3,552	20	100	148
CSR_20	Khanak	clay	soil	31,051	13	23,623	10	115	233	3,572	20	80	193
CSR_22	Khanak	clay	soil	123,085	20	5,389	33	38	101	10,191	33	213	282
CSR_23	na	na	soil	207,133	0	2,221	8	27	126	1,520	32	217	82
CSR_24	Kanoh	clay	soil	48,497	20	29,029	16	169	169	4,763	24	150	174
CSR_25	Kanoh	clay	soil	47,626	18	29,516	14	158	157	4,754	23	142	169
CSR_26	Lohari Ragho	clay	soil	43,221	16	26,842	12	137	149	4,027	24	127	201
CSR_27	Lohari Ragho	clay	soil	45,416	16	28,479	14	136	154	4,222	24	132	189

CSR_28	Lohari Ragho	clay	soil	40,396	15	26,273	13	122	150	3,814	25	114	187
CSR_29	Lohari Ragho	clay	soil	26,566	11	19,452	10	92	426	3,520	24	68	257
CSR_30	Lohari Ragho	clay	soil	33,474	13	24,607	10	116	301	3,303	17	95	152
CSR_34	Lohari Ragho	clay	soil	28,398	11	17,321	12	86	125	3,767	22	72	284
CSR_35	Alamgirpur	clay	soil	39,623	15	26,914	11	144	143	3,818	21	116	161
CSR_36	Alamgirpur	clay	soil	38,343	15	25,070	10	131	171	3,703	19	110	144
CSR_37	Alamgirpur	clay	soil	43,024	17	23,093	16	149	89	4,583	32	104	250
CSR_38	Alamgirpur	clay	soil	43,033	16	23,474	16	148	90	4,710	34	104	257
CSR_39	Alamgirpur	clay	soil	39,582	16	23,859	14	145	97	4,482	31	99	267
CSR_40	Alamgirpur	clay	soil	42,884	18	25,377	15	148	99	4,603	29	111	226
CSR_41	Alamgirpur	clay	soil	29,254	13	19,890	12	122	253	3,820	23	77	207
CSR_45	Masudpur	*clay*	soil	36,241	14	28,941	12	133	257	3,709	19	97	134
CSR_46	Masudpur	clay	soil	34,237	13	21,607	12	106	135	3,863	22	88	229
CSR_47	Masudpur	clay	soil	37,469	15	21,911	12	124	137	4,224	23	97	201
CSR_48	Masudpur	clay	soil	37,793	15	21,479	13	137	149	4,091	23	99	217
CSR_49	Masudpur	clay	soil	33,464	14	20,569	12	106	132	3,671	22	85	202
CSR_51	Masudpur	clay	soil	31,314	13	21,079	10	99	200	3,775	25	83	238
CSR_52	Masudpur	clay	soil	40,324	15	24,809	11	128	176	3,930	22	129	169
CSR_53	Masudpur	clay	soil	37,966	15	28,508	11	133	578	3,609	21	106	159
CSR_54	Masudpur	clay	soil	33,746	13	20,336	12	112	158	3,742	23	83	218
CSR_55	Masudpur	clay	soil	36,813	13	28,434	11	133	210	3,799	19	109	150
CSR_56	Masudpur	clay	soil	34,400	13	18,771	11	103	176	4,146	23	79	245
CSR_57	Masudpur	clay	soil	36,150	14	20,230	12	115	199	4,193	24	86	233
CSR_58	Masudpur	clay	soil	26,870	12	19,374	10	81	275	3,223	17	64	193
CSR_59	Masudpur	clay	soil	32,908	13	20,159	11	99	195	3,799	21	72	235
CSR_60	Masudpur	clay	soil	40,839	15	24,019	14	135	130	4,291	27	127	191
CSR_61	Masudpur	clay	soil	36,977	13	22,028	11	122	138	4,267	27	101	226
CSR_62	Masudpur	clay	soil	45,398	16	30,286	11	149	437	4,050	21	127	137
CSR_63	Masudpur	clay	soil	38,741	14	23,012	12	126	133	4,029	23	98	222
CSR_64	Masudpur	clay	soil	36,904	15	26,837	11	134	1,002	3,748	20	103	156

CSR_65	Masudpur	clay	soil	41,890	16	24,474	15	153	120	4,333	25	121	190
CSR_66	Bahola	clay	soil	43,143	17	49,415	15	165	85	4,275	28	126	185
CSR_67	Bahola	clay	soil	32,585	12	21,836	12	113	72	3,993	27	82	252
CSR_68	Bahola	clay	soil	39,256	16	29,836	14	139	69	4,344	28	103	206
CSR_69	Bahola	clay	soil	49,804	19	28,120	17	177	81	4,821	28	146	177
CSR_70	Bahola	clay	soil	50,326	19	28,501	17	183	83	4,532	29	150	182
CSR_71	Nighdu, Bahola	clay	soil	45,973	20	24,229	14	173	91	4,310	27	133	187
CSR_72	na	clay	soil	47,158	19	26,011	16	174	88	4,534	29	140	185
CSR-73	Sampla,Rhotak	clay	soil	39,607	16	22,958	15	145	224	4,301	29	127	174
ALM-103-70	ALM-SC	archaeo	103	56,643	21	36,199	19	192	76	4,776	29	163	191
ALM-103-81	ALM-SC	archaeo	103	55,637	20	32,332	16	190	102	4,603	30	168	175
ALM-104-105	ALM-SC	archaeo	104	57,921	20	34,395	17	201	94	4,809	31	177	173
ALM-104-111	ALM-SC	archaeo	104	55,071	21	35,914	16	186	106	4,831	29	141	201
ALM-104-115	ALM-SC	archaeo	104	46,883	16	42,581	14	171	71	4,171	26	143	177
ALM-104-121	ALM-SC	archaeo	104	56,570	19	32,024	16	180	115	4,834	28	151	201
ALM-105-130	ALM-SC	archaeo	105	57,063	22	32,922	17	194	101	4,763	32	157	179
ALM-105-133	ALM-SC	archaeo	105	53,698	20	32,698	16	177	89	4,220	30	150	161
ALM-105-137	ALM-SC	archaeo	105	45,098	18	30,609	15	164	84	4,697	25	130	203
ALM-105-149	ALM-SC	archaeo	105	50,328	16	32,458	14	163	156	4,389	28	129	194
ALM-105-153	ALM-SC	archaeo	105	43,436	18	32,301	14	172	85	4,903	24	133	196
ALM-105-159	ALM-SC	archaeo	105	56,964	20	33,745	16	186	102	4,747	30	164	181
ALM-106-177	ALM-SC	archaeo	106	48,531	18	28,990	16	176	96	4,473	28	128	211

ALM-106-180	ALM-SC	archaeo	106	58,474	20	31,147	18	192	79	4,949	30	151	182
ALM-106-192	ALM-SC	archaeo	106	52,796	17	39,593	16	171	80	4,518	25	144	175
ALM-107-201	ALM-SC	archaeo	107	49,386	20	29,008	15	182	80	4,547	27	144	174
ALM-107-203	ALM-SC	archaeo	107	52,449	20	33,040	17	188	83	4,968	27	157	190
ALM-107-207	ALM-SC	archaeo	107	52,460	21	35,038	17	187	74	4,697	28	155	198
ALM-108-221	ALM-SC	archaeo	108	52,996	20	32,944	16	190	118	4,732	32	151	195
ALM-108-222	ALM-SC	archaeo	108	58,159	20	33,197	18	192	72	5,145	30	155	186
ALM-128-521	ALM-SC	archaeo	128	53,776	20	31,671	18	190	76	4,602	29	142	182
ALM-110-228	ALM-SC	archaeo	110	56,414	20	31,675	17	188	105	4,791	32	157	195
ALM-110-229	ALM-SC	archaeo	110	57,070	18	33,363	16	190	83	4,727	30	158	185
ALM-110-234	ALM-SC	archaeo	110	53,093	18	30,621	14	179	94	4,813	30	145	202
ALM-112-238	ALM-SC	archaeo	112	59,716	21	35,036	17	210	73	5,102	26	164	194
ALM-112-242	ALM-SC	archaeo	112	44,739	18	39,806	13	154	69	4,326	23	148	165
ALM-119-361	ALM-SC	archaeo	119	47,533	17	38,726	15	165	63	4,660	28	140	203
ALM-119-364	ALM-SC	archaeo	119	50,256	20	32,823	16	176	74	4,860	24	159	194
ALM-119-370	ALM-SC	archaeo	119	36,293	17	30,628	14	174	179	4,229	24	114	197
ALM-122-1836	ALM-SC	archaeo	122	48,176	17	34,390	17	159	69	4,680	25	111	232
ALM-122-397	ALM-SC	archaeo	122	51,163	19	41,264	17	173	61	4,708	27	135	181
ALM-122-399	ALM-SC	archaeo	122	50,355	18	34,795	16	170	72	4,418	25	147	181
ALM-122-400	ALM-SC	archaeo	122	50,282	17	33,061	18	181	81	4,576	31	138	214

ALM-122-402	ALM-SC	archaeo	122	60,913	21	36,127	16	190	72	5,056	29	158	214
ALM-123-1867	ALM-SC	archaeo	123	56,346	20	35,299	18	192	73	5,134	31	164	205
ALM-123-411	ALM-SC	archaeo	123	48,239	18	35,398	15	162	71	4,450	27	122	207
ALM-123-414	ALM-SC	archaeo	123	47,661	17	29,607	11	147	83	4,059	21	117	141
ALM-123-415	ALM-SC	archaeo	123	52,505	18	27,737	15	159	81	4,648	28	132	207
ALM-123-423	ALM-SC	archaeo	123	51,383	19	37,428	15	177	78	4,821	33	139	208
ALM-123-473	ALM-SC	archaeo	125	51,124	19	31,418	16	175	79	4,675	29	145	193
ALM-124-1342	ALM-SC	archaeo	124	42,791	14	35,584	12	138	77	4,031	24	112	186
ALM-124-446	ALM-SC	archaeo	124	50,965	17	29,418	16	166	83	4,628	29	120	221
ALM-124-450	ALM-SC	archaeo	124	56,124	20	31,710	16	190	76	4,808	29	146	207
ALM-124-453	ALM-SC	archaeo	124	57,195	18	31,923	15	172	79	4,389	27	141	182
ALM-124-455	ALM-SC	archaeo	124	68,184	21	37,071	16	179	70	4,525	30	138	186
ALM-124-456	ALM-SC	archaeo	124	53,648	20	28,397	14	149	85	4,290	31	124	171
ALM-125-1983	ALM-SC	archaeo	125	44,704	16	38,471	12	152	72	4,512	25	114	196
ALM-125-470	ALM-SC	archaeo	125	45,073	16	38,250	16	162	63	4,520	25	138	200
ALM-125-474	ALM-SC	archaeo	125	49,113	17	31,694	15	168	72	4,433	25	136	183
ALM-125-476	ALM-SC	archaeo	125	52,447	20	39,512	14	178	61	4,467	26	154	185
ALM-125-479	ALM-SC	archaeo	125	52,726	18	42,339	14	176	62	4,530	28	140	194
ALM-125-481	ALM-SC	archaeo	125	52,526	20	40,326	16	178	86	4,623	29	144	196
ALM-125-484	ALM-SC	archaeo	125	52,252	19	33,510	16	178	162	4,527	24	172	132

ALM-125-494	ALM-SC	archaeo	126	51,829	20	36,199	16	193	84	4,812	26	156	176
ALM-126-2053	ALM-SC	archaeo	126	44,509	16	35,481	13	143	87	4,446	25	140	218
ALM-126-490	ALM-SC	archaeo	126	51,095	20	33,487	16	178	78	4,680	29	195	219
ALM-126-491	ALM-SC	archaeo	126	65,032	23	37,863	20	224	68	5,478	26	182	169
ALM-126-493	ALM-SC	archaeo	126	46,810	22	32,124	19	205	76	4,536	23	132	176
ALM-126-498	ALM-SC	archaeo	126	51,435	19	36,122	14	178	79	4,499	27	158	196
ALM-127-2067	ALM-SC	archaeo	127	52,960	20	33,285	15	176	85	4,495	27	173	177
ALM-127-2078	ALM-SC	archaeo	127	52,927	19	43,720	16	189	57	4,538	23	154	181
ALM-127-2091	ALM-SC	archaeo	127	45,196	16	37,679	14	151	71	4,435	20	136	185
ALM-127-2092	ALM-SC	archaeo	127	50,418	14	36,222	12	150	77	3,961	24	117	186
ALM-127-504	ALM-SC	archaeo	127	60,094	20	32,995	17	184	84	4,660	28	150	187
ALM-127-506	ALM-SC	archaeo	127	54,020	20	31,352	17	185	75	4,719	29	153	209
ALM-127-517	ALM-SC	archaeo	127	53,328	20	31,028	17	186	72	4,782	28	146	181
ALM-128-2157	ALM-SC	archaeo	128	43,547	15	33,021	14	147	78	4,352	22	123	240
ALM-128-2241	ALM-SC	archaeo	128	43,998	15	31,394	12	152	83	4,309	23	124	197
ALM-128-524	ALM-SC	archaeo	128	52,146	18	29,837	16	178	72	4,724	29	137	226
ALM-128-526	ALM-SC	archaeo	128	49,966	20	38,666	16	192	82	4,427	23	156	152
ALM-128-536	ALM-SC	archaeo	128	49,941	18	30,801	15	166	89	4,664	24	142	225
ALM-128-551	ALM-SC	archaeo	128	48,342	20	32,395	14	171	87	4,426	26	126	178
ALM-128-553	ALM-SC	archaeo	128	54,845	20	32,210	15	183	83	4,922	31	152	200

ALM-128-559	ALM-SC	archaeo	128	41,270	15	31,555	11	147	112	4,155	23	121	197
ALM-105-172	ALM-SC	archaeo	105	55,474	21	34,510	18	188	72	4,965	31	157	204
ALM-107-202	ALM-SC	archaeo	107	53,404	20	30,767	15	190	82	4,998	31	147	208
ALM-107-204	ALM-SC	archaeo	107	49,827	19	24,926	16	152	90	5,033	27	128	264
ALM-107-210	ALM-SC	archaeo	107	33,207	13	28,440	11	118	148	3,683	22	89	226
ALM-108-214	ALM-SC	archaeo	108	55,479	19	30,135	16	180	115	4,646	27	149	201
LHR-1017	LHR_I	archaeo	574	41,103	18	27,389	13	131	169	4,197	23	115	189
LHR-102	LHR_I	archaeo	518	44,027	15	25,838	14	139	184	4,379	24	111	234
LHR-214	LHR_I	archaeo	515	40,533	15	27,785	13	143	170	4,313	24	121	215
LHR-239	LHR_I	archaeo	515	39,549	16	26,713	13	158	176	4,146	23	130	204
LHR-245	LHR_I	archaeo	515	43,744	17	28,929	15	147	224	4,208	22	104	228
LHR-256	LHR_I	archaeo	515	38,220	15	26,875	15	163	167	4,238	23	110	202
LHR-289	LHR_I	archaeo	515	40,481	18	27,940	14	151	196	4,334	26	121	226
LHR-291	LHR_I	archaeo	515	44,335	18	24,779	14	146	165	4,224	27	114	196
LHR-30	LHR_I	archaeo	508	39,547	16	26,921	13	128	170	3,971	27	124	196
LHR-322	LHR_I	archaeo	515	35,519	15	25,435	13	129	171	4,076	26	124	206
LHR-372	LHR_I	archaeo	520	41,408	17	27,323	13	145	138	4,037	24	107	196
LHR-391	LHR_I	archaeo	520	41,293	16	25,177	14	149	177	4,041	25	119	218
LHR-414	LHR_I	archaeo	520	40,233	17	28,822	14	148	169	4,361	21	118	223
LHR-478	LHR_I	archaeo	520	42,264	2	30,658	14	140	159	4,379	24	135	204
LHR-482	LHR_I	archaeo	520	44,786	19	26,079	14	147	196	4,408	25	116	210
LHR-499	LHR_I	archaeo	520	42,627	16	27,739	15	159	177	4,522	26	129	206
LHR-502	LHR_I	archaeo	520	35,470	16	25,406	13	134	222	3,903	24	102	212
LHR-532	LHR_I	archaeo	520	37,549	18	29,178	12	124	191	3,986	22	115	203
LHR-547	LHR_I	archaeo	520	37,915	19	30,880	13	134	175	4,241	19	124	220
LHR-550	LHR_I	archaeo	520	40,257	18	30,231	14	139	339	4,405	22	130	255
LHR-574	LHR_I	archaeo	521	39,357	16	24,648	11	121	227	4,274	23	108	234
LHR-576	LHR_I	archaeo	521	39,713	16	25,305	11	115	250	4,294	20	104	239
LHR-592	LHR_I	archaeo	521	43,655	16	30,773	13	147	198	4,387	22	109	237

LHR-674	LHR_I	archaeo	538	38,015	17	27,817	14	126	192	3,909	23	108	208
LHR-678	LHR_I	archaeo	538	39,259	17	25,869	13	124	199	4,273	22	105	226
LHR-780	LHR_I	archaeo	553	41,173	17	26,885	14	144	212	4,166	25	113	191
LHR-810	LHR_I	archaeo	520	43,617	15	28,515	15	154	177	4,408	26	120	199
LHR-814	LHR_I	archaeo	520	39,335	14	25,600	14	154	158	4,340	24	120	201
LHR-815	LHR_I	archaeo	520	42,329	14	28,610	14	157	222	4,138	27	127	209
LHR-821	LHR_I	archaeo	520	41,501	16	26,881	15	153	210	4,400	25	122	201
LHR-1083	LHR_I	archaeo	572	55,148	16	33,137	18	185	128	4,717	26	151	166
LHR-242	LHR_I	archaeo	515	45,845	18	27,790	15	160	168	4,190	27	124	179
LHR-303	LHR_I	archaeo	515	44,883	18	35,019	15	156	148	4,471	23	131	182
LHR-323	LHR_I	archaeo	515	53,991	21	35,851	18	192	135	4,808	25	148	180
LHR-327	LHR_I	archaeo	515	44,011	18	30,464	14	163	179	4,417	23	124	184
LHR-342	LHR_I	archaeo	515	41,327	16	32,321	16	143	207	4,668	23	129	207
LHR-37	LHR_I	archaeo	508	45,093	17	30,577	16	157	189	4,395	23	129	174
LHR-400	LHR_I	archaeo	520	47,085	19	30,285	17	181	143	4,625	24	153	190
LHR-401	LHR_I	archaeo	520	43,452	17	27,857	15	156	180	4,583	24	131	181
LHR-402	LHR_I	archaeo	520	39,204	18	29,860	13	151	186	4,564	23	119	198
LHR-407	LHR_I	archaeo	520	45,883	19	30,901	15	171	156	4,403	25	135	185
LHR-429	LHR_I	archaeo	520	45,055	19	29,720	15	168	286	4,774	24	132	179
LHR-433	LHR_I	archaeo	520	42,978	18	29,469	14	156	164	4,737	24	133	197
LHR-436	LHR_I	archaeo	520	40,391	18	33,565	14	176	189	4,596	27	169	178
LHR-448	LHR_I	archaeo	520	43,256	16	28,582	14	165	205	4,473	24	148	190
LHR-455	LHR_I	archaeo	520	49,217	13	31,839	16	175	152	4,438	24	135	183
LHR-494	LHR_I	archaeo	520	45,977	22	29,056	14	155	217	4,327	24	124	225
LHR-495	LHR_I	archaeo	520	48,627	14	31,348	16	179	151	4,598	26	139	189
LHR-497	LHR_I	archaeo	520	39,186	18	28,417	16	163	194	4,586	22	121	216
LHR-506	LHR_I	archaeo	520	43,879	14	31,039	15	155	199	4,643	27	145	198
LHR-556	LHR_I	archaeo	520	47,776	18	30,682	15	159	113	4,258	24	128	186
LHR-566	LHR_I	archaeo	520	46,296	13	27,481	15	154	151	4,398	25	161	180
LHR-590	LHR_I	archaeo	521	51,859	18	32,509	16	167	189	4,700	23	121	186
LHR-7	LHR_I	archaeo	508	46,352	18	30,255	15	163	153	4,629	25	140	187
LHR-812	LHR_I	archaeo	520	51,935	15	30,455	16	165	215	4,732	24	136	184
LHR-818	LHR_I	archaeo	520	43,512	18	28,243	16	164	227	4,142	26	127	199

LHR-819	LHR_I	archaeo	520	45,390	18	28,629	12	149	216	4,480	26	125	189
LHR-108	LHR_I	archaeo	518	36,496	16	30,797	14	134	194	4,087	23	124	170
LHR-20	LHR_I	archaeo	508	41,476	17	32,044	12	141	153	4,039	21	124	176
LHR-218	LHR_I	archaeo	515	40,384	14	31,193	12	124	315	4,052	23	125	183
LHR-240	LHR_I	archaeo	515	49,315	16	31,351	15	146	219	4,307	20	130	189
LHR-408	LHR_I	archaeo	520	41,406	15	29,690	12	123	501	3,979	21	99	206
LHR-428	LHR_I	archaeo	520	43,289	19	36,071	15	159	286	4,357	24	127	182
LHR-428-BIS	LHR_I	archaeo	520	42,526	18	36,518	15	154	280	4,417	23	123	177
LHR-428-TRIS	LHR_I	archaeo	520	42,873	19	35,879	15	155	281	4,256	24	126	181
LHR-489	LHR_I	archaeo	520	41,066	19	29,944	14	149	330	4,367	22	114	202
LHR-549	LHR_I	archaeo	520	37,275	21	38,634	13	134	379	4,433	23	103	203
LHR-561	LHR_I	archaeo	520	40,745	15	32,697	13	137	257	4,291	20	133	189
LHR-465	LHR_I	archaeo	520	45,733	19	28,305	17	169	150	4,430	28	126	203
LHR-612	LHR_I	archaeo	521	42,256	16	28,353	15	162	114	4,666	27	131	200
LHR-23	LHR_I	archaeo	508	45,954	18	27,681	15	161	159	4,593	28	123	187
LHR-241	LHR_I	archaeo	515	50,035	18	29,682	15	167	159	4,993	27	127	203
LHR-268	LHR_I	archaeo	515	42,821	18	29,167	15	163	127	4,403	27	117	208
LHR-290	LHR_I	archaeo	515	37,684	15	24,193	13	131	189	4,473	28	111	240
LHR-304	LHR_I	archaeo	515	47,693	20	28,856	16	170	113	4,786	30	123	219
LHR-313	LHR_I	archaeo	515	41,147	17	29,231	16	157	130	4,318	27	120	207
LHR-359	LHR_I	archaeo	520	48,415	19	30,269	16	173	147	4,578	30	137	206
LHR-422	LHR_I	archaeo	520	51,497	18	31,752	17	177	173	4,788	31	133	203
LHR-43	LHR_I	archaeo	508	31,306	12	22,570	13	100	179	4,047	23	75	261
LHR-437	LHR_I	archaeo	520	50,959	14	29,666	16	168	153	4,784	28	137	178
LHR-440	LHR_I	archaeo	520	42,743	10	25,955	13	143	140	4,280	26	109	224
LHR-458	LHR_I	archaeo	520	38,629	18	24,159	14	126	142	4,058	26	95	238
LHR-483	LHR_I	archaeo	520	41,503	16	21,534	13	114	242	4,432	25	95	266
LHR-49	LHR_I	archaeo	518	44,819	18	25,610	13	145	134	4,371	26	103	232
LHR-5	LHR_I	archaeo	508	46,577	18	27,439	17	167	147	4,562	26	123	198
LHR-565	LHR_I	archaeo	520	49,695	17	30,068	17	177	202	4,601	30	140	190
LHR-567	LHR_I	archaeo	520	43,320	15	26,471	17	166	175	4,487	29	113	215
LHR-58	LHR_I	archaeo	518	41,875	17	25,786	12	148	150	4,434	25	102	238

LHR-602	LHR_I	archaeo	521	43,861	20	36,569	17	145	120	4,354	26	117	208
LHR-619	LHR_I	archaeo	521	43,823	18	26,007	13	148	128	4,188	26	103	224
LHR-620	LHR_I	archaeo	521	48,037	16	25,378	15	163	120	4,383	25	106	204
LHR-632	LHR_I	archaeo	521	41,731	14	31,984	12	122	145	4,132	26	93	248
LHR-809	LHR_I	archaeo	520	42,258	18	30,106	15	172	177	4,794	28	145	221
LHR-811	LHR_I	archaeo	520	38,024	16	25,084	14	128	170	4,149	26	94	240
LHR-816	LHR_I	archaeo	520	27,067	16	31,961	11	95	244	3,630	22	75	229
LHR-87	LHR_I	archaeo	518	44,637	18	21,999	16	138	110	4,798	30	104	293
LHR-88	LHR_I	archaeo	518	46,994	18	29,873	16	161	120	4,697	30	144	215
LHR-93	LHR_I	archaeo	518	42,106	17	25,787	15	148	143	4,470	26	111	226
LHR-98	LHR_I	archaeo	518	29,452	12	28,601	10	99	211	3,917	21	69	230
593	MSD	archaeo	655	42,103	15	35,396	14	140	787	4,058	24	135	134
52	MSD	archaeo	612	6,968	6	7,570	3	11	121	967	9	55	112
472	MSD	archaeo	619	48,004	18	35,273	14	148	195	4,408	25	147	171
304	MSD	archaeo	645	40,759	16	29,773	13	134	174	4,422	27	113	244
328	MSD	archaeo	686	47,670	17	24,518	15	146	178	4,538	27	111	223
3	MSD	archaeo	612	47,795	16	25,626	15	143	149	4,634	27	115	218
16	MSD	archaeo	612	38,611	17	26,049	15	158	154	4,334	27	113	219
100	MSD	archaeo	632	42,720	14	23,596	14	134	144	4,372	23	105	221
193	MSD	archaeo	671	43,820	16	26,241	13	131	195	4,471	24	100	224
196	MSD	archaeo	671	39,087	16	23,130	12	123	141	4,097	26	103	240
201	MSD	archaeo	671	40,329	15	26,654	12	133	181	4,167	22	104	246
231	MSD	archaeo	685	41,266	17	23,829	14	152	133	4,331	25	113	208
232	MSD	archaeo	685	45,337	16	26,378	13	133	172	4,542	24	106	227
240	MSD	archaeo	685	42,791	16	36,029	14	135	158	4,034	24	108	198
245	MSD	archaeo	685	44,599	16	24,824	14	139	175	4,365	25	107	234
315	MSD	archaeo	686	45,401	16	26,749	14	137	143	4,440	25	111	231
366	MSD	archaeo	692	47,208	16	28,380	15	147	164	4,561	28	121	219
384	MSD	archaeo	619	43,972	17	23,466	13	128	157	4,424	26	108	242
424	MSD	archaeo	619	42,444	17	23,017	14	125	150	4,311	25	104	245
426	MSD	archaeo	619	44,734	16	24,299	14	126	153	4,649	24	105	254
436	MSD	archaeo	619	44,833	17	27,375	15	142	169	4,567	25	120	215
465	MSD	archaeo	619	41,480	16	25,553	15	136	165	4,446	25	124	199

468	MSD	archaeo	619	42,530	17	26,755	16	141	183	4,526	26	129	203
493	MSD	archaeo	622	46,192	17	27,785	15	142	159	4,431	26	126	226
849	MSD	archaeo	646	43,964	16	25,940	14	136	163	4,322	23	114	220
853	MSD	archaeo	646	43,420	16	25,192	15	141	158	4,240	26	118	229
44	MSD	archaeo	612	38,145	14	24,385	12	109	134	4,172	24	93	237
270	MSD	archaeo	685	36,926	14	20,988	13	111	173	4,061	23	92	234
471	MSD	archaeo	619	34,415	13	25,843	12	103	228	3,977	22	84	239
504	MSD	archaeo	622	38,317	15	26,583	12	104	149	4,179	22	92	231
592	MSD	archaeo	655	34,425	12	27,145	11	94	223	3,902	23	88	246
383	MSD	archaeo	619	35,522	14	23,057	13	118	152	4,300	21	97	237
45	MSD	archaeo	612	33,759	13	27,760	13	113	225	3,856	23	108	216
70	MSD	archaeo	631	43,706	16	28,640	14	135	195	4,285	24	122	204
361	MSD	archaeo	692	47,354	17	31,094	15	136	233	4,657	28	124	218
446	MSD	archaeo	619	39,997	15	26,419	15	134	185	4,279	26	120	214
11	MSD	archaeo	612	41,996	14	25,997	15	111	197	4,474	26	105	266
14	MSD	archaeo	612	44,583	16	26,786	14	140	181	4,344	24	118	207
86	MSD	archaeo	632	36,663	15	30,756	12	123	206	4,177	24	105	219
160	MSD	archaeo	641	41,126	16	30,100	15	147	197	4,106	26	111	203
233	MSD	archaeo	685	43,449	16	24,283	13	126	233	4,556	24	115	234
402	MSD	archaeo	619	41,465	16	25,667	14	138	186	4,325	23	124	197
408	MSD	archaeo	619	41,877	15	25,177	13	131	256	4,452	23	115	201
410	MSD	archaeo	619	41,705	17	24,705	14	133	205	4,524	24	112	209
431	MSD	archaeo	619	35,659	15	22,256	13	122	227	4,223	24	96	232
778	MSD	archaeo	646	44,855	16	24,324	13	137	243	4,356	24	110	221
803	MSD	archaeo	646	40,730	14	32,240	13	127	201	4,195	24	106	218
293	MSD	archaeo	645	43,184	17	30,178	15	149	168	4,622	25	134	193
332	MSD	archaeo	688	50,452	21	32,449	16	183	184	5,295	28	156	193
34	MSD	archaeo	612	53,813	20	34,983	15	168	223	4,739	25	137	184
433	MSD	archaeo	619	45,341	19	28,413	16	160	222	4,159	27	134	192
9	MSD	archaeo	612	43,547	18	27,343	14	144	219	4,454	27	118	182
12	MSD	archaeo	612	46,188	17	29,738	15	141	166	4,679	23	132	177
30	MSD	archaeo	612	47,687	18	27,647	15	161	191	4,611	25	127	211
234	MSD	archaeo	685	49,597	17	32,055	14	162	158	4,496	24	169	163

238	MSD	archaeo	685	46,768	19	31,888	14	149	167	4,694	24	141	165
429	MSD	archaeo	619	48,890	18	25,993	16	160	178	4,445	29	130	229
438	MSD	archaeo	619	50,393	19	27,205	16	152	173	4,865	26	124	221
637	MSD	archaeo	680	47,001	18	25,666	13	157	201	4,529	23	120	212
642	MSD	archaeo	680	45,367	17	28,621	14	149	170	4,686	25	135	181
654	MSD	archaeo	680	48,151	18	29,002	14	158	206	4,562	26	153	172
461	MSD	archaeo	619	46,309	18	29,581	16	162	138	4,534	26	128	189
387	MSD	archaeo	619	44,723	18	24,767	15	147	62	4,121	28	111	204
388	MSD	archaeo	619	49,841	18	28,219	17	157	151	4,714	26	131	215
420	MSD	archaeo	619	46,895	21	26,805	16	170	121	4,367	30	142	195
421	MSD	archaeo	619	49,876	20	28,890	17	172	108	4,511	30	140	196
15	MSD	archaeo	612	47,222	19	29,830	15	169	161	4,405	25	131	196
199	MSD	archaeo	671	46,244	17	32,105	13	147	134	4,585	23	115	177
202	MSD	archaeo	671	45,662	18	28,492	16	141	126	4,375	25	126	199
236	MSD	archaeo	685	48,905	19	25,862	16	146	144	4,503	26	121	224
237	MSD	archaeo	685	46,327	16	27,328	14	134	130	4,417	24	120	191
423	MSD	archaeo	619	51,427	17	26,928	16	161	139	4,687	27	123	211
427	MSD	archaeo	619	46,875	18	28,278	15	161	127	4,513	24	133	172
428	MSD	archaeo	619	49,467	18	25,723	16	156	146	4,652	28	129	214
430	MSD	archaeo	619	48,778	17	26,223	15	146	149	4,653	23	125	203
432	MSD	archaeo	619	50,618	16	29,664	15	163	153	4,669	24	128	222
439	MSD	archaeo	619	50,832	17	28,502	14	155	140	4,713	26	121	211
653	MSD	archaeo	680	50,310	17	31,998	15	170	134	4,683	23	145	177
658	MSD	archaeo	680	49,792	17	28,657	14	152	155	4,627	24	119	199
772	MSD	archaeo	646	44,547	18	27,180	14	157	147	4,523	25	131	204
186	MSD	archaeo	641	37,429	14	34,211	12	116	365	3,820	22	139	174
521	MSD	archaeo	636	42,987	18	39,137	14	137	262	4,326	25	111	204
49	MSD	archaeo	612	44,271	16	26,956	14	141	386	4,323	26	124	204
57	MSD	archaeo	612	43,428	17	32,345	13	123	405	4,125	23	130	164
690	MSD	archaeo	647	46,179	16	29,328	14	145	289	4,518	25	114	219
696	MSD	archaeo	647	37,542	14	29,754	13	129	271	4,057	23	116	203
13	MSD	archaeo	612	46,927	18	30,387	13	153	284	4,490	24	123	182
462	MSD	archaeo	619	48,352	19	32,025	15	153	402	4,634	24	144	181

627	MSD	archaeo	668	44,330	18	31,494	15	168	304	4,729	26	129	177
693	MSD	archaeo	647	36,539	14	30,068	12	120	307	3,961	23	108	186
405	MSD	archaeo	619	40,951	16	26,427	13	124	318	4,423	27	118	211
638	MSD	archaeo	680	44,136	16	26,607	13	144	275	4,756	23	115	208
657	MSD	archaeo	680	46,950	18	34,383	14	148	381	4,599	24	149	176
838	MSD	archaeo	646	42,325	16	27,761	14	133	285	4,329	23	113	211
557 / 75	MSD	archaeo	636	39,746	15	27,623	13	135	213	4,070	23	119	178
470 /70	MSD	archaeo	619	40,355	15	28,423	12	131	215	4,263	23	115	201
691 /87	MSD	archaeo	647	44,725	15	31,038	16	143	215	4,338	27	115	235
695 /90	MSD	archaeo	647	45,575	14	29,565	15	146	193	4,504	25	116	226
753 /92	MSD	archaeo	646	43,299	16	26,758	14	138	213	4,233	26	113	212
694 /89	MSD	archaeo	647	33,361	13	28,539	12	117	194	3,691	19	101	203
468 (-bis)	MSD	archaeo	619	42,231	15	27,135	14	141	184	4,531	26	126	211

Table C2. Log10 transformation of the chemical data mass fraction (wt%).

Sample No.	Fe_Log10	Ga_Log10	K_Log10	Nb_Log10	Rb_Log10	Sr_Log10	Ti_Log10	Y_Log10	Zn_Log10	Zr_Log10
CSR_01	0.49027	-2.98712	0.57090	-3.02315	-1.97678	-1.45041	-0.49477	-2.78255	-2.10022	-1.90742
CSR_04	0.66432	-2.79281	0.47802	-2.83900	-1.81751	-1.82224	-0.37340	-2.60206	-1.79180	-1.74757
CSR_05	0.57030	-2.91828	0.27493	-2.92319	-2.05723	-1.85149	-0.41366	-2.57217	-2.15574	-1.52756
CSR_09	0.44316	-2.91240	0.36172	-2.95931	-2.03445	-1.74801	-0.46731	-2.61220	-2.16549	-1.61945
CSR_10	0.46944	-2.92209	0.23458	-2.93981	-2.04408	-1.77086	-0.40513	-2.61092	-2.21486	-1.53958
CSR_11	0.48560	-2.86091	0.26713	-3.00384	-1.99917	-1.83385	-0.41878	-2.66446	-2.00292	-1.62029
CSR_12	0.50080	-2.86653	0.29410	-2.94548	-1.96557	-1.86875	-0.40660	-2.67132	-1.99579	-1.66663
CSR_13	0.47620	-2.89482	0.22886	-3.00096	-2.03932	-1.75439	-0.45687	-2.68346	-2.18116	-1.61903
CSR_14	0.48866	-3.01271	0.29723	-3.04602	-2.01060	-0.87818	-0.45585	-2.81871	-2.10938	-1.66972
CSR_15	0.55557	-2.85406	0.30749	-2.87042	-1.95686	-1.76529	-0.39359	-2.64381	-2.04741	-1.64731
CSR_16	0.53511	-2.82925	0.37743	-2.90694	-1.87608	-1.90519	-0.42593	-2.61454	-2.04206	-1.68138
CSR_17	0.55212	-2.90184	0.35870	-2.86990	-1.93446	-1.86947	-0.35387	-2.52556	-2.06506	-1.57848
CSR_19	0.56325	-2.88323	0.43957	-2.87233	-1.89197	-1.75951	-0.44956	-2.69195	-2.00149	-1.83013
CSR_20	0.49208	-2.89704	0.37334	-3.00728	-1.94040	-1.63314	-0.44706	-2.70747	-2.09680	-1.71345
CSR_22	1.09021	-2.70265	-0.26846	-2.47774	-2.42141	-1.99463	0.00822	-2.48014	-1.67088	-1.54936
CSR_23	1.31625	-4.33114	-0.65343	-3.12493	-2.56229	-1.90098	-0.81819	-2.49136	-1.66413	-2.08852
CSR_24	0.68571	-2.69389	0.46283	-2.80911	-1.77182	-1.77096	-0.32209	-2.61426	-1.82509	-1.75918
CSR_25	0.67784	-2.74197	0.47006	-2.85425	-1.80049	-1.80467	-0.32294	-2.63758	-1.84783	-1.77144
CSR_26	0.63570	-2.78723	0.42882	-2.93342	-1.86299	-1.82674	-0.39497	-2.62046	-1.89587	-1.69610
CSR_27	0.65721	-2.80055	0.45453	-2.85985	-1.86578	-1.81122	-0.37452	-2.61248	-1.87952	-1.72356
CSR_28	0.60634	-2.82423	0.41952	-2.89412	-1.91303	-1.82347	-0.41858	-2.60259	-1.94366	-1.72870
CSR_29	0.42433	-2.95269	0.28897	-2.98091	-2.03604	-1.37063	-0.45350	-2.61753	-2.17006	-1.58930
CSR_30	0.52470	-2.87422	0.39107	-3.01839	-1.93623	-1.52185	-0.48105	-2.76356	-2.02244	-1.81869
CSR_34	0.45328	-2.95539	0.23857	-2.90605	-2.06654	-1.90276	-0.42399	-2.65992	-2.14096	-1.54601
CSR_35	0.59795	-2.82703	0.42998	-2.97116	-1.84296	-1.84337	-0.41812	-2.67160	-1.93548	-1.79300
CSR_36	0.58369	-2.82833	0.39915	-2.99468	-1.88439	-1.76826	-0.43143	-2.73281	-1.95961	-1.84312
CSR_37	0.63371	-2.78112	0.36348	-2.80840	-1.82567	-2.04985	-0.33882	-2.49401	-1.98498	-1.60251
CSR_38	0.63380	-2.80717	0.37059	-2.78459	-1.82893	-2.04814	-0.32695	-2.47158	-1.98149	-1.59082
CSR_39	0.59750	-2.78421	0.37765	-2.84572	-1.83870	-2.01174	-0.34849	-2.51217	-2.00564	-1.57424
CSR_40	0.63229	-2.75608	0.40445	-2.83555	-1.83077	-2.00330	-0.33697	-2.53335	-1.95362	-1.64657
CSR_41	0.46618	-2.87034	0.29864	-2.91804	-1.91310	-1.59652	-0.41789	-2.63147	-2.11451	-1.68493
CSR_45	0.55920	-2.86083	0.46151	-2.92611	-1.87458	-1.59052	-0.43076	-2.72417	-2.01112	-1.87441

CSR_46	0.53449	-2.88776	0.33460	-2.92804	-1.97595	-1.86828	-0.41308	-2.65283	-2.05587	-1.64106
CSR_47	0.57368	-2.82980	0.34067	-2.93276	-1.90543	-1.86350	-0.37428	-2.64307	-2.01383	-1.69784
CSR_48	0.57741	-2.81417	0.33202	-2.87438	-1.86308	-1.82674	-0.38818	-2.63143	-2.00341	-1.66369
CSR_49	0.52458	-2.85021	0.31322	-2.92053	-1.97676	-1.88019	-0.43519	-2.64827	-2.06890	-1.69368
CSR_51	0.49574	-2.90093	0.32385	-2.99226	-2.00640	-1.69998	-0.42312	-2.61055	-2.08286	-1.62272
CSR_52	0.60557	-2.81649	0.39460	-2.95061	-1.89202	-1.75557	-0.40557	-2.65521	-1.88901	-1.77161
CSR_53	0.57940	-2.82125	0.45496	-2.97607	-1.87569	-1.23792	-0.44255	-2.67323	-1.97529	-1.79768
CSR_54	0.52822	-2.87332	0.30827	-2.92890	-1.94898	-1.80039	-0.42694	-2.63451	-2.08237	-1.66097
CSR_55	0.56600	-2.88127	0.45384	-2.95525	-1.87685	-1.67766	-0.42036	-2.72356	-1.96450	-1.82377
CSR_56	0.53656	-2.89143	0.27348	-2.96524	-1.98882	-1.75475	-0.38237	-2.63083	-2.10315	-1.61111
CSR_57	0.55811	-2.86191	0.30599	-2.92724	-1.94102	-1.70199	-0.37753	-2.62427	-2.06542	-1.63331
CSR_58	0.42926	-2.93311	0.28721	-2.98882	-2.09196	-1.56115	-0.49168	-2.76466	-2.19470	-1.71388
CSR_59	0.51730	-2.87130	0.30447	-2.96107	-2.00420	-1.71066	-0.42036	-2.67026	-2.14417	-1.62819
CSR_60	0.61107	-2.81459	0.38056	-2.86789	-1.87057	-1.88561	-0.36747	-2.56937	-1.89587	-1.71951
CSR_61	0.56794	-2.88123	0.34297	-2.95340	-1.91303	-1.85928	-0.36986	-2.57289	-1.99739	-1.64584
CSR_62	0.65703	-2.79949	0.48125	-2.94564	-1.82807	-1.35985	-0.39254	-2.68499	-1.89522	-1.86452
CSR_63	0.58817	-2.83910	0.36196	-2.90851	-1.90135	-1.87634	-0.39478	-2.63796	-2.00813	-1.65310
CSR_64	0.56707	-2.82115	0.42874	-2.94963	-1.87182	-0.99921	-0.42621	-2.70101	-1.98587	-1.80684
CSR_65	0.62211	-2.78696	0.38871	-2.81715	-1.81631	-1.92139	-0.36325	-2.60493	-1.91587	-1.72153
CSR_66	0.63491	-2.78228	0.69386	-2.83158	-1.78380	-2.07312	-0.36905	-2.55185	-1.90068	-1.73380
CSR_67	0.51302	-2.91109	0.33918	-2.93711	-1.94664	-2.14295	-0.39872	-2.57242	-2.08393	-1.59879
CSR_68	0.59391	-2.79265	0.47474	-2.84692	-1.85746	-2.16328	-0.36208	-2.54991	-1.98915	-1.68606
CSR_69	0.69727	-2.72376	0.44901	-2.77823	-1.75290	-2.09420	-0.31687	-2.55641	-1.83634	-1.75177
CSR_70	0.70179	-2.71573	0.45487	-2.76407	-1.73813	-2.08308	-0.34375	-2.54484	-1.82435	-1.74103
CSR_71	0.66251	-2.70654	0.38434	-2.84735	-1.76189	-2.04245	-0.36550	-2.56406	-1.87510	-1.72914
CSR_72	0.67356	-2.72536	0.41516	-2.79670	-1.75989	-2.05693	-0.34350	-2.54295	-1.85302	-1.73210
CSR-73	0.59777	-2.80141	0.36093	-2.82737	-1.83937	-1.64978	-0.36638	-2.54378	-1.89646	-1.75964
ALM-103-70	0.75315	-2.67922	0.55869	-2.72785	-1.71646	-2.11878	-0.32092	-2.53695	-1.78872	-1.71998
ALM-103-81	0.74537	-2.69986	0.50963	-2.79326	-1.72210	-1.99303	-0.33699	-2.52002	-1.77583	-1.75816
ALM-104-105	0.76284	-2.69852	0.53649	-2.75742	-1.69743	-2.02785	-0.31795	-2.51378	-1.75093	-1.76125
ALM-104-111	0.74093	-2.68527	0.55526	-2.79075	-1.73076	-1.97446	-0.31593	-2.53731	-1.85052	-1.69685
ALM-104-115	0.67101	-2.79065	0.62922	-2.85832	-1.76799	-2.14952	-0.37979	-2.58646	-1.84457	-1.75282
ALM-104-121	0.75259	-2.72519	0.50547	-2.79755	-1.74580	-1.93908	-0.31570	-2.54713	-1.82175	-1.69710
ALM-105-130	0.75636	-2.65945	0.51749	-2.77062	-1.71150	-1.99545	-0.32211	-2.49689	-1.80429	-1.74663

ALM-105-133	0.72996	-2.70850	0.51452	-2.79815	-1.75094	-2.05219	-0.37473	-2.51644	-1.82289	-1.79201
ALM-105-137	0.65415	-2.75148	0.48584	-2.81052	-1.78600	-2.07578	-0.32821	-2.60902	-1.88513	-1.69229
ALM-105-149	0.70181	-2.78459	0.51132	-2.86180	-1.78801	-1.80599	-0.35768	-2.54589	-1.89102	-1.71163
ALM-105-153	0.63785	-2.75534	0.50922	-2.83947	-1.76385	-2.07063	-0.30958	-2.62766	-1.87613	-1.70678
ALM-105-159	0.75560	-2.69744	0.52821	-2.80292	-1.73131	-1.99182	-0.32355	-2.51584	-1.78586	-1.74173
ALM-106-177	0.68602	-2.74562	0.46225	-2.79788	-1.75566	-2.01645	-0.34940	-2.54857	-1.89265	-1.67595
ALM-106-180	0.76697	-2.70260	0.49342	-2.74995	-1.71625	-2.10054	-0.30547	-2.52851	-1.82079	-1.73937
ALM-106-192	0.72260	-2.75817	0.59762	-2.79121	-1.76655	-2.09893	-0.34507	-2.60658	-1.84037	-1.75695
ALM-107-201	0.69361	-2.70230	0.46252	-2.82621	-1.73908	-2.09785	-0.34225	-2.57171	-1.84218	-1.75835
ALM-107-203	0.71974	-2.69305	0.51904	-2.77966	-1.72623	-2.08284	-0.30384	-2.56337	-1.80362	-1.72047
ALM-107-207	0.71982	-2.68827	0.54453	-2.75865	-1.72931	-2.13339	-0.32818	-2.55715	-1.81038	-1.70274
ALM-108-221	0.72425	-2.69075	0.51778	-2.79911	-1.72056	-1.92881	-0.32493	-2.49654	-1.82235	-1.71023
ALM-108-222	0.76462	-2.69372	0.52110	-2.74513	-1.71772	-2.14042	-0.28865	-2.52035	-1.81056	-1.72937
ALM-128-521	0.73058	-2.70220	0.50066	-2.75634	-1.72150	-2.12070	-0.33705	-2.53607	-1.84692	-1.74011
ALM-110-228	0.75139	-2.70239	0.50071	-2.77017	-1.72646	-1.97915	-0.31958	-2.50001	-1.80462	-1.70897
ALM-110-229	0.75641	-2.73718	0.52326	-2.79430	-1.72148	-2.07849	-0.32544	-2.52960	-1.80146	-1.73361
ALM-110-234	0.72504	-2.74793	0.48602	-2.84269	-1.74653	-2.02496	-0.31759	-2.52212	-1.83731	-1.69456
ALM-112-238	0.77609	-2.67062	0.54451	-2.77052	-1.67864	-2.13503	-0.29226	-2.58781	-1.78628	-1.71155
ALM-112-242	0.65068	-2.74756	0.59995	-2.87970	-1.81111	-2.16037	-0.36387	-2.63620	-1.82983	-1.78354
ALM-119-361	0.67699	-2.76641	0.58800	-2.82046	-1.78197	-2.19784	-0.33158	-2.54796	-1.85484	-1.69249
ALM-119-364	0.70119	-2.70369	0.51617	-2.79173	-1.75534	-2.12956	-0.31333	-2.61396	-1.79795	-1.71114
ALM-119-370	0.55983	-2.75968	0.48612	-2.85155	-1.75978	-1.74650	-0.37378	-2.62404	-1.94303	-1.70659
ALM-122-1836	0.68283	-2.76795	0.53643	-2.77655	-1.79781	-2.16045	-0.32972	-2.60472	-1.95601	-1.63524
ALM-122-397	0.70896	-2.71905	0.61557	-2.76074	-1.76191	-2.21492	-0.32715	-2.57555	-1.87124	-1.74123
ALM-122-399	0.70204	-2.74400	0.54151	-2.79440	-1.76869	-2.14206	-0.35473	-2.59787	-1.83219	-1.74264
ALM-122-400	0.70142	-2.77388	0.51931	-2.75670	-1.74185	-2.09119	-0.33951	-2.50364	-1.85863	-1.66938
ALM-122-402	0.78471	-2.67154	0.55783	-2.78432	-1.72157	-2.14115	-0.29624	-2.53162	-1.80140	-1.66970
ALM-123-1867	0.75086	-2.69884	0.54776	-2.73980	-1.71584	-2.13914	-0.28952	-2.50587	-1.78466	-1.68776
ALM-123-411	0.68340	-2.73882	0.54898	-2.83154	-1.79075	-2.14705	-0.35161	-2.57211	-1.91430	-1.68344
ALM-123-414	0.67817	-2.77044	0.47139	-2.96137	-1.83125	-2.07983	-0.39155	-2.67128	-1.93283	-1.84964
ALM-123-415	0.72020	-2.74094	0.44307	-2.82437	-1.79872	-2.09373	-0.33274	-2.55781	-1.87824	-1.68442
ALM-123-423	0.71082	-2.71098	0.57319	-2.81060	-1.75207	-2.11027	-0.31684	-2.48805	-1.85624	-1.68143
ALM-123-473	0.70862	-2.71512	0.49718	-2.78901	-1.75593	-2.09970	-0.33026	-2.53523	-1.83973	-1.71333
ALM-124-1342	0.63136	-2.85876	0.55125	-2.90478	-1.85961	-2.11418	-0.39460	-2.62515	-1.95002	-1.73052

ALM-124-446	0.70727	-2.76152	0.46861	-2.80812	-1.78006	-2.07886	-0.33462	-2.53840	-1.91966	-1.65652
ALM-124-450	0.74915	-2.68923	0.50120	-2.79198	-1.72099	-2.11664	-0.31803	-2.53224	-1.83431	-1.68468
ALM-124-453	0.75736	-2.75209	0.50410	-2.81693	-1.76353	-2.10081	-0.35761	-2.56172	-1.85126	-1.74062
ALM-124-455	0.83369	-2.68040	0.56903	-2.78306	-1.74670	-2.15695	-0.34434	-2.52580	-1.86115	-1.73055
ALM-124-456	0.72956	-2.70772	0.45327	-2.83915	-1.82729	-2.07066	-0.36757	-2.50365	-1.90741	-1.76620
ALM-125-1983	0.65035	-2.78534	0.58513	-2.91121	-1.81959	-2.14203	-0.34564	-2.60423	-1.94167	-1.70743
ALM-125-470	0.65392	-2.79040	0.58264	-2.79148	-1.78980	-2.20117	-0.34488	-2.60142	-1.85949	-1.69791
ALM-125-474	0.69120	-2.76513	0.50098	-2.82797	-1.77528	-2.14317	-0.35332	-2.59845	-1.86777	-1.73846
ALM-125-476	0.71972	-2.70541	0.59673	-2.85137	-1.74940	-2.21498	-0.35000	-2.58580	-1.81326	-1.73335
ALM-125-479	0.72203	-2.75381	0.62674	-2.85393	-1.75347	-2.20956	-0.34388	-2.55409	-1.85413	-1.71299
ALM-125-481	0.72038	-2.70848	0.60559	-2.80667	-1.74999	-2.06325	-0.33510	-2.53591	-1.84217	-1.70848
ALM-125-484	0.71810	-2.72996	0.52517	-2.80946	-1.75023	-1.79055	-0.34418	-2.61604	-1.76490	-1.88021
ALM-125-494	0.71458	-2.69101	0.55870	-2.78615	-1.71555	-2.07786	-0.31769	-2.59241	-1.80677	-1.75510
ALM-126-2053	0.64845	-2.80849	0.54999	-2.88581	-1.84546	-2.06196	-0.35206	-2.60341	-1.85425	-1.66200
ALM-126-490	0.70837	-2.69546	0.52488	-2.78819	-1.74917	-2.11039	-0.32978	-2.54260	-1.70891	-1.65905
ALM-126-491	0.81313	-2.64241	0.57821	-2.70166	-1.64950	-2.16808	-0.26142	-2.58887	-1.74103	-1.77289
ALM-126-493	0.67034	-2.66687	0.50683	-2.73172	-1.68841	-2.12188	-0.34333	-2.63083	-1.87913	-1.75424
ALM-126-498	0.71126	-2.72642	0.55778	-2.84773	-1.74998	-2.09994	-0.34685	-2.57449	-1.80224	-1.70814
ALM-127-2067	0.72395	-2.69533	0.52224	-2.82062	-1.75328	-2.07187	-0.34727	-2.57057	-1.76194	-1.75157
ALM-127-2078	0.72368	-2.72122	0.64068	-2.80689	-1.72395	-2.24060	-0.34313	-2.63362	-1.81320	-1.74290
ALM-127-2091	0.65510	-2.79685	0.57610	-2.86620	-1.82008	-2.15119	-0.35307	-2.69235	-1.86528	-1.73294
ALM-127-2092	0.70259	-2.85738	0.55898	-2.91014	-1.82302	-2.11187	-0.40223	-2.62073	-1.93218	-1.73013
ALM-127-504	0.77883	-2.70449	0.51845	-2.76216	-1.73476	-2.07769	-0.33161	-2.54663	-1.82427	-1.72880
ALM-127-506	0.73256	-2.69281	0.49626	-2.77060	-1.73357	-2.12453	-0.32611	-2.53248	-1.81441	-1.67899
ALM-127-517	0.72695	-2.70274	0.49175	-2.77911	-1.72996	-2.14191	-0.32037	-2.54669	-1.83593	-1.74119
ALM-128-2157	0.63896	-2.81240	0.51880	-2.84869	-1.83211	-2.10909	-0.36128	-2.66288	-1.91024	-1.61926
ALM-128-2241	0.64343	-2.81492	0.49684	-2.92580	-1.81823	-2.07896	-0.36558	-2.64231	-1.90508	-1.70629
ALM-128-524	0.71722	-2.74353	0.47475	-2.78492	-1.74972	-2.14524	-0.32566	-2.54391	-1.86188	-1.64518
ALM-128-526	0.69868	-2.70768	0.58733	-2.80082	-1.71670	-2.08381	-0.35391	-2.63366	-1.80679	-1.81709
ALM-128-536	0.69846	-2.75495	0.48856	-2.81988	-1.77922	-2.05193	-0.33120	-2.61902	-1.84700	-1.64801
ALM-128-551	0.68433	-2.70967	0.51048	-2.84885	-1.76577	-2.05984	-0.35401	-2.59302	-1.89912	-1.74910
ALM-128-553	0.73914	-2.70225	0.50799	-2.82045	-1.73751	-2.08003	-0.30788	-2.51069	-1.81774	-1.69928
ALM-128-559	0.61563	-2.81317	0.49907	-2.94584	-1.83353	-1.95077	-0.38142	-2.63009	-1.91842	-1.70564
ALM-105-172	0.74409	-2.67334	0.53795	-2.75473	-1.72518	-2.14566	-0.30405	-2.50646	-1.80430	-1.69029

ALM-xxx-202	0.72757	-2.70394	0.48808	-2.82649	-1.72150	-2.08605	-0.30118	-2.51051	-1.83397	-1.68143
ALM-XXX-204	0.69747	-2.71534	0.39665	-2.78827	-1.81899	-2.04507	-0.29819	-2.57232	-1.89321	-1.57836
ALM-107-210	0.52123	-2.89129	0.45393	-2.95943	-1.92806	-1.82883	-0.43382	-2.65216	-2.05129	-1.64631
ALM-xxx-214	0.74413	-2.72612	0.47907	-2.79375	-1.74441	-1.94036	-0.33292	-2.56240	-1.82578	-1.69678
LHR-1017	0.61388	-2.73867	0.43757	-2.88994	-1.88393	-1.77111	-0.37703	-2.63630	-1.94031	-1.72456
LHR-102	0.64372	-2.82683	0.41225	-2.84290	-1.85593	-1.73573	-0.35867	-2.61257	-1.95578	-1.63016
LHR-214	0.60781	-2.81319	0.44382	-2.89436	-1.84548	-1.76995	-0.36522	-2.61995	-1.91561	-1.66781
LHR-239	0.59713	-2.78711	0.42672	-2.88857	-1.80121	-1.75550	-0.38240	-2.63040	-1.88458	-1.69063
LHR-245	0.64092	-2.76688	0.46134	-2.82992	-1.83410	-1.64934	-0.37593	-2.65396	-1.98423	-1.64152
LHR-256	0.58229	-2.82230	0.42936	-2.82612	-1.78914	-1.77764	-0.37282	-2.63251	-1.95720	-1.69390
LHR-289	0.60725	-2.74690	0.44622	-2.86650	-1.82240	-1.70771	-0.36314	-2.58024	-1.91877	-1.64568
LHR-291	0.64675	-2.74984	0.39408	-2.86615	-1.83640	-1.78256	-0.37427	-2.56120	-1.94417	-1.70799
LHR-30	0.59711	-2.80094	0.43010	-2.88493	-1.89246	-1.77013	-0.40109	-2.57662	-1.90815	-1.70727
LHR-322	0.55046	-2.82004	0.40542	-2.87998	-1.88818	-1.76659	-0.38981	-2.58924	-1.90623	-1.68655
LHR-372	0.61708	-2.77156	0.43653	-2.88174	-1.83784	-1.85905	-0.39398	-2.61161	-1.97258	-1.70832
LHR-391	0.61588	-2.80108	0.40101	-2.85476	-1.82645	-1.75164	-0.39355	-2.60012	-1.92280	-1.66153
LHR-414	0.60458	-2.76764	0.45972	-2.84077	-1.82843	-1.77340	-0.36038	-2.67076	-1.92674	-1.65132
LHR-478	0.62597	-3.72674	0.48654	-2.86661	-1.85333	-1.79829	-0.35862	-2.61756	-1.86812	-1.69005
LHR-482	0.65114	-2.72572	0.41630	-2.85089	-1.83159	-1.70869	-0.35580	-2.60470	-1.93737	-1.67768
LHR-499	0.62968	-2.80161	0.44310	-2.82310	-1.79759	-1.75101	-0.34465	-2.58460	-1.89066	-1.68525
LHR-502	0.54986	-2.78865	0.40494	-2.87817	-1.87175	-1.65329	-0.40857	-2.62634	-1.99243	-1.67287
LHR-532	0.57459	-2.75520	0.46506	-2.90633	-1.90604	-1.71794	-0.39950	-2.66001	-1.93837	-1.69223
LHR-547	0.57881	-2.72642	0.48968	-2.88528	-1.87420	-1.75713	-0.37251	-2.71425	-1.90642	-1.65729
LHR-550	0.60484	-2.75222	0.48045	-2.85001	-1.85823	-1.47013	-0.35606	-2.66547	-1.88608	-1.59269
LHR-574	0.59502	-2.79951	0.39179	-2.94521	-1.91683	-1.64322	-0.36917	-2.64700	-1.96619	-1.63093
LHR-576	0.59893	-2.78868	0.40321	-2.94652	-1.94097	-1.60195	-0.36710	-2.69053	-1.98100	-1.62248
LHR-592	0.64004	-2.78446	0.48817	-2.88692	-1.83326	-1.70260	-0.35780	-2.66232	-1.96250	-1.62466
LHR-674	0.57996	-2.76851	0.44430	-2.86382	-1.89874	-1.71604	-0.40799	-2.64421	-1.96861	-1.68261
LHR-678	0.59394	-2.77648	0.41279	-2.90180	-1.90769	-1.70185	-0.36928	-2.65830	-1.97718	-1.64670
LHR-780	0.61461	-2.77841	0.42952	-2.86427	-1.84215	-1.67470	-0.38031	-2.59402	-1.94665	-1.71827
LHR-810	0.63966	-2.81223	0.45508	-2.82084	-1.81228	-1.75264	-0.35581	-2.58674	-1.92074	-1.70202
LHR-814	0.59478	-2.85733	0.40823	-2.85714	-1.81225	-1.80164	-0.36251	-2.62860	-1.92122	-1.69668
LHR-815	0.62664	-2.84357	0.45652	-2.86909	-1.80518	-1.65295	-0.38325	-2.57323	-1.89709	-1.68022
LHR-821	0.61806	-2.79488	0.42944	-2.81805	-1.81590	-1.67809	-0.35651	-2.59569	-1.91281	-1.69752

LHR-1083	0.74153	-2.78376	0.52031	-2.75596	-1.73356	-1.89293	-0.32629	-2.57978	-1.81994	-1.77989
LHR-242	0.66130	-2.74557	0.44389	-2.82713	-1.79488	-1.77355	-0.37783	-2.56096	-1.90569	-1.74769
LHR-303	0.65208	-2.73897	0.54430	-2.82853	-1.80807	-1.83052	-0.34964	-2.63950	-1.88195	-1.73970
LHR-323	0.73232	-2.68311	0.55451	-2.74881	-1.71781	-1.87001	-0.31806	-2.59517	-1.82971	-1.74578
LHR-327	0.64356	-2.74452	0.48379	-2.85295	-1.78865	-1.74787	-0.35483	-2.63830	-1.90585	-1.73545
LHR-342	0.61623	-2.79049	0.50948	-2.79475	-1.84528	-1.68363	-0.33088	-2.63916	-1.89052	-1.68446
LHR-37	0.65411	-2.75872	0.48540	-2.78461	-1.80481	-1.72385	-0.35707	-2.63503	-1.88928	-1.75914
LHR-400	0.67288	-2.72964	0.48122	-2.77476	-1.74243	-1.84518	-0.33492	-2.61118	-1.81561	-1.72078
LHR-401	0.63801	-2.77072	0.44494	-2.82962	-1.80626	-1.74521	-0.33883	-2.61425	-1.88318	-1.74258
LHR-402	0.59333	-2.74198	0.47509	-2.87847	-1.82013	-1.73008	-0.34069	-2.63259	-1.92349	-1.70269
LHR-407	0.66165	-2.71299	0.48998	-2.81679	-1.76829	-1.80656	-0.35622	-2.60974	-1.86947	-1.73274
LHR-429	0.65375	-2.71708	0.47306	-2.82895	-1.77578	-1.54298	-0.32109	-2.61473	-1.88059	-1.74710
LHR-433	0.63324	-2.75215	0.46936	-2.85026	-1.80737	-1.78548	-0.32452	-2.62389	-1.87522	-1.70575
LHR-436	0.60629	-2.74575	0.52589	-2.84784	-1.75374	-1.72247	-0.33761	-2.57245	-1.77202	-1.74908
LHR-448	0.63604	-2.80627	0.45610	-2.84532	-1.78378	-1.68769	-0.34939	-2.61637	-1.82845	-1.72152
LHR-455	0.69212	-2.88351	0.50296	-2.78607	-1.75583	-1.81798	-0.35279	-2.61115	-1.86943	-1.73795
LHR-494	0.66254	-2.66724	0.46323	-2.84310	-1.80948	-1.66274	-0.36382	-2.62277	-1.90719	-1.64811
LHR-495	0.68688	-2.85382	0.49621	-2.80136	-1.74736	-1.82019	-0.33743	-2.59163	-1.85733	-1.72274
LHR-497	0.59313	-2.73731	0.45358	-2.79070	-1.78822	-1.71187	-0.33857	-2.64984	-1.91834	-1.66584
LHR-506	0.64225	-2.84005	0.49190	-2.83217	-1.80913	-1.70166	-0.33319	-2.57433	-1.83729	-1.70332
LHR-556	0.67921	-2.73552	0.48689	-2.81053	-1.79894	-1.94867	-0.37082	-2.62785	-1.89239	-1.72993
LHR-566	0.66555	-2.87233	0.43904	-2.82944	-1.81203	-1.82040	-0.35671	-2.59840	-1.79348	-1.74459
LHR-590	0.71482	-2.73310	0.51201	-2.79423	-1.77858	-1.72267	-0.32791	-2.62942	-1.91664	-1.73065
LHR-7	0.66607	-2.75444	0.48080	-2.83205	-1.78796	-1.81596	-0.33454	-2.60522	-1.85302	-1.72871
LHR-812	0.71546	-2.81685	0.48365	-2.79305	-1.78367	-1.66757	-0.32500	-2.61131	-1.86512	-1.73457
LHR-818	0.63861	-2.75073	0.45090	-2.80820	-1.78500	-1.64407	-0.38280	-2.58830	-1.89570	-1.70051
LHR-819	0.65696	-2.74605	0.45680	-2.90536	-1.82633	-1.66570	-0.34876	-2.57794	-1.90484	-1.72447
LHR-108	0.56225	-2.79243	0.48851	-2.85626	-1.87274	-1.71203	-0.38862	-2.64322	-1.90726	-1.77054
LHR-20	0.61780	-2.78238	0.50575	-2.93832	-1.85059	-1.81660	-0.39376	-2.68305	-1.90722	-1.75339
LHR-218	0.60621	-2.86677	0.49406	-2.91395	-1.90662	-1.50168	-0.39232	-2.63739	-1.90188	-1.73657
LHR-240	0.69298	-2.78616	0.49625	-2.82470	-1.83631	-1.65886	-0.36587	-2.69768	-1.88598	-1.72443
LHR-408	0.61706	-2.81930	0.47261	-2.92327	-1.91068	-1.30023	-0.40023	-2.66818	-2.00529	-1.68649
LHR-428	0.63638	-2.72209	0.55716	-2.82649	-1.79804	-1.54319	-0.36081	-2.62821	-1.89775	-1.73998
LHR-428-BIS	0.62865	-2.75528	0.56250	-2.82153	-1.81138	-1.55274	-0.35486	-2.63258	-1.91173	-1.75240

LHR-428-TRIS	0.63219	-2.72548	0.55484	-2.82579	-1.80978	-1.55063	-0.37104	-2.62840	-1.89819	-1.74303
LHR-489	0.61348	-2.72834	0.47631	-2.84693	-1.82823	-1.48164	-0.35981	-2.64862	-1.94350	-1.69550
LHR-549	0.57142	-2.67696	0.58697	-2.87000	-1.87357	-1.42129	-0.35329	-2.63567	-1.98843	-1.69246
LHR-561	0.61007	-2.82515	0.51451	-2.89340	-1.86448	-1.59090	-0.36741	-2.70493	-1.87649	-1.72300
LHR-465	0.66023	-2.72218	0.45187	-2.76873	-1.77237	-1.82431	-0.35360	-2.54816	-1.89838	-1.69279
LHR-612	0.62589	-2.78379	0.45259	-2.81148	-1.78935	-1.94155	-0.33109	-2.57662	-1.88141	-1.69983
LHR-23	0.66233	-2.74895	0.44219	-2.83329	-1.79416	-1.79807	-0.33787	-2.56019	-1.90858	-1.72794
LHR-241	0.69928	-2.73866	0.47250	-2.82028	-1.77727	-1.79875	-0.30161	-2.57055	-1.89665	-1.69306
LHR-268	0.63166	-2.74453	0.46490	-2.83120	-1.78689	-1.89475	-0.35627	-2.56177	-1.93069	-1.68200
LHR-290	0.57616	-2.82266	0.38369	-2.88050	-1.88359	-1.72314	-0.34939	-2.55177	-1.95542	-1.62063
LHR-304	0.67846	-2.70929	0.46024	-2.79460	-1.76903	-1.94701	-0.32001	-2.52409	-1.90907	-1.66053
LHR-313	0.61433	-2.77243	0.46584	-2.79877	-1.80545	-1.88498	-0.36472	-2.56386	-1.92147	-1.68305
LHR-359	0.68498	-2.72482	0.48100	-2.80292	-1.76185	-1.83149	-0.33937	-2.52806	-1.86306	-1.68515
LHR-422	0.71178	-2.74323	0.50177	-2.78010	-1.75203	-1.76268	-0.31989	-2.51050	-1.87478	-1.69287
LHR-43	0.49563	-2.90667	0.35354	-2.88337	-2.00129	-1.74659	-0.39285	-2.63129	-2.12736	-1.58257
LHR-437	0.70722	-2.84983	0.47226	-2.79434	-1.77580	-1.81653	-0.32022	-2.55248	-1.86292	-1.75080
LHR-440	0.63087	-2.98458	0.41423	-2.87052	-1.84573	-1.85411	-0.36853	-2.58373	-1.96118	-1.64952
LHR-458	0.58691	-2.74308	0.38307	-2.85486	-1.89955	-1.84912	-0.39173	-2.59330	-2.02335	-1.62431
LHR-483	0.61808	-2.78553	0.33313	-2.89945	-1.94439	-1.61675	-0.35344	-2.60242	-2.02155	-1.57563
LHR-49	0.65147	-2.74932	0.40841	-2.89124	-1.83779	-1.87179	-0.35941	-2.58544	-1.98599	-1.63424
LHR-5	0.66817	-2.74272	0.43836	-2.76385	-1.77746	-1.83272	-0.34082	-2.57776	-1.90908	-1.70251
LHR-565	0.69632	-2.76278	0.47811	-2.78070	-1.75140	-1.69451	-0.33719	-2.51831	-1.85518	-1.72213
LHR-567	0.63669	-2.83154	0.42276	-2.76920	-1.78115	-1.75769	-0.34802	-2.54351	-1.94661	-1.66693
LHR-58	0.62195	-2.77130	0.41139	-2.90707	-1.82844	-1.82253	-0.35316	-2.60678	-1.99007	-1.62390
LHR-602	0.64208	-2.69962	0.56311	-2.76865	-1.83844	-1.92037	-0.36115	-2.58169	-1.93151	-1.68127
LHR-619	0.64170	-2.73935	0.41509	-2.87238	-1.83024	-1.89302	-0.37794	-2.59330	-1.98538	-1.64887
LHR-620	0.68157	-2.79798	0.40446	-2.83778	-1.78877	-1.91951	-0.35820	-2.59725	-1.97347	-1.68939
LHR-632	0.62046	-2.85428	0.50494	-2.92278	-1.91320	-1.83902	-0.38386	-2.58721	-2.03065	-1.60550
LHR-809	0.62591	-2.74518	0.47865	-2.81564	-1.76494	-1.75131	-0.31934	-2.55805	-1.83878	-1.65589
LHR-811	0.58006	-2.79844	0.39940	-2.86500	-1.89162	-1.76990	-0.38207	-2.59175	-2.02734	-1.62004
LHR-816	0.43244	-2.79379	0.50462	-2.95696	-2.02162	-1.61217	-0.44015	-2.66057	-2.12629	-1.64078
LHR-87	0.64969	-2.75452	0.34241	-2.80941	-1.85859	-1.95706	-0.31891	-2.52750	-1.98219	-1.53321
LHR-88	0.67204	-2.73645	0.47528	-2.79132	-1.79257	-1.92044	-0.32821	-2.52373	-1.84206	-1.66745
LHR-93	0.62434	-2.77125	0.41141	-2.81880	-1.83046	-1.84477	-0.34965	-2.58051	-1.95575	-1.64501

LHR-98	0.46912	-2.93065	0.45638	-3.00579	-2.00551	-1.67606	-0.40705	-2.67979	-2.15841	-1.63831
MSD-593	0.62432	-2.82771	0.54895	-2.86203	-1.85351	-1.10425	-0.39165	-2.61162	-1.87006	-1.87334
MSD-52	-0.15686	-3.20911	-0.12092	-3.59909	-2.96755	-1.91704	-1.01461	-3.05702	-2.26284	-1.95124
MSD-472	0.68128	-2.75163	0.54744	-2.84275	-1.82953	-1.71064	-0.35577	-2.59444	-1.83234	-1.76798
MSD-304	0.61022	-2.79406	0.47382	-2.86990	-1.87358	-1.75971	-0.35439	-2.57358	-1.94762	-1.61261
MSD-328	0.67824	-2.77405	0.38948	-2.82845	-1.83620	-1.74940	-0.34318	-2.57521	-1.95474	-1.65175
MSD-3	0.67938	-2.80761	0.40869	-2.83535	-1.84503	-1.82781	-0.33407	-2.56458	-1.94047	-1.66185
MSD-16	0.58671	-2.76018	0.41579	-2.82619	-1.80220	-1.81177	-0.36312	-2.56438	-1.94645	-1.65922
MSD-100	0.63063	-2.84085	0.37285	-2.85840	-1.87212	-1.84222	-0.35928	-2.62950	-1.97795	-1.65562
MSD-193	0.64167	-2.80870	0.41898	-2.87124	-1.88416	-1.70901	-0.34955	-2.62843	-1.99882	-1.64925
MSD-196	0.59203	-2.80296	0.36418	-2.91296	-1.91151	-1.85073	-0.38751	-2.58094	-1.98605	-1.61944
MSD-201	0.60562	-2.82570	0.42576	-2.92330	-1.87523	-1.74318	-0.38021	-2.65408	-1.98367	-1.60836
MSD-231	0.61559	-2.76606	0.37710	-2.85081	-1.81767	-1.87645	-0.36341	-2.60988	-1.94725	-1.68123
MSD-232	0.65645	-2.79327	0.42125	-2.87985	-1.87625	-1.76531	-0.34276	-2.62298	-1.97564	-1.64355
MSD-240	0.63136	-2.78801	0.55665	-2.84633	-1.86946	-1.80212	-0.39425	-2.62597	-1.96524	-1.70439
MSD-245	0.64932	-2.80785	0.39487	-2.85186	-1.85708	-1.75628	-0.35998	-2.60577	-1.97141	-1.63031
MSD-315	0.65707	-2.80092	0.42730	-2.84113	-1.86317	-1.84397	-0.35265	-2.60124	-1.95543	-1.63617
MSD-366	0.67401	-2.79458	0.45301	-2.82855	-1.83293	-1.78523	-0.34096	-2.54931	-1.91744	-1.65923
MSD-384	0.64318	-2.77702	0.37043	-2.87635	-1.89439	-1.80411	-0.35421	-2.58109	-1.96477	-1.61686
MSD-424	0.62782	-2.78206	0.36205	-2.85192	-1.90153	-1.82458	-0.36537	-2.59917	-1.98205	-1.61062
MSD-426	0.65064	-2.80094	0.38559	-2.86694	-1.89890	-1.81651	-0.33264	-2.61174	-1.97943	-1.59534
MSD-436	0.65160	-2.76628	0.43735	-2.82711	-1.84699	-1.77119	-0.34039	-2.59967	-1.92137	-1.66664
MSD-465	0.61783	-2.78634	0.40744	-2.81218	-1.86684	-1.78161	-0.35203	-2.60318	-1.90529	-1.70018
MSD-468	0.62869	-2.76098	0.42741	-2.80450	-1.85032	-1.73646	-0.34427	-2.58733	-1.88864	-1.69210
MSD-493	0.66457	-2.76433	0.44380	-2.82360	-1.84923	-1.79977	-0.35350	-2.58779	-1.89870	-1.64619
MSD-849	0.64309	-2.79418	0.41396	-2.85342	-1.86504	-1.78703	-0.36429	-2.63943	-1.94181	-1.65809
MSD-853	0.63769	-2.80654	0.40126	-2.83318	-1.85077	-1.80068	-0.37262	-2.58064	-1.92710	-1.64071
MSD-44	0.58144	-2.85886	0.38713	-2.91114	-1.96076	-1.87245	-0.37968	-2.61244	-2.03324	-1.62471
MSD-270	0.56733	-2.84545	0.32196	-2.88825	-1.95560	-1.76308	-0.39131	-2.63592	-2.03448	-1.63101
MSD-471	0.53674	-2.87757	0.41234	-2.93744	-1.98520	-1.64210	-0.40046	-2.66085	-2.07733	-1.62140
MSD-504	0.58339	-2.82647	0.42460	-2.93568	-1.98471	-1.82708	-0.37893	-2.65661	-2.03545	-1.63703
MSD-592	0.53687	-2.93133	0.43369	-2.97472	-2.02490	-1.65251	-0.40876	-2.63139	-2.05725	-1.60970
MSD-383	0.55050	-2.85221	0.36279	-2.89105	-1.92820	-1.81916	-0.36654	-2.67803	-2.01544	-1.62488
MSD-45	0.52840	-2.89736	0.44342	-2.88495	-1.94601	-1.64687	-0.41392	-2.64268	-1.96839	-1.66488

MSD-70	0.64054	-2.78723	0.45698	-2.85275	-1.86910	-1.70981	-0.36809	-2.61454	-1.91367	-1.68971
MSD-361	0.67536	-2.76733	0.49267	-2.83327	-1.86527	-1.63222	-0.33192	-2.55945	-1.90677	-1.66186
MSD-446	0.60203	-2.83529	0.42192	-2.81634	-1.87234	-1.73214	-0.36864	-2.58390	-1.92143	-1.66967
MSD-11	0.62321	-2.84053	0.41492	-2.82800	-1.95353	-1.70604	-0.34932	-2.57723	-1.97819	-1.57488
MSD-14	0.64917	-2.80529	0.42792	-2.86446	-1.85453	-1.74265	-0.36212	-2.61446	-1.92771	-1.68389
MSD-86	0.56423	-2.81466	0.48793	-2.91379	-1.90889	-1.68527	-0.37910	-2.62866	-1.97869	-1.65876
MSD-160	0.61411	-2.78691	0.47857	-2.81322	-1.83348	-1.70611	-0.38660	-2.59345	-1.95582	-1.69356
MSD-233	0.63798	-2.80053	0.38530	-2.88590	-1.89844	-1.63271	-0.34146	-2.61148	-1.93752	-1.63056
MSD-402	0.61768	-2.79194	0.40937	-2.84281	-1.86125	-1.72947	-0.36401	-2.63663	-1.90769	-1.70463
MSD-408	0.62197	-2.83598	0.40101	-2.87209	-1.88405	-1.59252	-0.35145	-2.63253	-1.93887	-1.69691
MSD-410	0.62019	-2.77466	0.39279	-2.84604	-1.87604	-1.68767	-0.34452	-2.61108	-1.94947	-1.67942
MSD-431	0.55217	-2.83183	0.34744	-2.87031	-1.91522	-1.64316	-0.37438	-2.62458	-2.01723	-1.63380
MSD-778	0.65182	-2.80850	0.38603	-2.89441	-1.86408	-1.61425	-0.36096	-2.61196	-1.96053	-1.65658
MSD-803	0.60992	-2.85760	0.50839	-2.88951	-1.89569	-1.69780	-0.37726	-2.62349	-1.97648	-1.66195
MSD-293	0.63532	-2.77355	0.47969	-2.83677	-1.82591	-1.77564	-0.33515	-2.59630	-1.87196	-1.71508
MSD-332	0.70287	-2.67859	0.51120	-2.80391	-1.73650	-1.73494	-0.27616	-2.54836	-1.80773	-1.71390
MSD-34	0.73089	-2.70863	0.54386	-2.81255	-1.77401	-1.65089	-0.32429	-2.60368	-1.86214	-1.73522
MSD-433	0.65649	-2.72862	0.45352	-2.80875	-1.79600	-1.65389	-0.38099	-2.57213	-1.87229	-1.71745
MSD-9	0.63896	-2.73388	0.43685	-2.84926	-1.84229	-1.65964	-0.35128	-2.56735	-1.92729	-1.73906
MSD-12	0.66453	-2.78185	0.47332	-2.81971	-1.85202	-1.77940	-0.32988	-2.64251	-1.87910	-1.75107
MSD-30	0.67840	-2.73313	0.44164	-2.83631	-1.79204	-1.71867	-0.33618	-2.60523	-1.89698	-1.67608
MSD-234	0.69546	-2.76206	0.50590	-2.86507	-1.78996	-1.80097	-0.34718	-2.61899	-1.77239	-1.78890
MSD-238	0.66995	-2.72812	0.50363	-2.86246	-1.82540	-1.77811	-0.32850	-2.62026	-1.85089	-1.78157
MSD-429	0.68922	-2.73751	0.41486	-2.79255	-1.79596	-1.74959	-0.35210	-2.53370	-1.88569	-1.64042
MSD-438	0.70237	-2.71506	0.43465	-2.79880	-1.81813	-1.76210	-0.31292	-2.59082	-1.90567	-1.65485
MSD-637	0.67211	-2.74260	0.40937	-2.88367	-1.80450	-1.69621	-0.34402	-2.62953	-1.92018	-1.67405
MSD-642	0.65674	-2.78006	0.45668	-2.85436	-1.82669	-1.76865	-0.32917	-2.60419	-1.86910	-1.74244
MSD-654	0.68260	-2.74820	0.46243	-2.84346	-1.80223	-1.68533	-0.34083	-2.58692	-1.81602	-1.76477
MSD-461	0.66567	-2.75691	0.47101	-2.79719	-1.79141	-1.86035	-0.34355	-2.58841	-1.89214	-1.72328
MSD-387	0.65053	-2.73458	0.39387	-2.83408	-1.83393	-2.20890	-0.38496	-2.54753	-1.95446	-1.69126
MSD-388	0.69759	-2.73680	0.45054	-2.78153	-1.80519	-1.82219	-0.32665	-2.58023	-1.88412	-1.66790
MSD-420	0.67113	-2.68627	0.42822	-2.79012	-1.76932	-1.91582	-0.35979	-2.52980	-1.84802	-1.70915
MSD-421	0.69789	-2.69732	0.46075	-2.75775	-1.76338	-1.96657	-0.34577	-2.52509	-1.85254	-1.70763
MSD-15	0.67414	-2.72873	0.47466	-2.81895	-1.77297	-1.79420	-0.35607	-2.59495	-1.88132	-1.70690

MSD-199	0.66506	-2.76046	0.50657	-2.89850	-1.83394	-1.87191	-0.33862	-2.64699	-1.93861	-1.75303
MSD-202	0.65955	-2.75249	0.45472	-2.80830	-1.85228	-1.89808	-0.35904	-2.59438	-1.89921	-1.70104
MSD-236	0.68935	-2.73136	0.41265	-2.78556	-1.83546	-1.84064	-0.34647	-2.58662	-1.91812	-1.64888
MSD-237	0.66583	-2.79072	0.43661	-2.85601	-1.87130	-1.88666	-0.35488	-2.62741	-1.92181	-1.71892
MSD-423	0.71119	-2.76859	0.43020	-2.79967	-1.79338	-1.85743	-0.32915	-2.57012	-1.91128	-1.67642
MSD-427	0.67095	-2.73620	0.45144	-2.81248	-1.79242	-1.89592	-0.34552	-2.62109	-1.87776	-1.76572
MSD-428	0.69432	-2.75148	0.41032	-2.79828	-1.80564	-1.83552	-0.33237	-2.56003	-1.88920	-1.66965
MSD-430	0.68823	-2.75734	0.41868	-2.81802	-1.83433	-1.82688	-0.33226	-2.63012	-1.90268	-1.69351
MSD-432	0.70430	-2.80246	0.47223	-2.81520	-1.78698	-1.81429	-0.33078	-2.62151	-1.89406	-1.65352
MSD-439	0.70614	-2.78141	0.45487	-2.83990	-1.80893	-1.85355	-0.32669	-2.59082	-1.91841	-1.67580
MSD-653	0.70166	-2.77564	0.50512	-2.83140	-1.76940	-1.87309	-0.32950	-2.63783	-1.83903	-1.75310
MSD-658	0.69716	-2.77144	0.45723	-2.84371	-1.81872	-1.80919	-0.33472	-2.62320	-1.92595	-1.70051
MSD-772	0.64882	-2.75610	0.43424	-2.84026	-1.80503	-1.83403	-0.34455	-2.59803	-1.88424	-1.69083
MSD-186	0.57321	-2.83983	0.53416	-2.93417	-1.93577	-1.43783	-0.41795	-2.64833	-1.85720	-1.75975
MSD-521	0.63334	-2.75480	0.59259	-2.85326	-1.86355	-1.58149	-0.36396	-2.59882	-1.95479	-1.69003
MSD-49	0.64612	-2.79214	0.43065	-2.84394	-1.85228	-1.41288	-0.36426	-2.59016	-1.90738	-1.68994
MSD-57	0.63777	-2.77100	0.50980	-2.87454	-1.91051	-1.39300	-0.38459	-2.63892	-1.88459	-1.78451
MSD-690	0.66445	-2.79315	0.46728	-2.85342	-1.83813	-1.53931	-0.34505	-2.60742	-1.94296	-1.65953
MSD-696	0.57452	-2.84445	0.47354	-2.89842	-1.88797	-1.56678	-0.39182	-2.64480	-1.93737	-1.69151
MSD-13	0.67142	-2.75292	0.48268	-2.87732	-1.81424	-1.54630	-0.34778	-2.62338	-1.90970	-1.73877
MSD-462	0.68442	-2.71990	0.50549	-2.82977	-1.81500	-1.39616	-0.33401	-2.61278	-1.84314	-1.74142
MSD-627	0.64670	-2.75148	0.49823	-2.82447	-1.77564	-1.51770	-0.32525	-2.59124	-1.88964	-1.75187
MSD-693	0.56276	-2.86279	0.47810	-2.90939	-1.92220	-1.51298	-0.40223	-2.64400	-1.96828	-1.73134
MSD-405	0.61227	-2.80331	0.42204	-2.87503	-1.90721	-1.49792	-0.35429	-2.56888	-1.92742	-1.67593
MSD-638	0.64480	-2.79171	0.42500	-2.88625	-1.84026	-1.55992	-0.32279	-2.63907	-1.94052	-1.68159
MSD-657	0.67163	-2.73831	0.53635	-2.85170	-1.82882	-1.41898	-0.33732	-2.62354	-1.82606	-1.75438
MSD-838	0.62659	-2.80552	0.44344	-2.85959	-1.87635	-1.54571	-0.36363	-2.64039	-1.94702	-1.67557
MSD-557/75	0.59929	-2.83329	0.44127	-2.89776	-1.86872	-1.67093	-0.39045	-2.64052	-1.92396	-1.74931
MSD-470 /70	0.60590	-2.82410	0.45368	-2.91255	-1.88435	-1.66742	-0.37029	-2.63351	-1.93836	-1.69736
MSD-691 /87	0.65055	-2.81773	0.49190	-2.80204	-1.84382	-1.66680	-0.36275	-2.56275	-1.94033	-1.62830
MSD-695 /90	0.65873	-2.84067	0.47078	-2.83868	-1.83581	-1.71462	-0.34642	-2.59606	-1.93667	-1.64565
MSD-753 /92	0.63648	-2.80558	0.42745	-2.86398	-1.86114	-1.67138	-0.37331	-2.58123	-1.94633	-1.67416
MSD-694 /89	0.52324	-2.89278	0.45544	-2.92096	-1.93036	-1.71170	-0.43289	-2.71040	-1.99584	-1.69281
MSD-468 (-bis)	0.62563	-2.81627	0.43354	-2.85570	-1.85226	-1.73446	-0.34383	-2.58819	-1.89862	-1.67472

Appendix D: Illustrations of ceramics

List of Plates

Plate I. Types of bases: flat, disk, ring, pointed, and pedestal types

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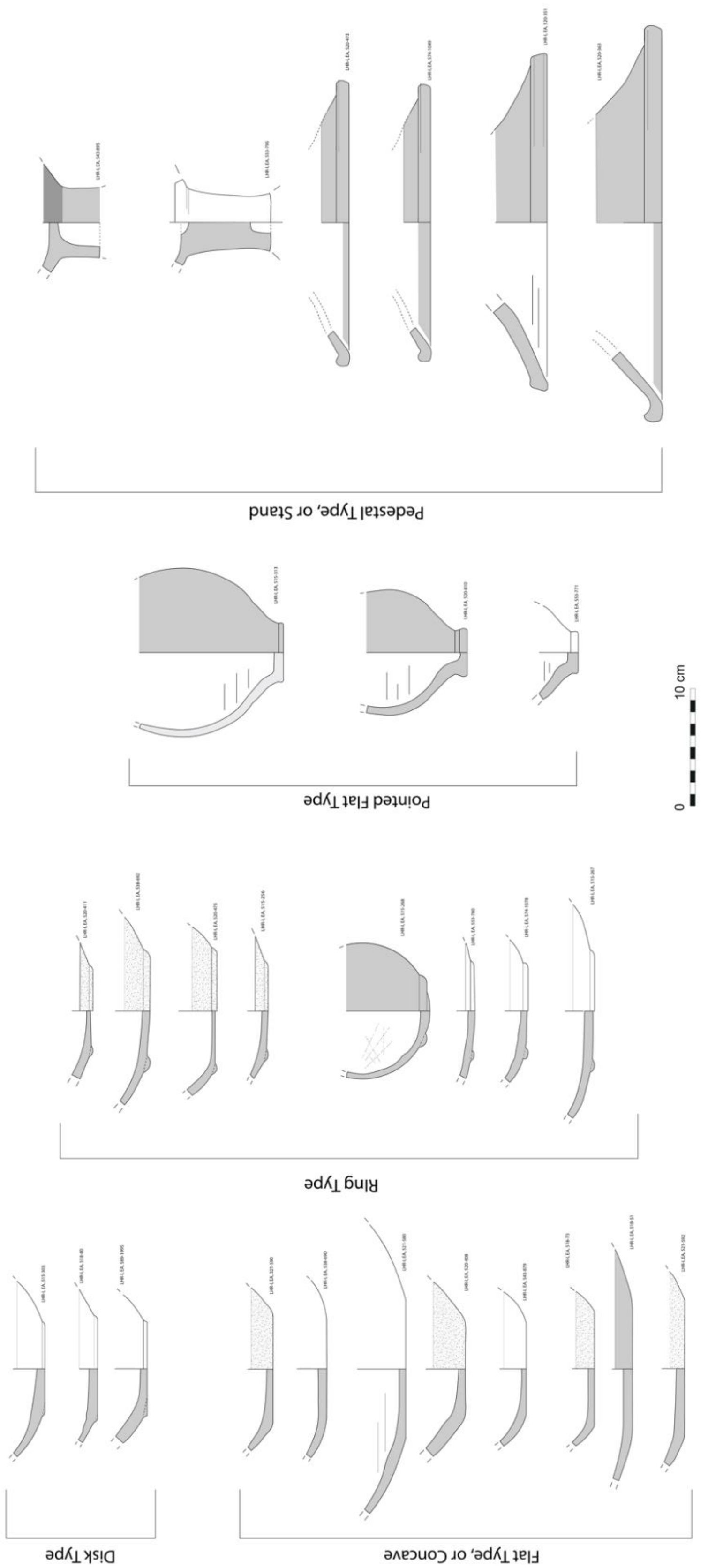


Plate II. LHR Bowl Types. Typologies consider the orientation and projection of the rim in section as determining factors.

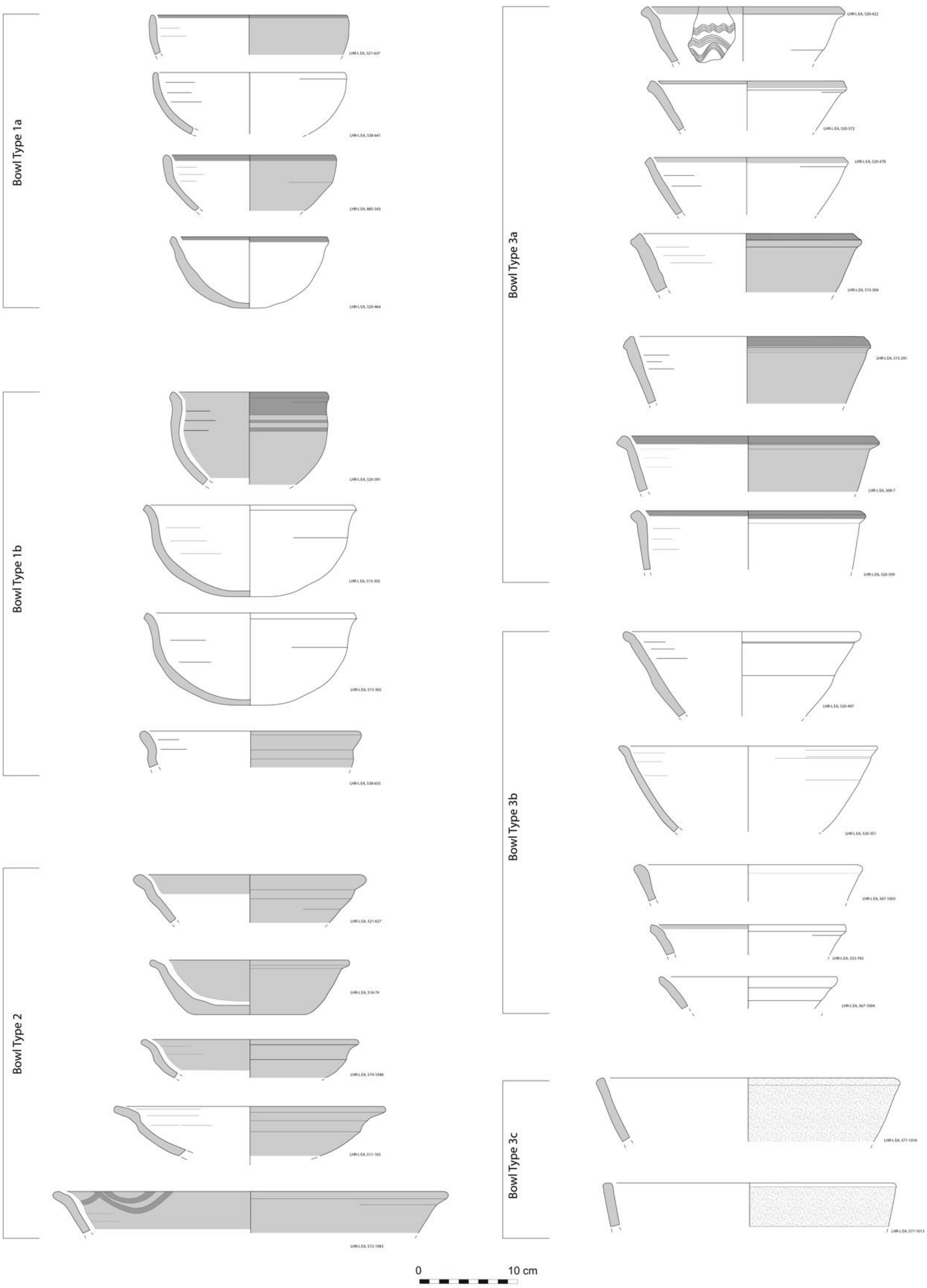

Bowl Type 1a
Bowl Type 1b
Bowl Type 2
Bowl Type 3a
Bowl Type 3b
Bowl Type 3c
0
10 cm

Plate III. LHR Jar Type 1. S-shaped sections of rim, neck and upper body. This type is mostly associate with globular or elliptical jars.

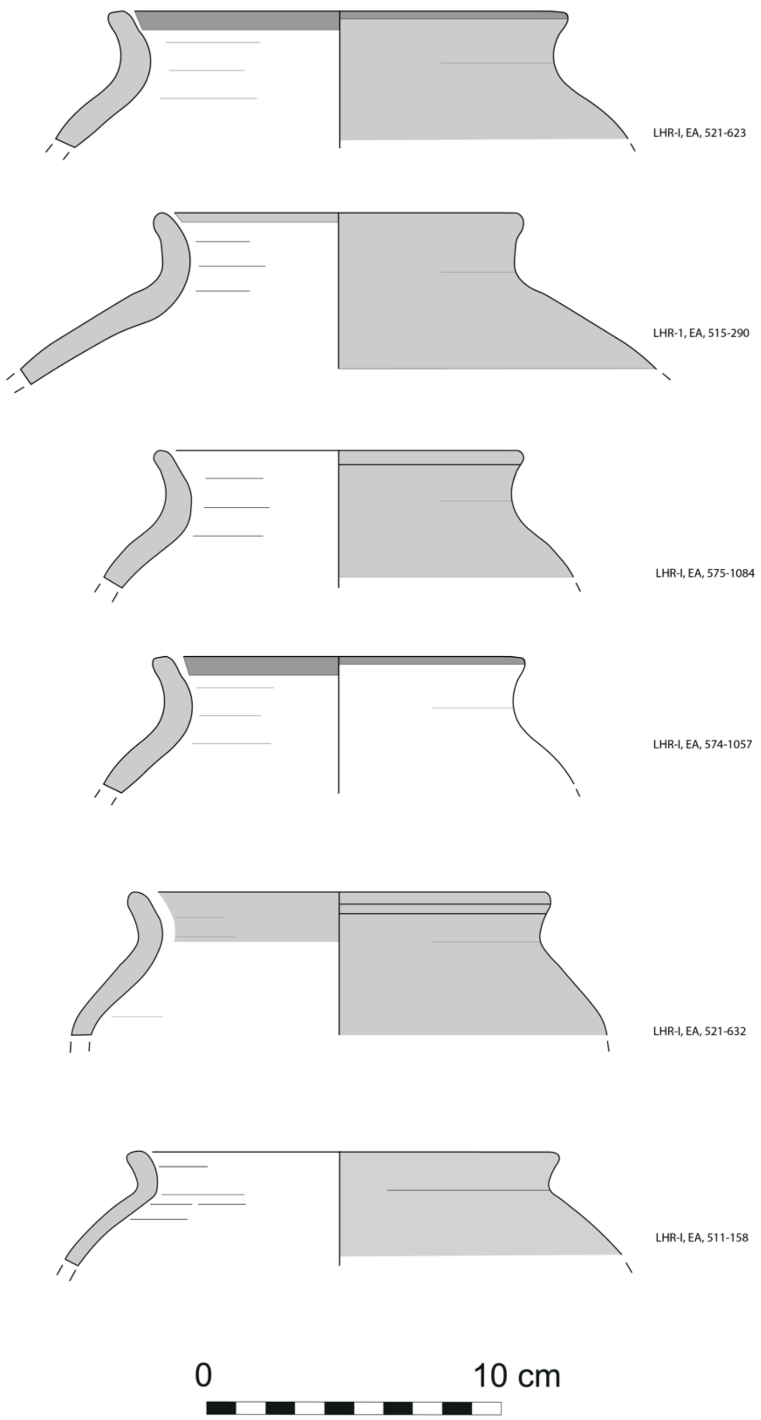


Plate IV. LHR Jar type 1. Sub-types could be grouped, according to the shape of the body, i.e. globular (Type 1a) or elliptical (Type 1b).

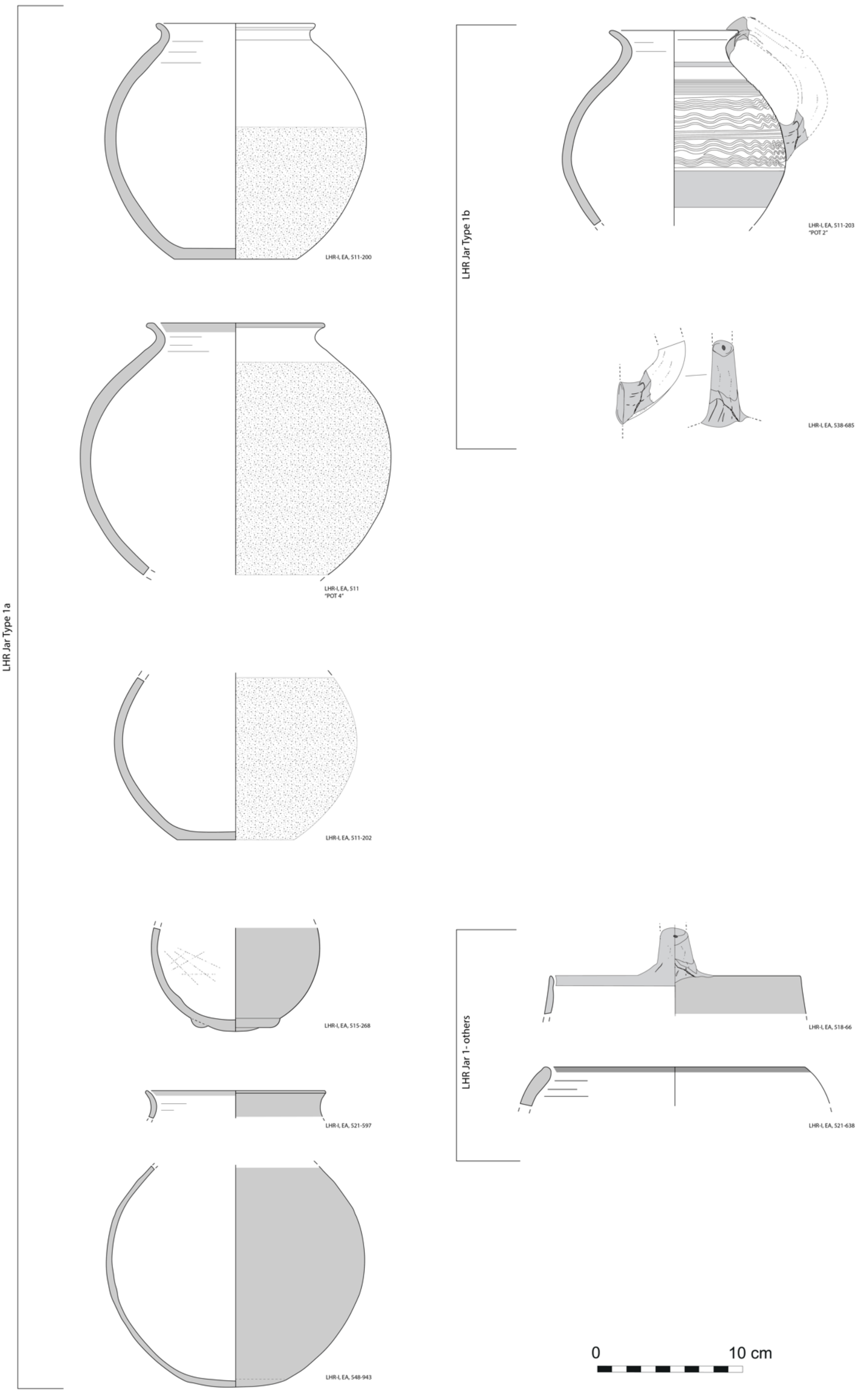


Plate V. LHR Jar Types 2 and 3. Type 1 shows distinctive long neck and projected rim. Time 3 show a U or V shape neck with everted rim.

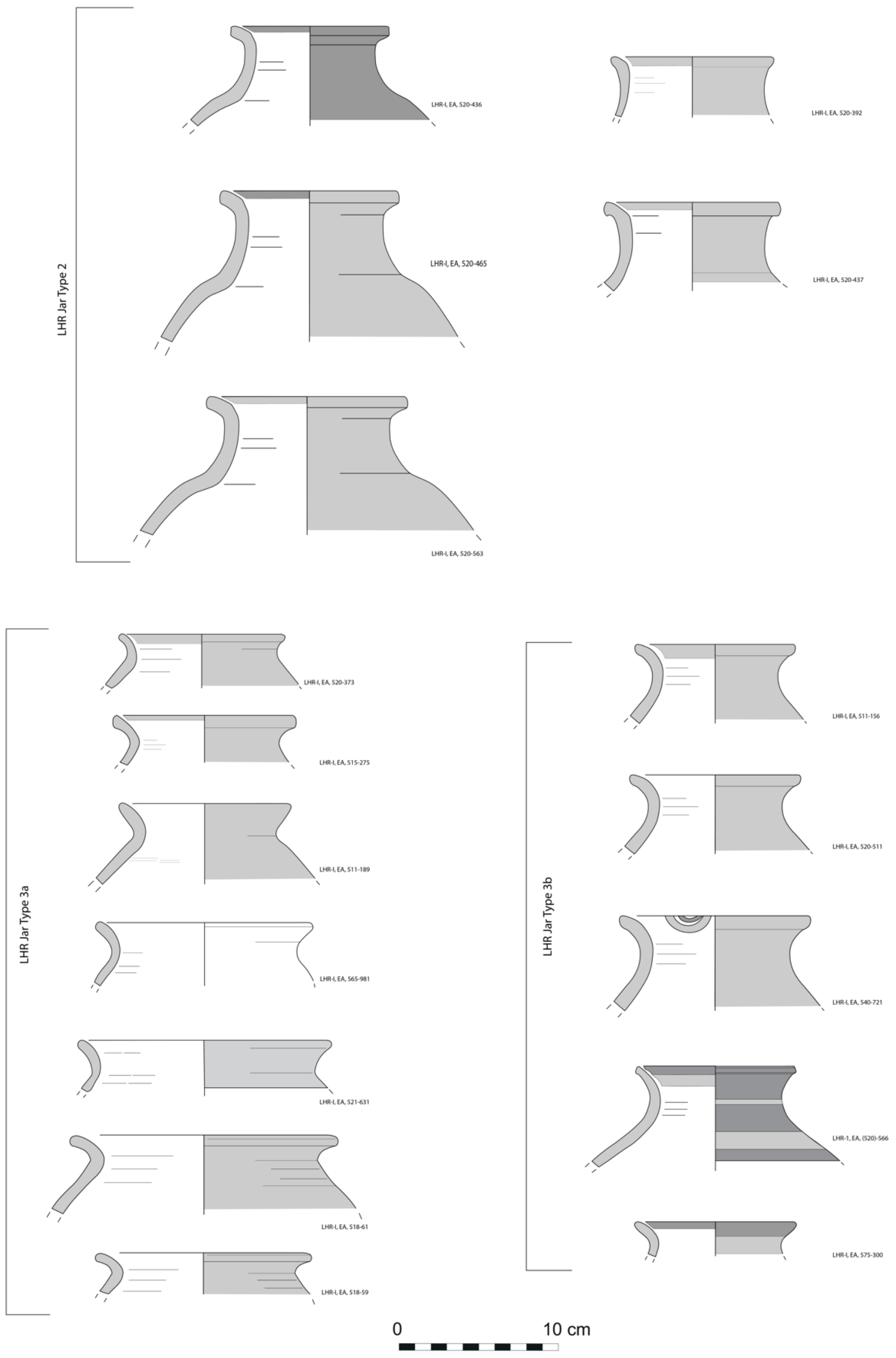


Plate VI. LHR small Jar Type 4, chocolate slipped 'bottles'.

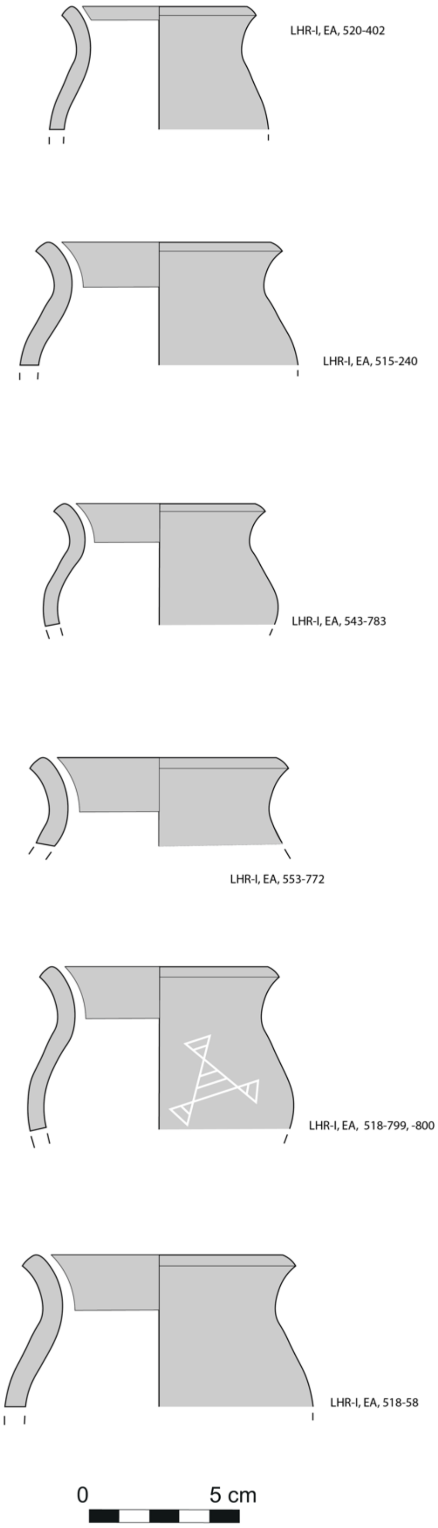


Plate VII. LHR Jar Type 5, or jars with semi-upright rims.

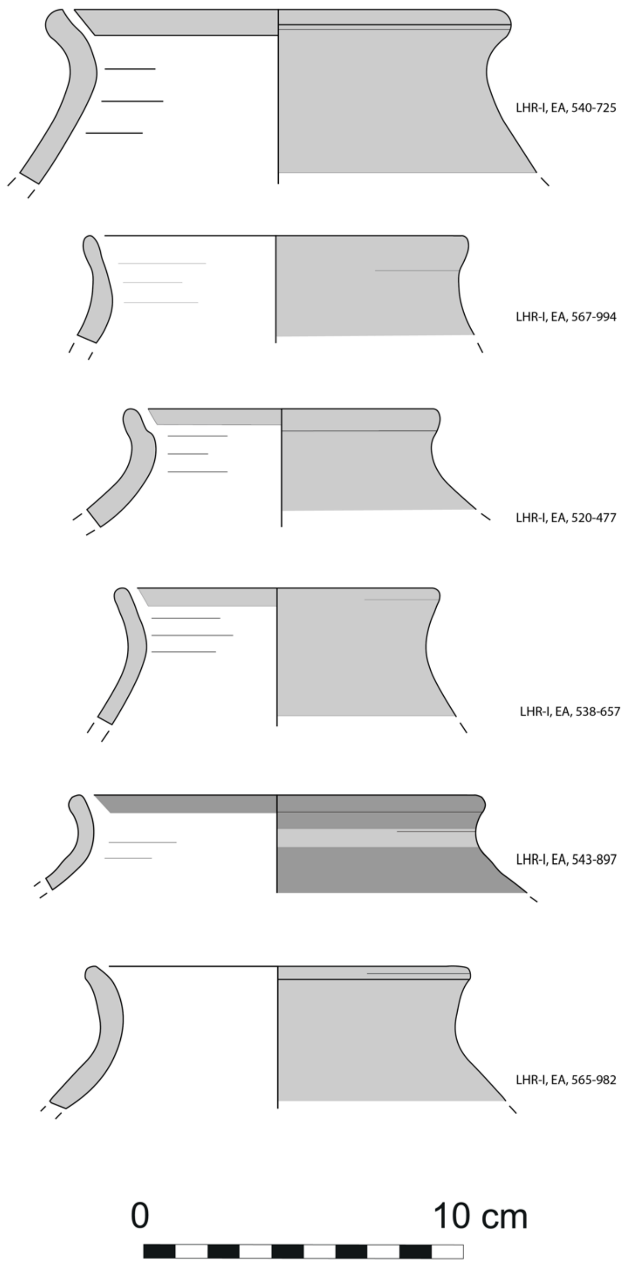


Plate VIII. LHR medium- and large- size Storage Jars

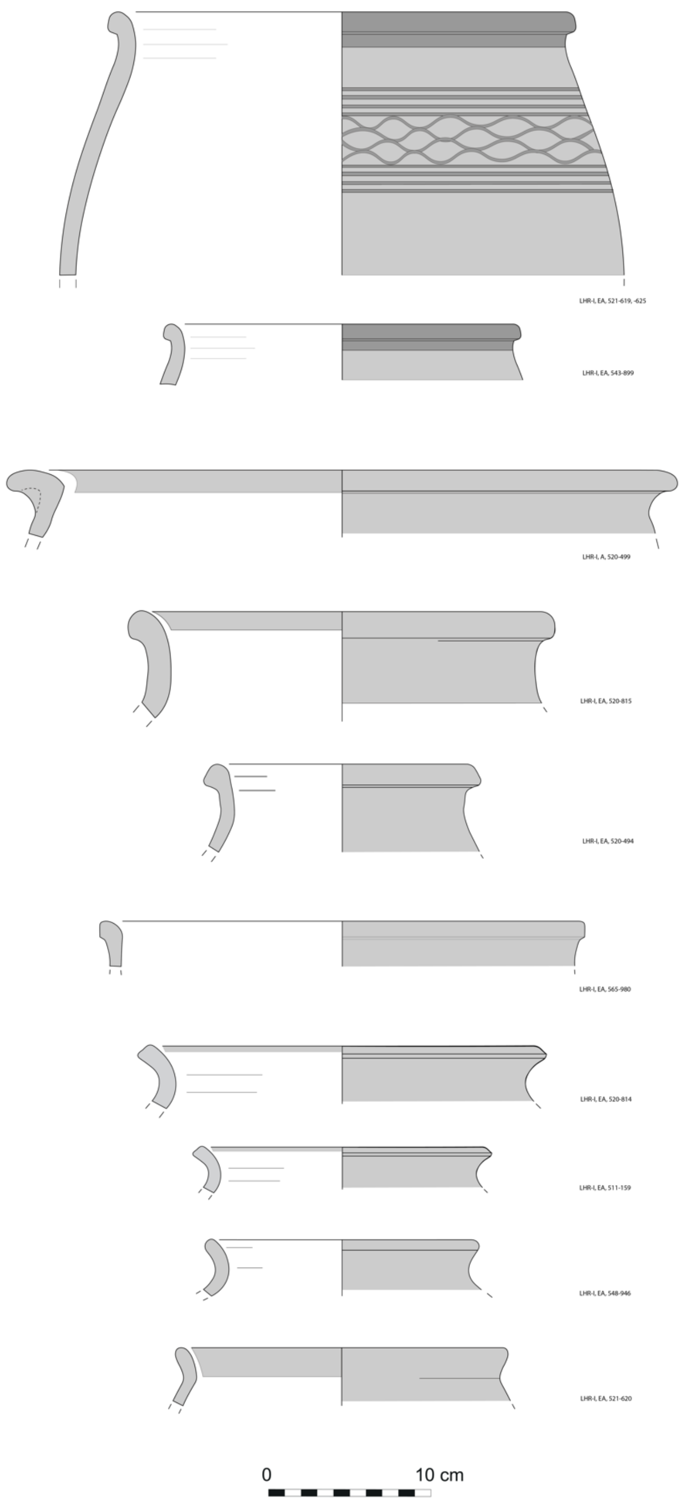


Plate IX.'Classic' Indus-like, or Farmana Harappan-like, types identified at LHR-I, EA

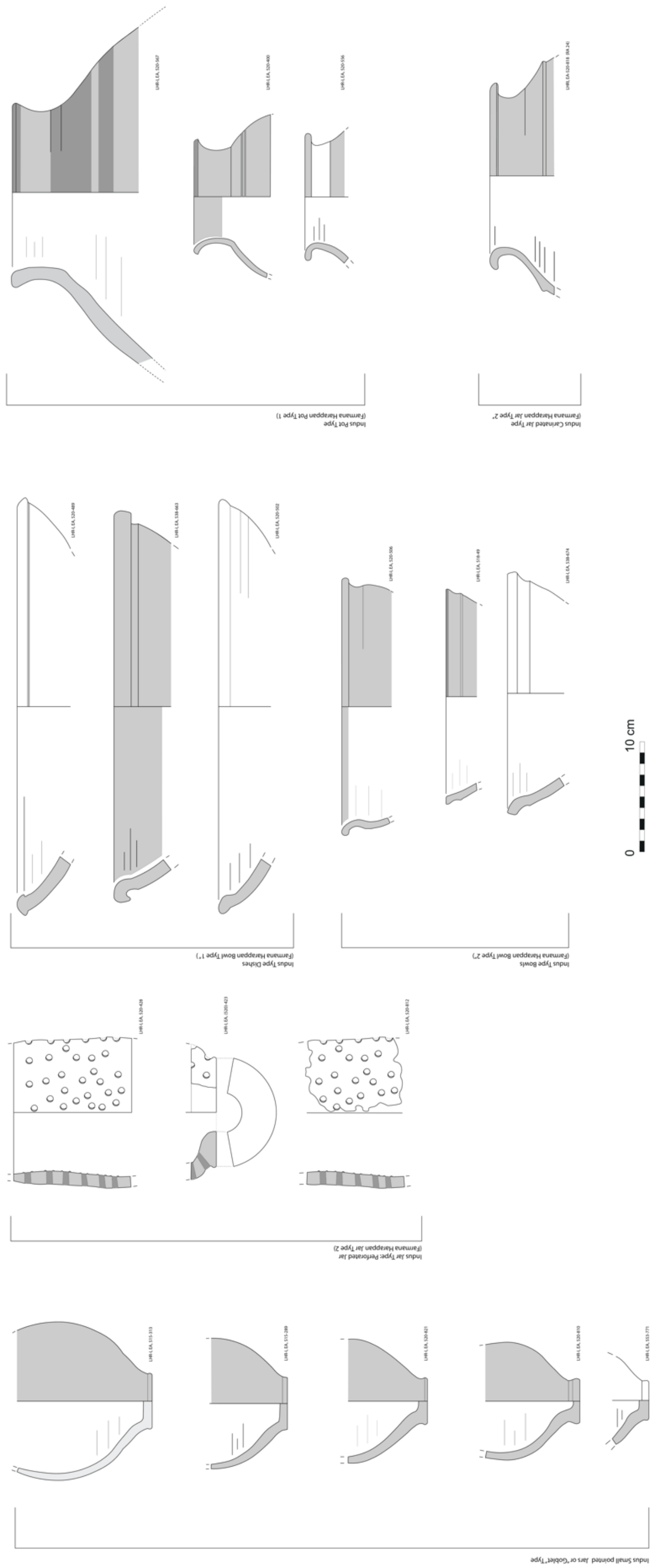


Plate X. LHR less common or rare types.

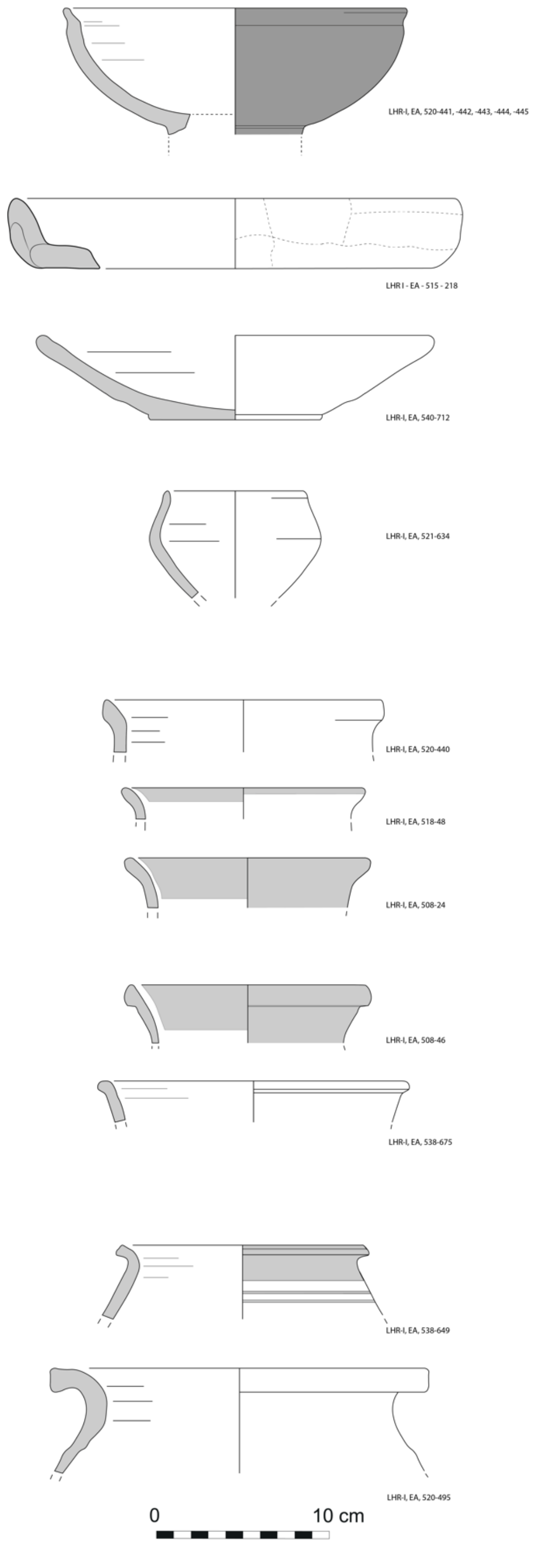


Plate XI Types of bases identified at MSD-I, XK2

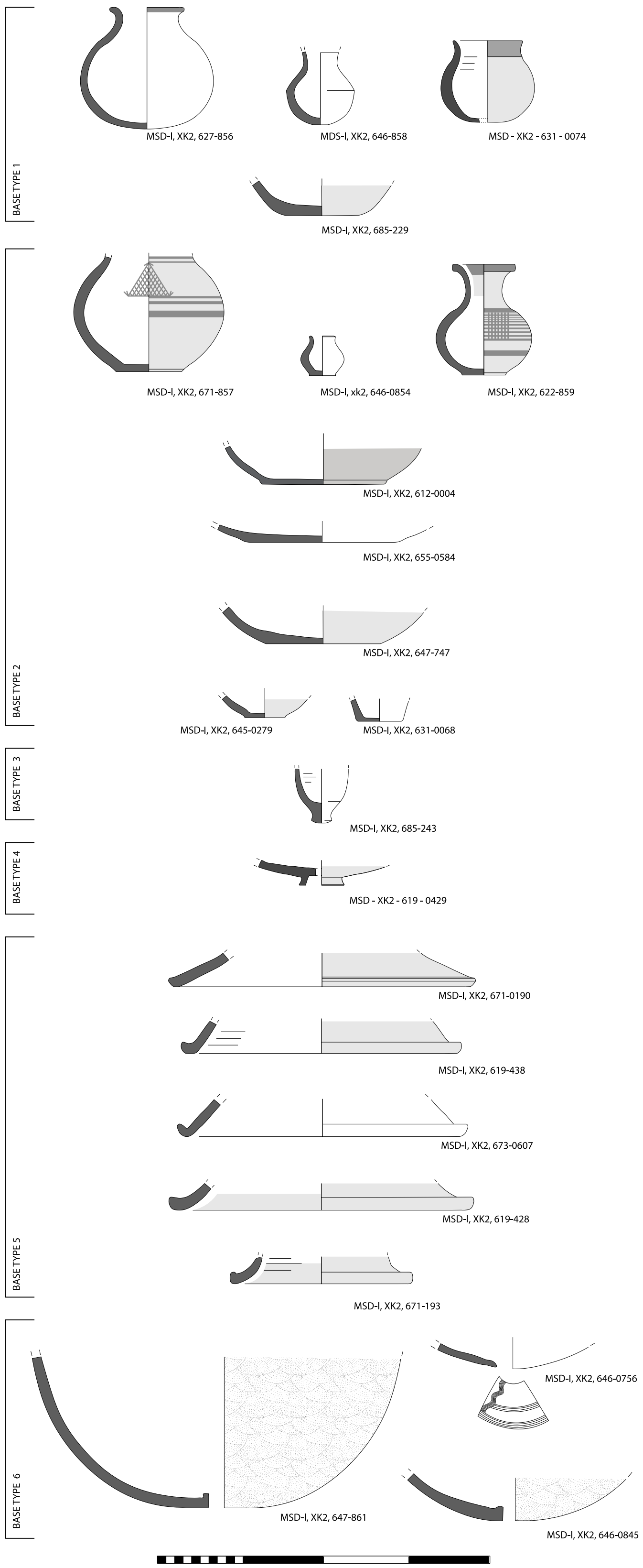


Plate XII Bowls types 1 and 2

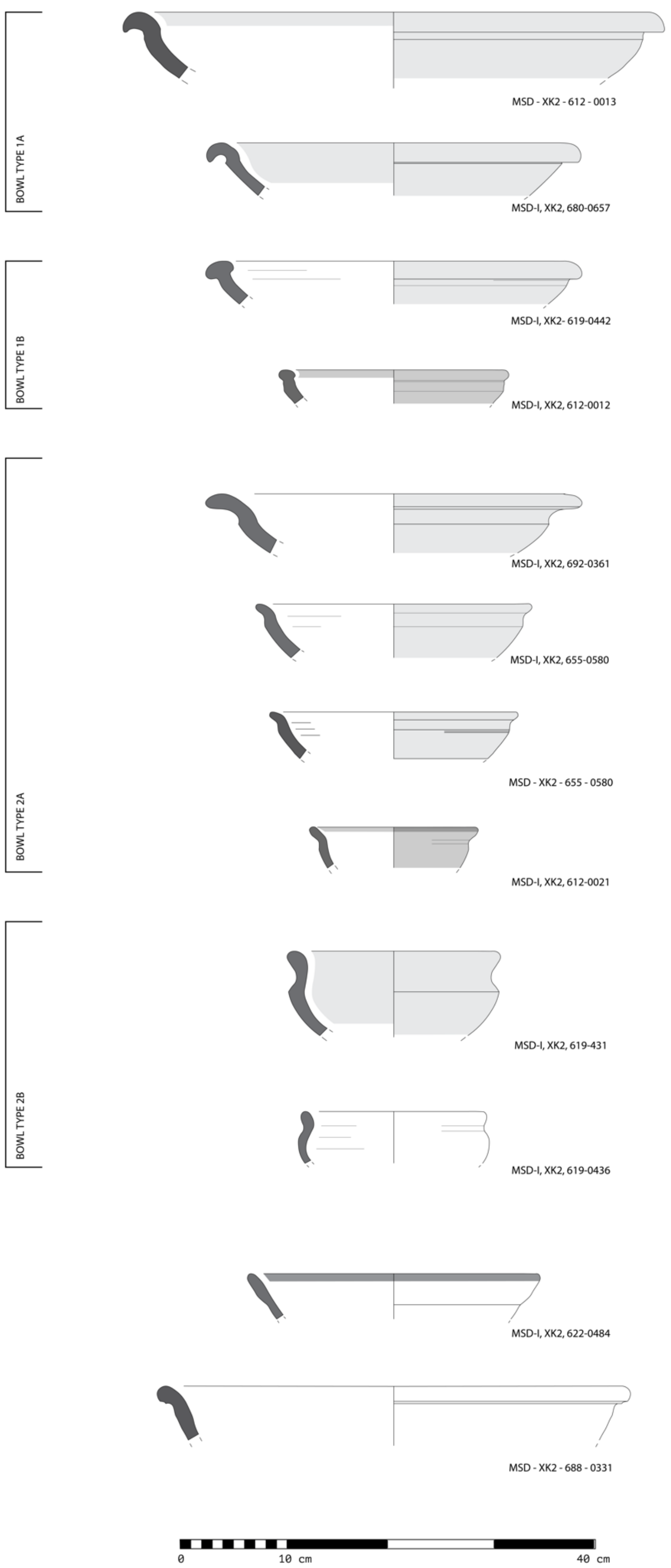


Plate XIII Bowls types 3 and 4

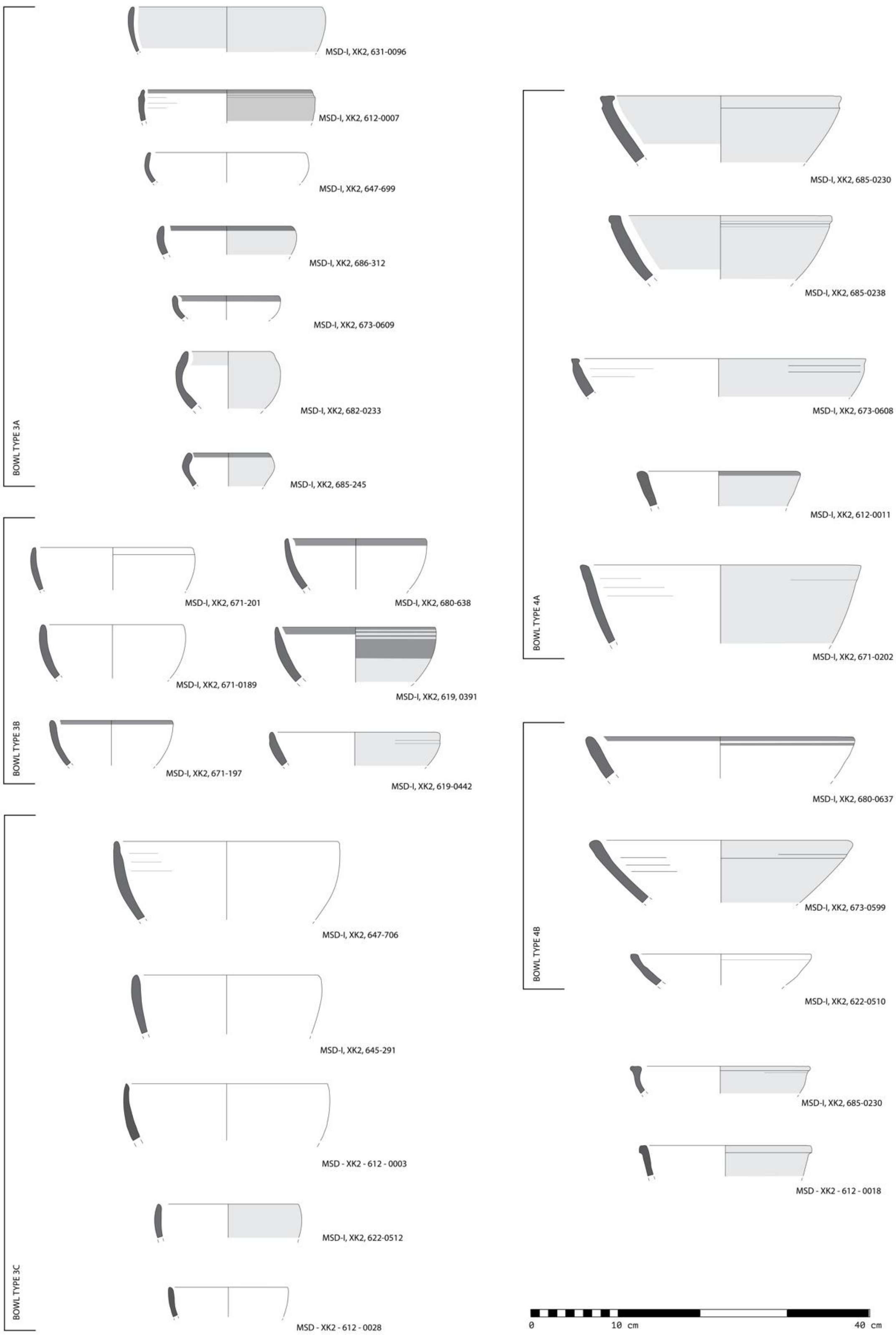


Plate XIV Large storage jars

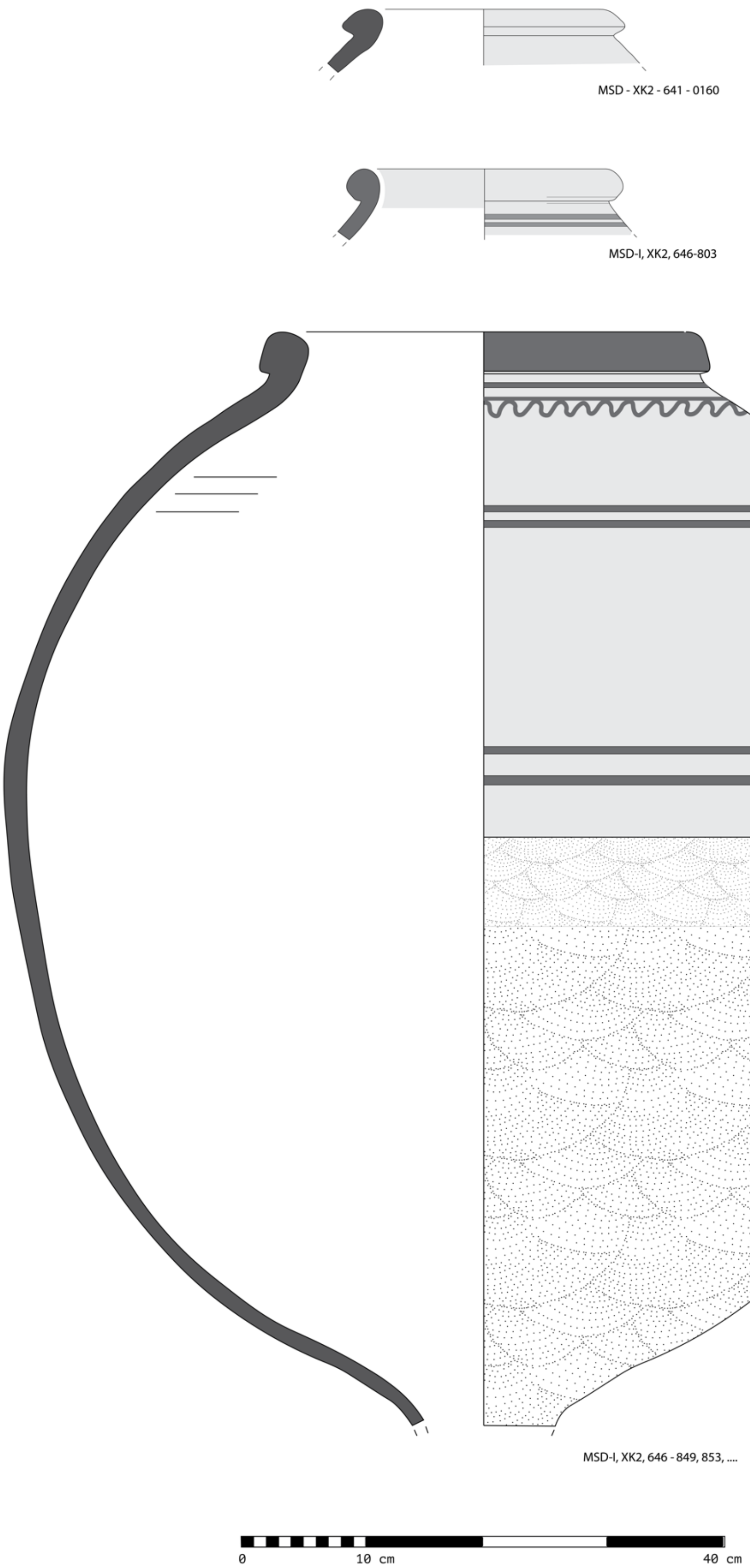


Plate XV MSD Outflaring Jars

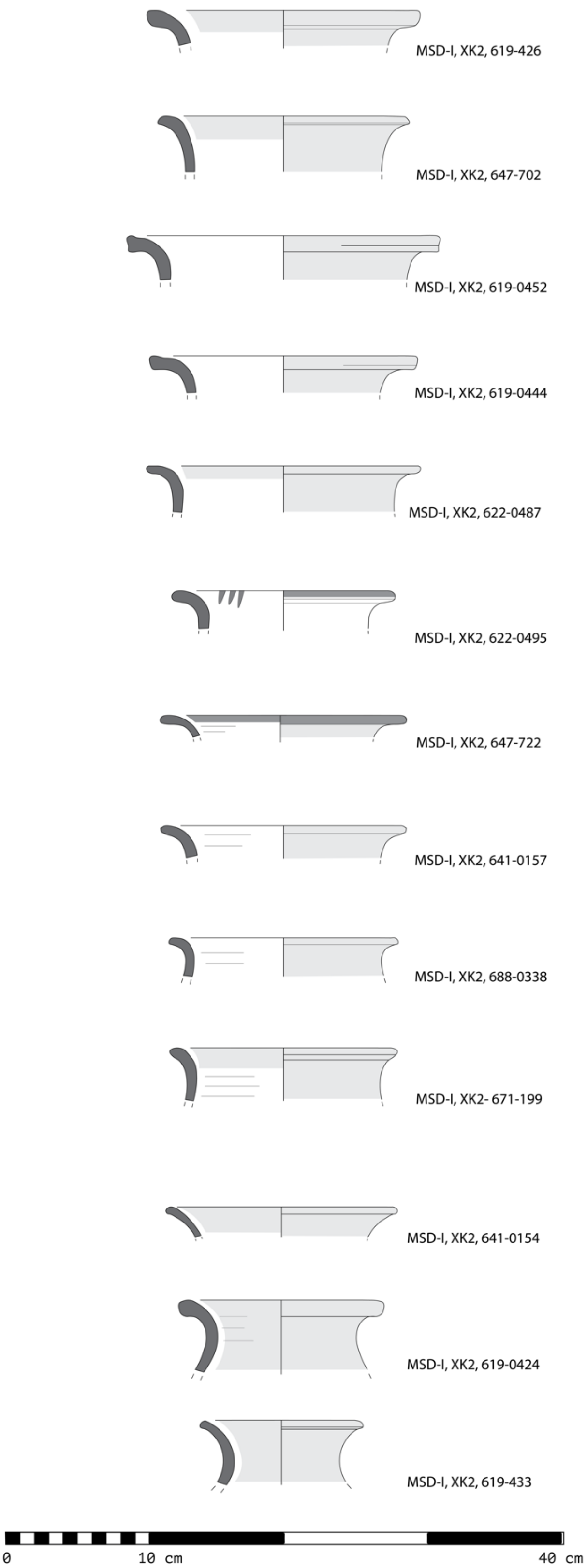


Plate XVI MSD-Narrow mouth

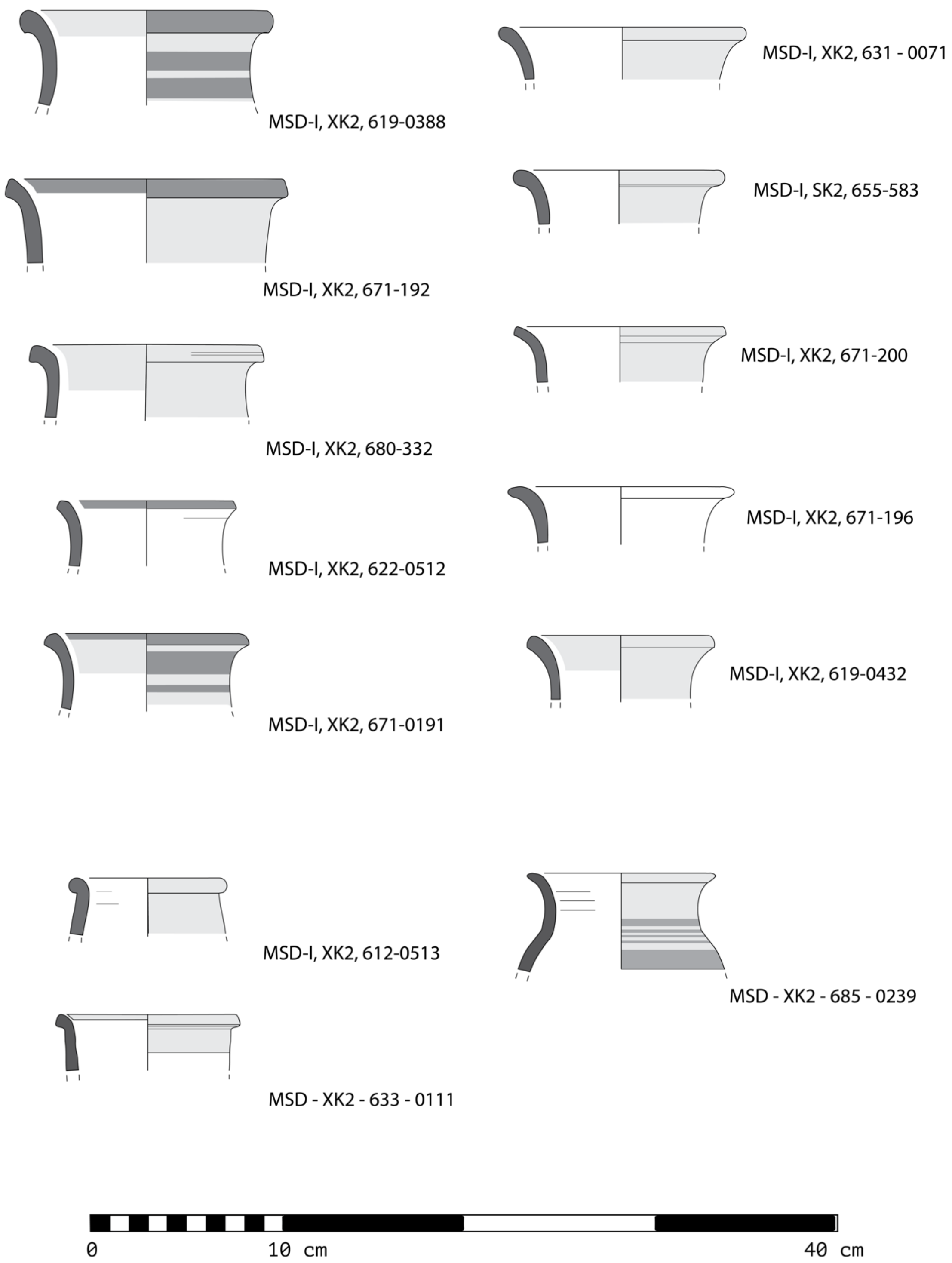

MSD-I, XK2, 619-0388
MSD-I, XK2, 631 - 0071
MSD-I, SK2, 655-583
MSD-I, XK2, 671-192
MSD-I, XK2, 671-200
MSD-I, XK2, 680-332
MSD-I, XK2, 671-196
MSD-I, XK2, 622-0512
MSD-I, XK2, 619-0432
MSD-I, XK2, 671-0191
MSD-I, XK2, 612-0513
MSD - XK2 - 685 - 0239
MSD - XK2 - 633 - 0111
0
10 cm
40 cm

Plate XVII Everted rim Jars types 1 and 2

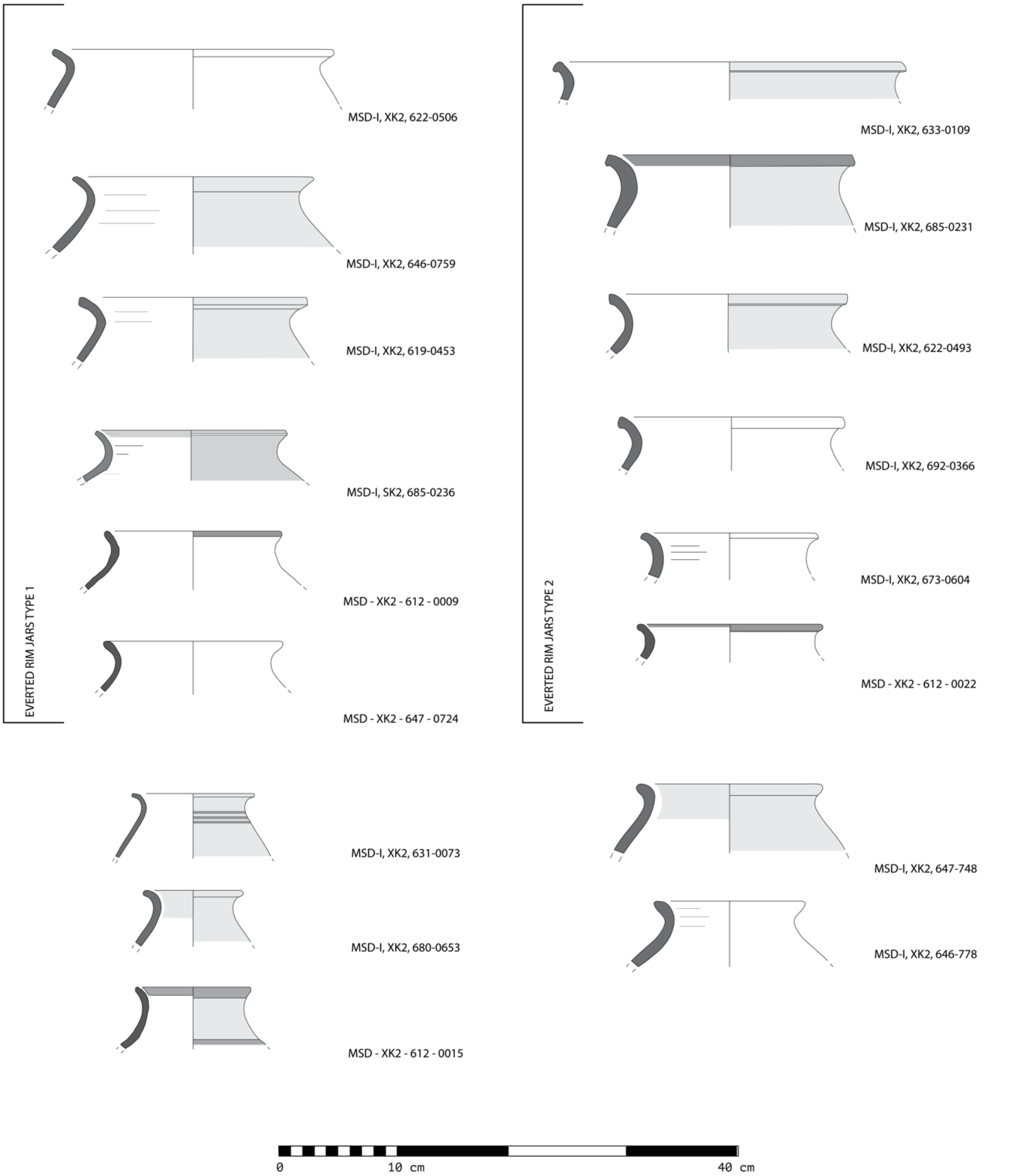


Plate XVIII Upright Rim Jars

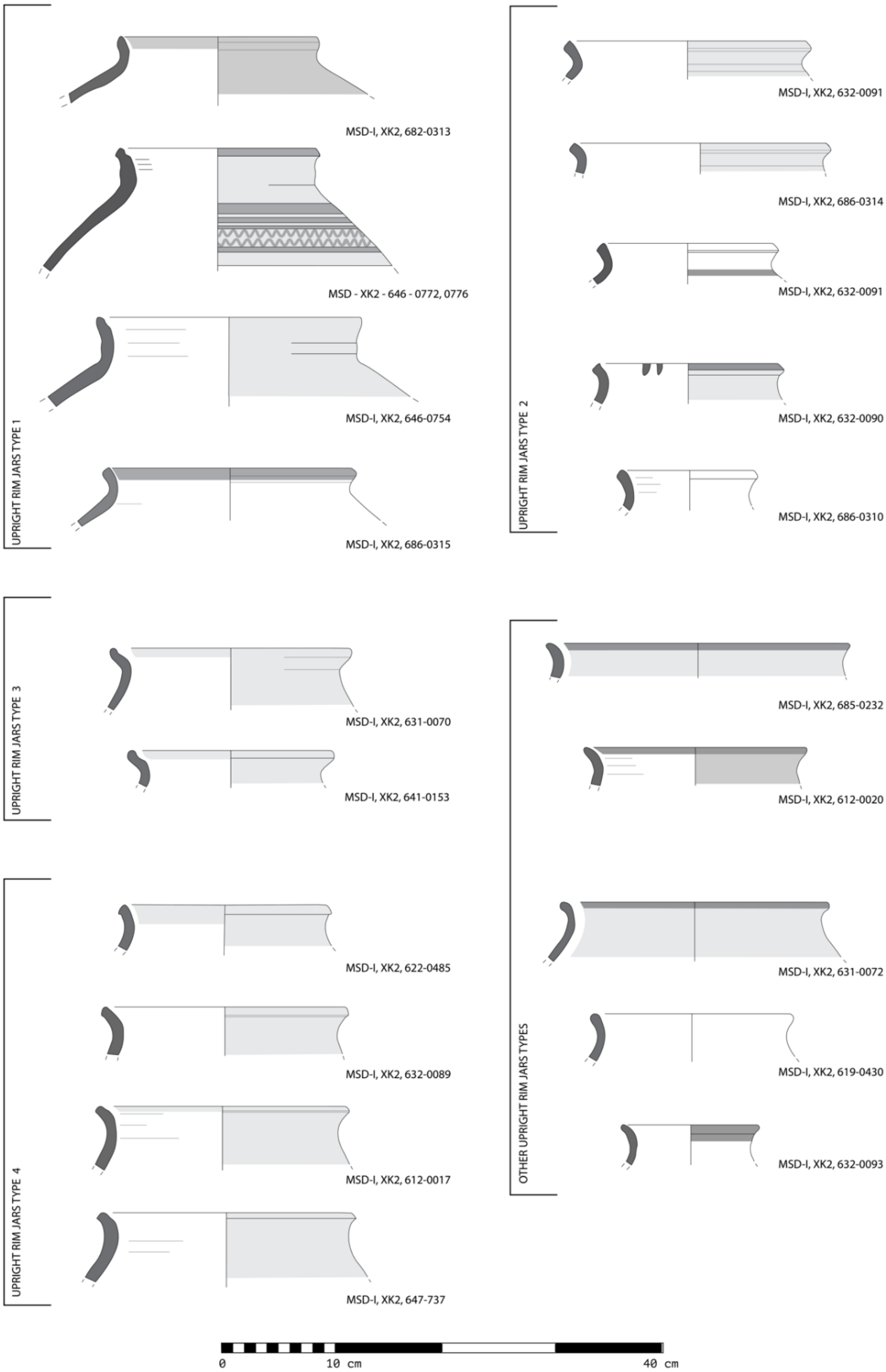


Plate XIX Short Neck Jar types

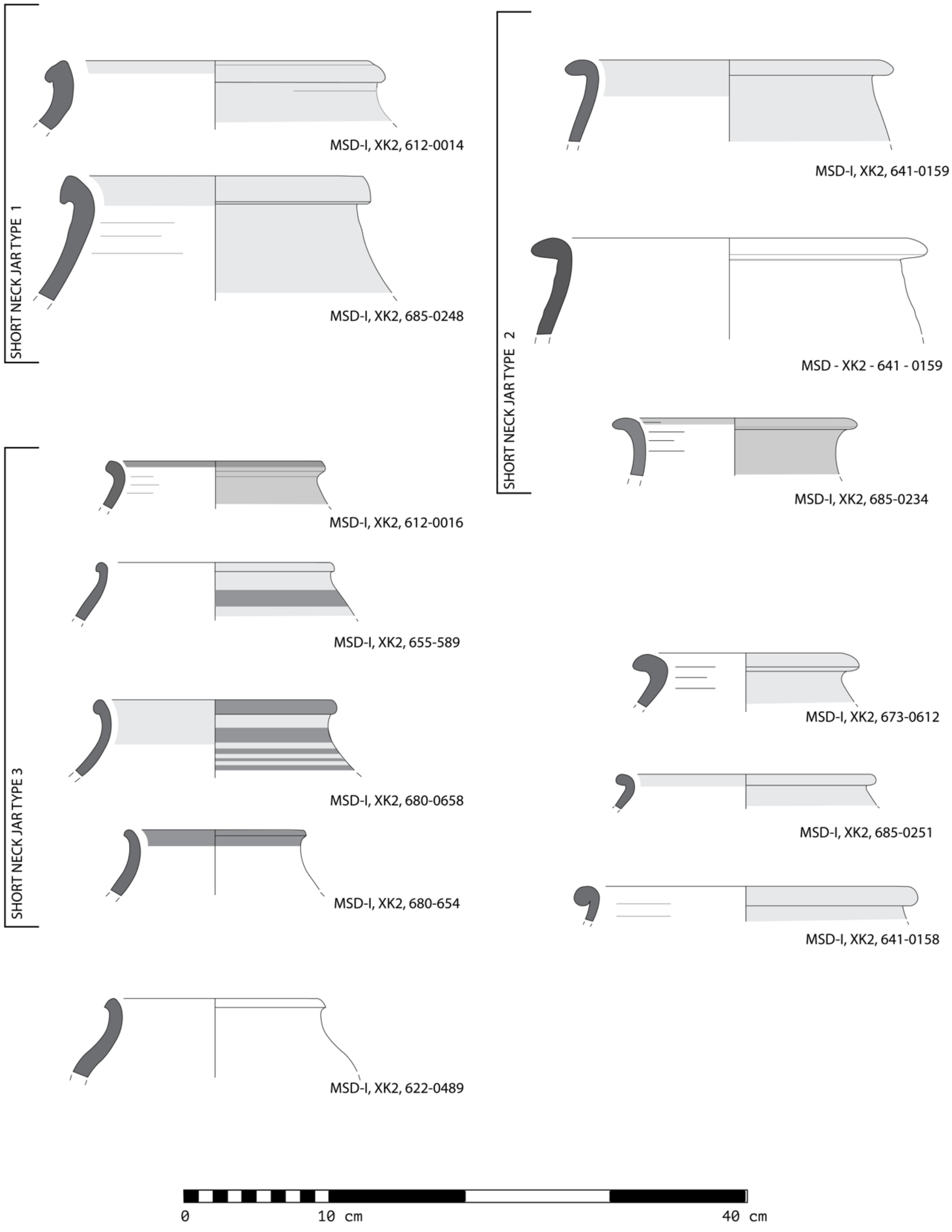


Plate XX Other forms

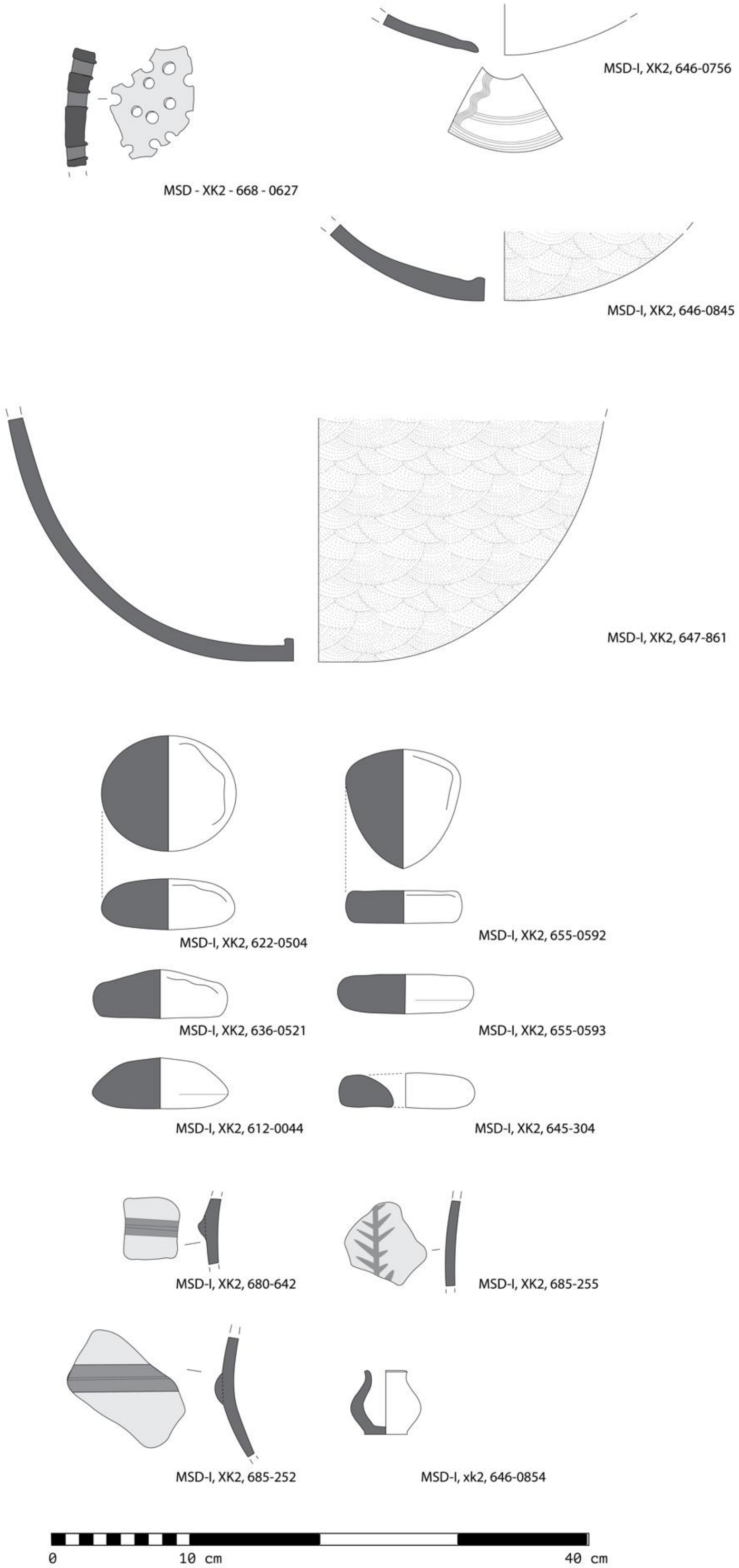
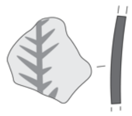
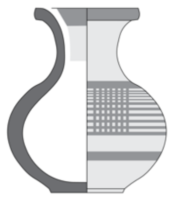


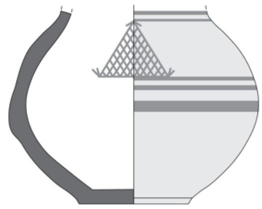
Plate XXI Other forms



MSD-I, XK2, 685-255



MSD-I, XK2, 622-859

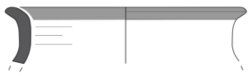


MSD-I, XK2, 671-857

MSD-I, XK2, 627-856

MDS-I, XK2, 646-858

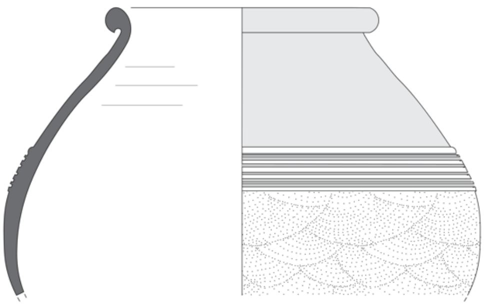
MSD - XK2 - 631 - 0074



MSD-I, XK2, 685-0231

MSD-I, XK2, 612-0009

MSD-I, XK2, 673-0610



MSD-I, XK2, 619-467, 463

Plate XXII ALM-SC Period II-A, Phase 1

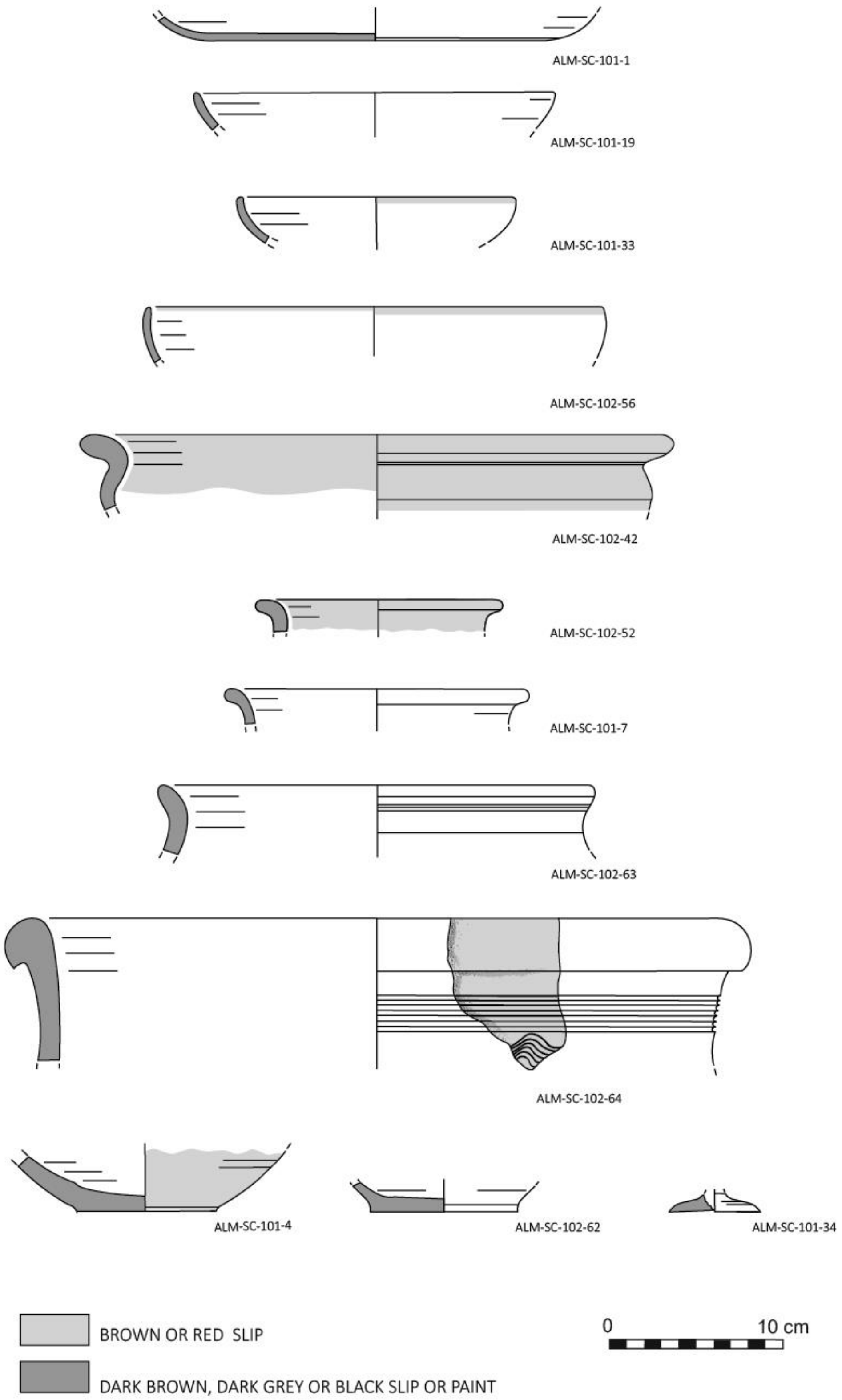


Plate XXIII ALM-SC Period II-A, Phase 1

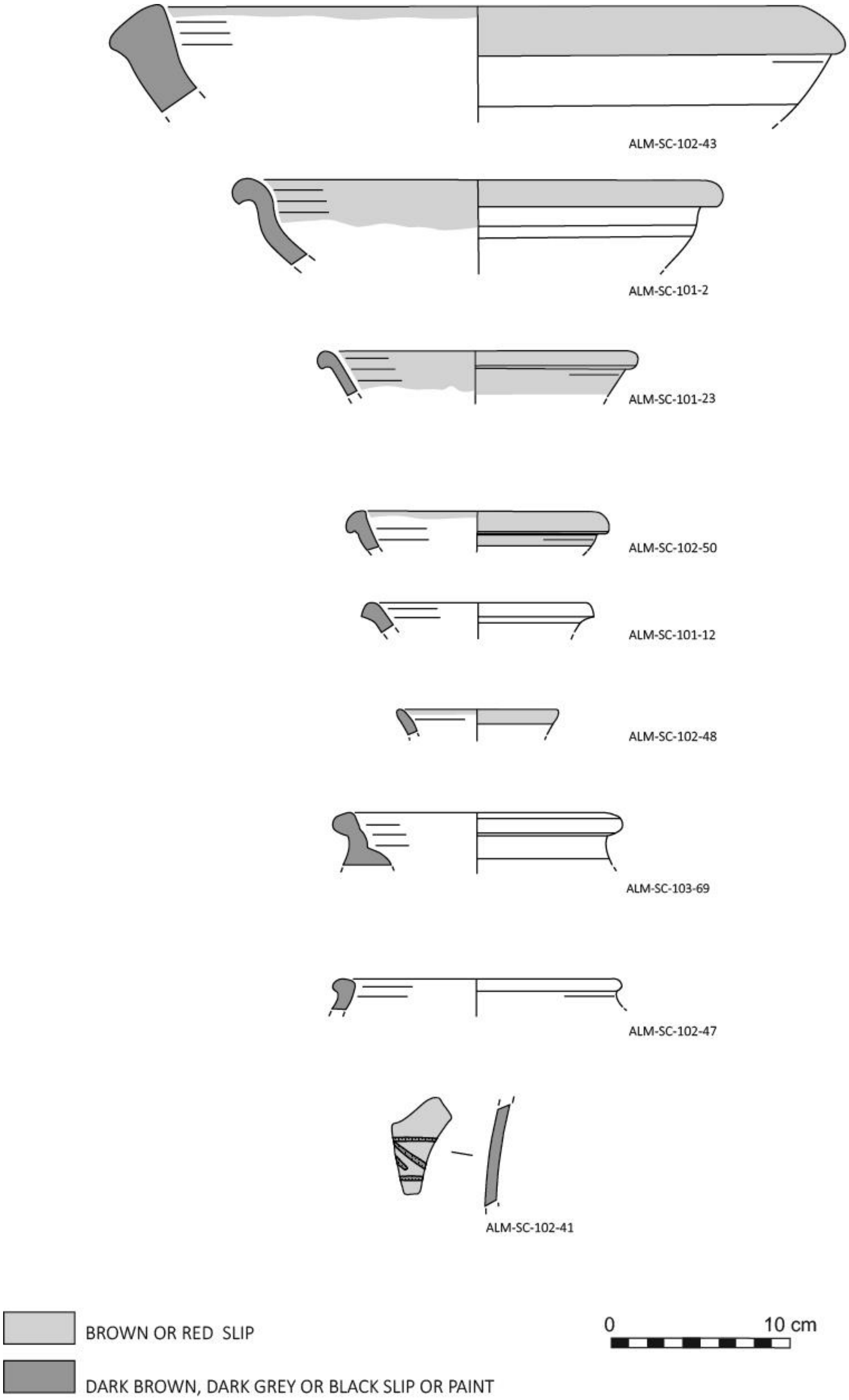


Plate XXIV ALM-SC Period I-C, Phase 2

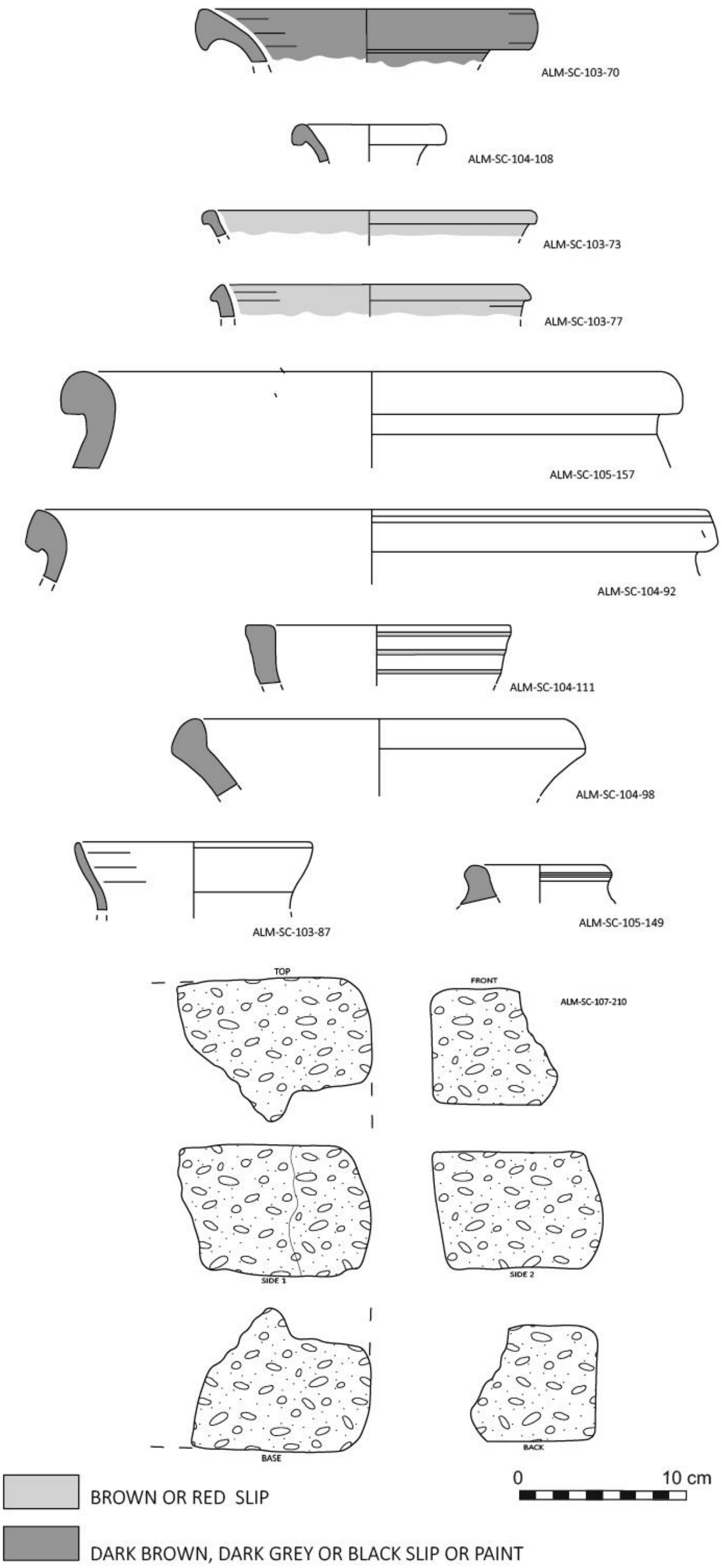


Plate XXV ALM-SC Period I-C, Phase 2

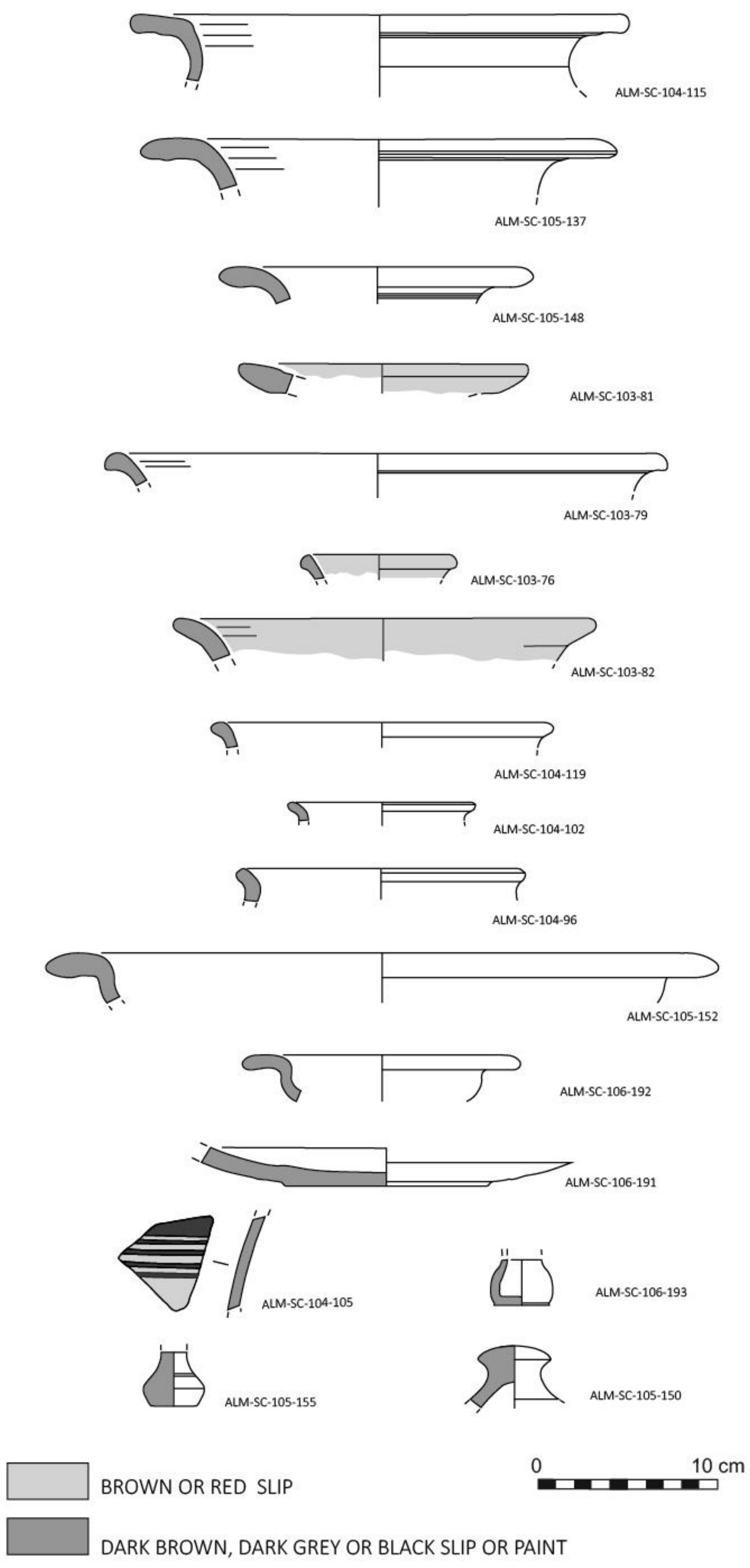


Plate XXVI ALM-SC Period I-C, Phase 3 and 4

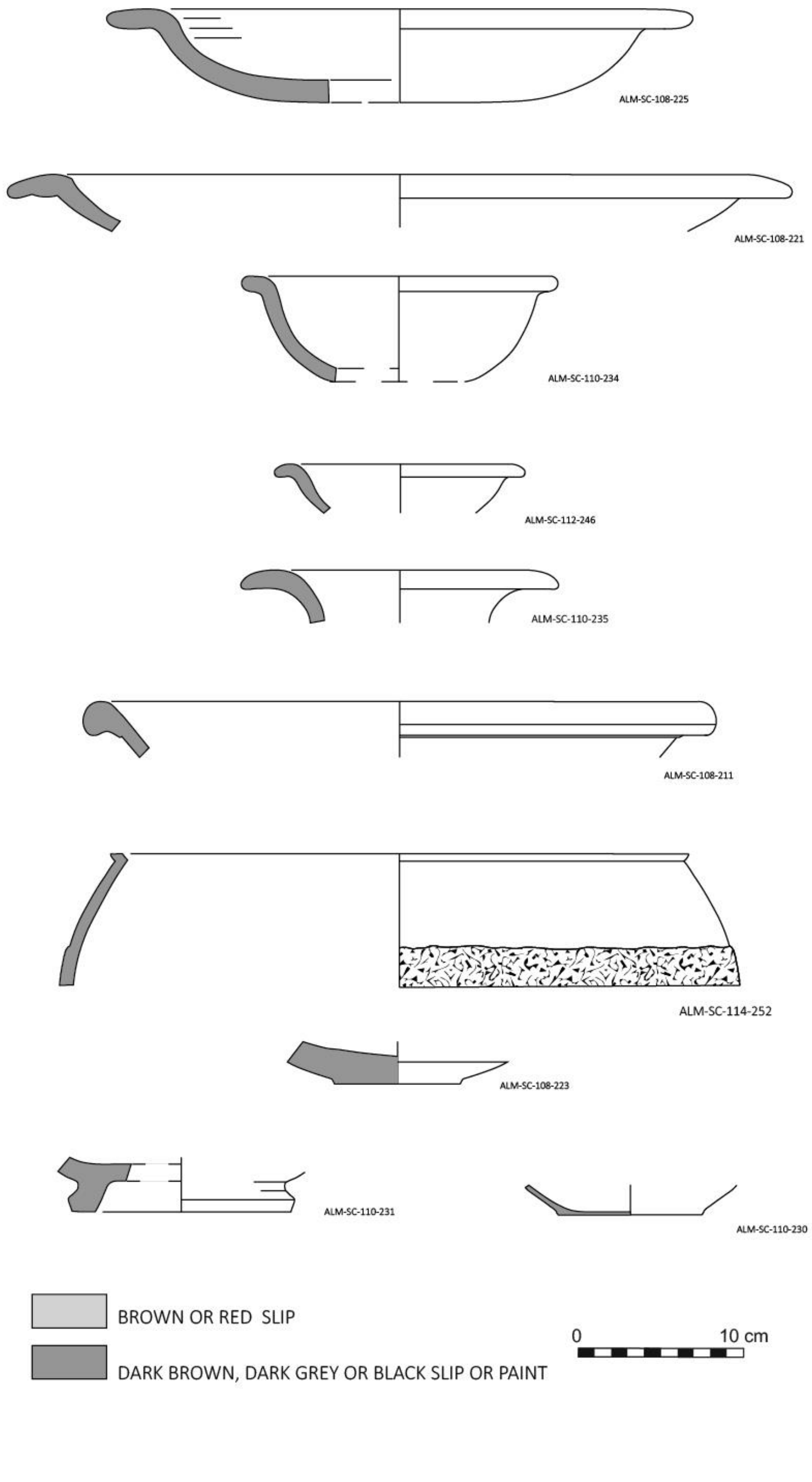


Plate XXVII ALM-SC Period I-B, Phase 5

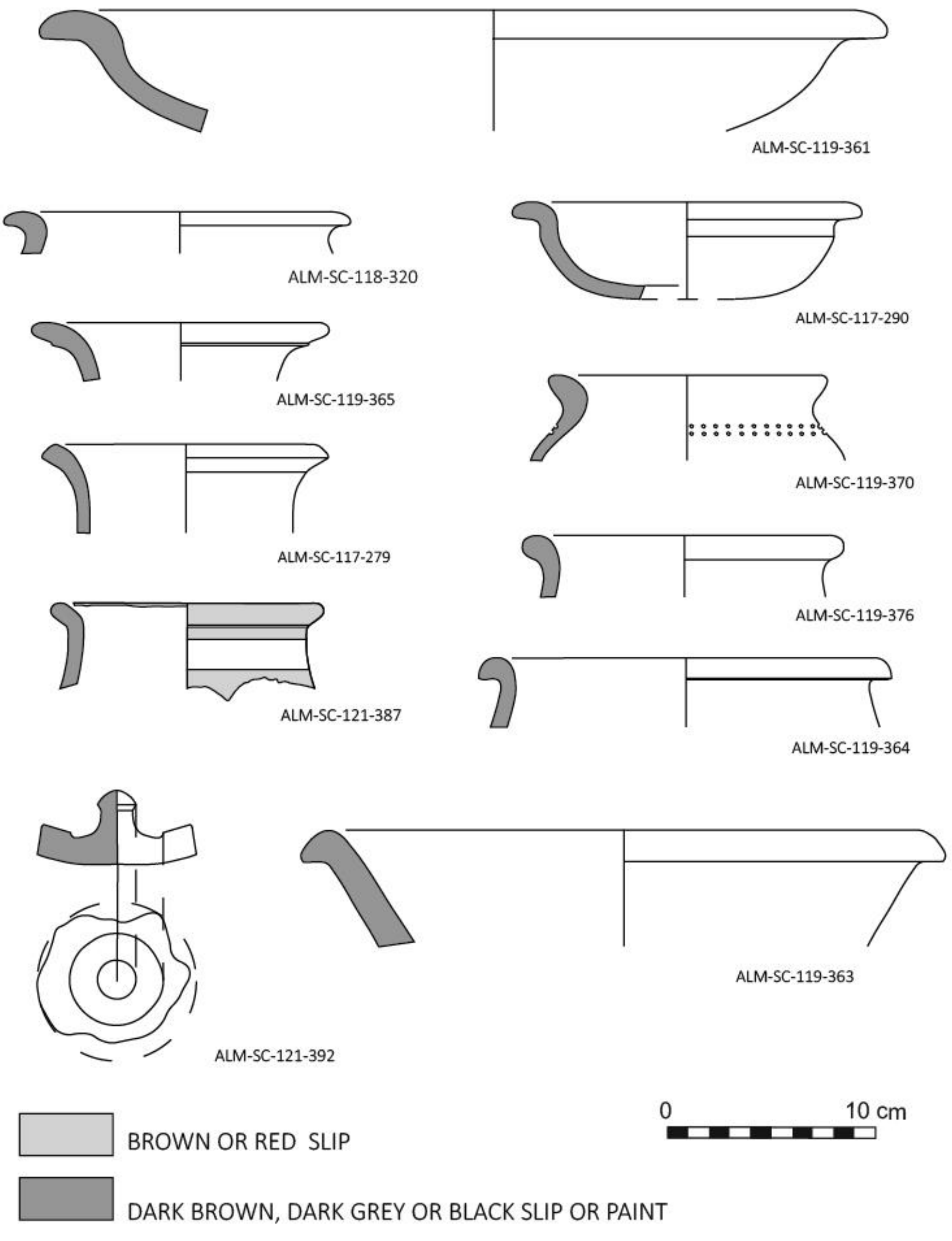


Plate XXVIII ALM-SC Period I-B, Phase 6

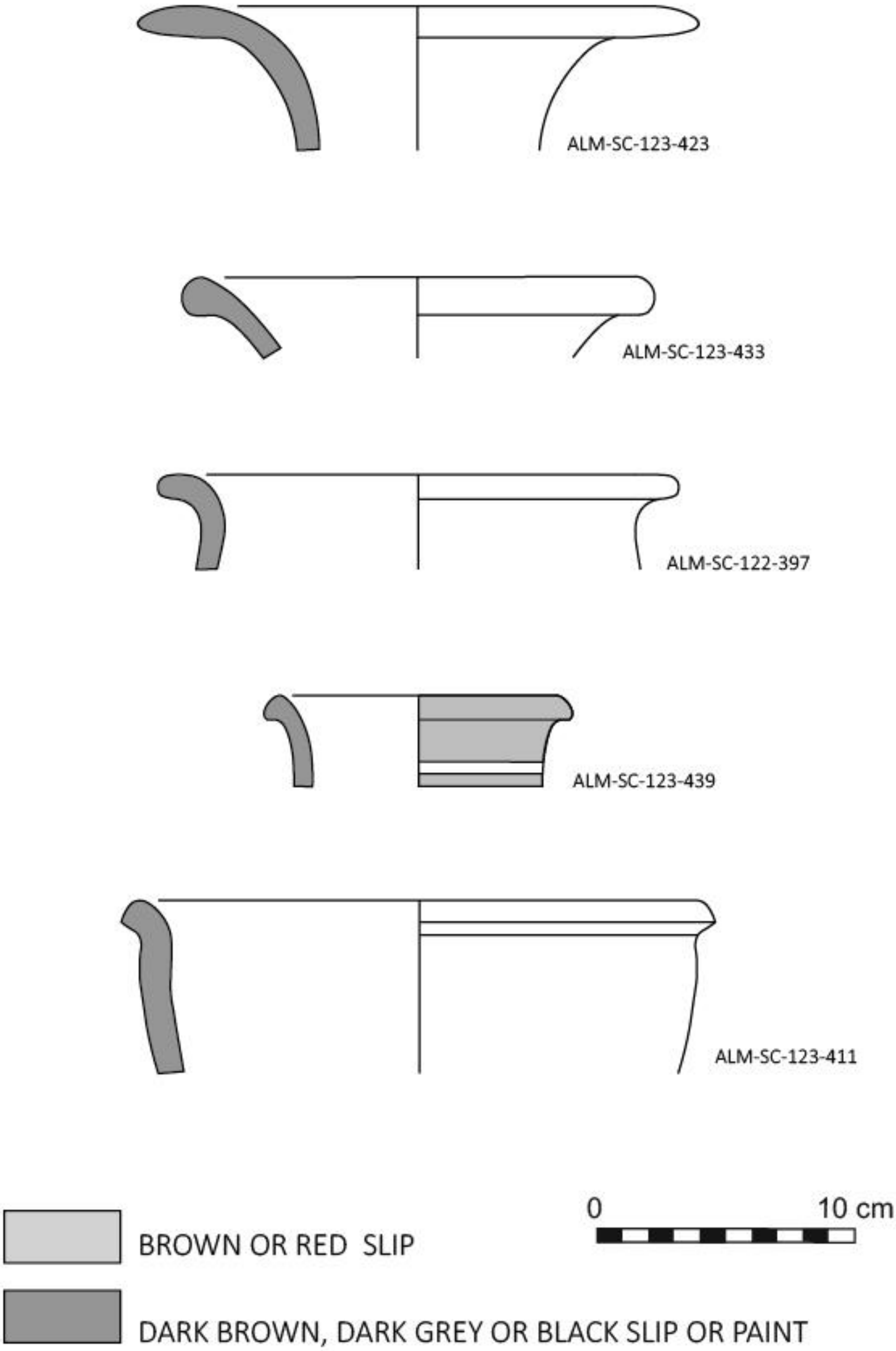

ALM-SC-123-423
ALM-SC-123-433
ALM-SC-122-397
ALM-SC-123-439
ALM-SC-123-411
BROWN OR RED SLIP
DARK BROWN, DARK GREY OR BLACK SLIP OR PAINT
0
10 cm

Plate XXIX ALM-SC Period I-B, Phase 7

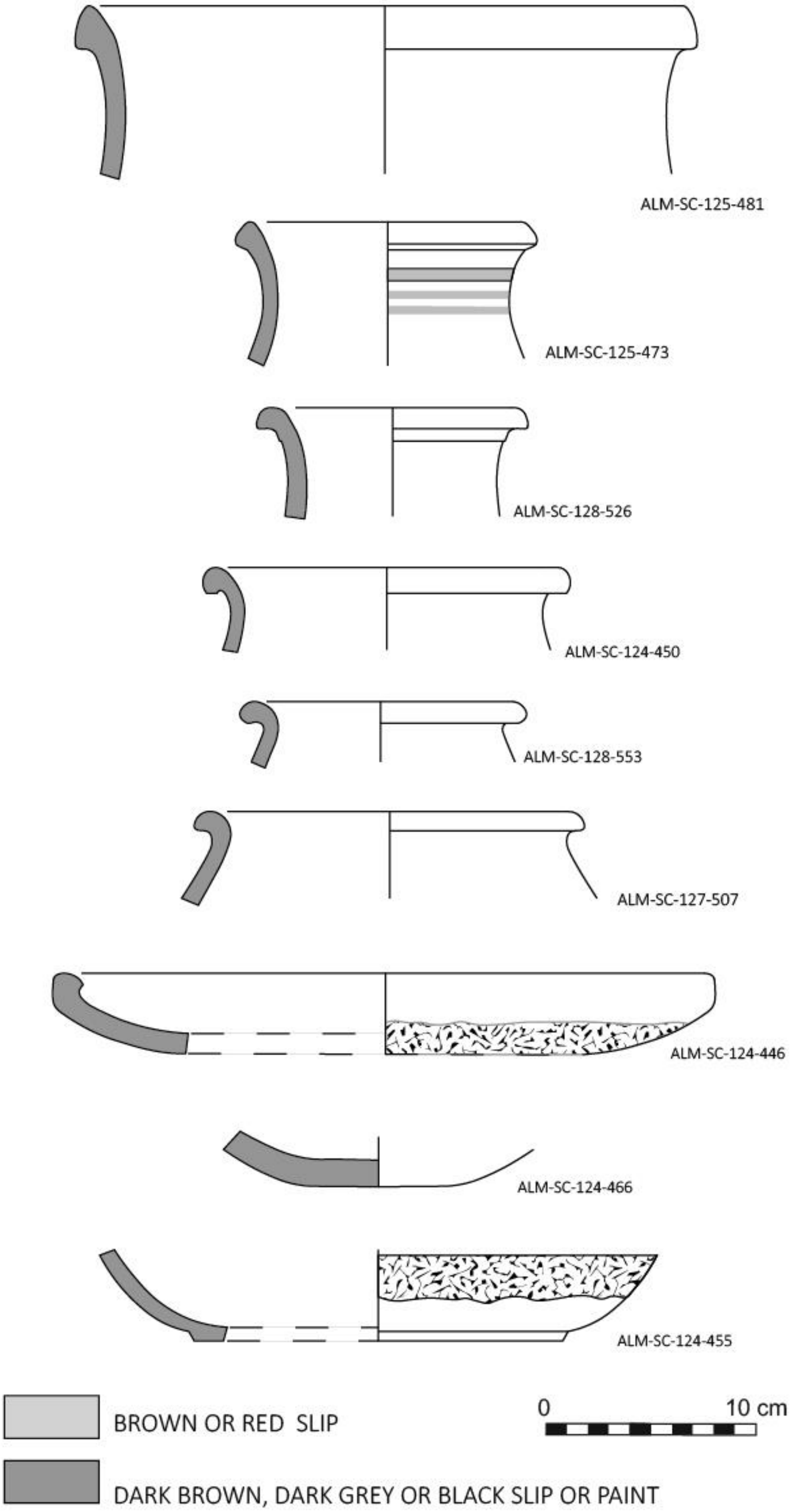
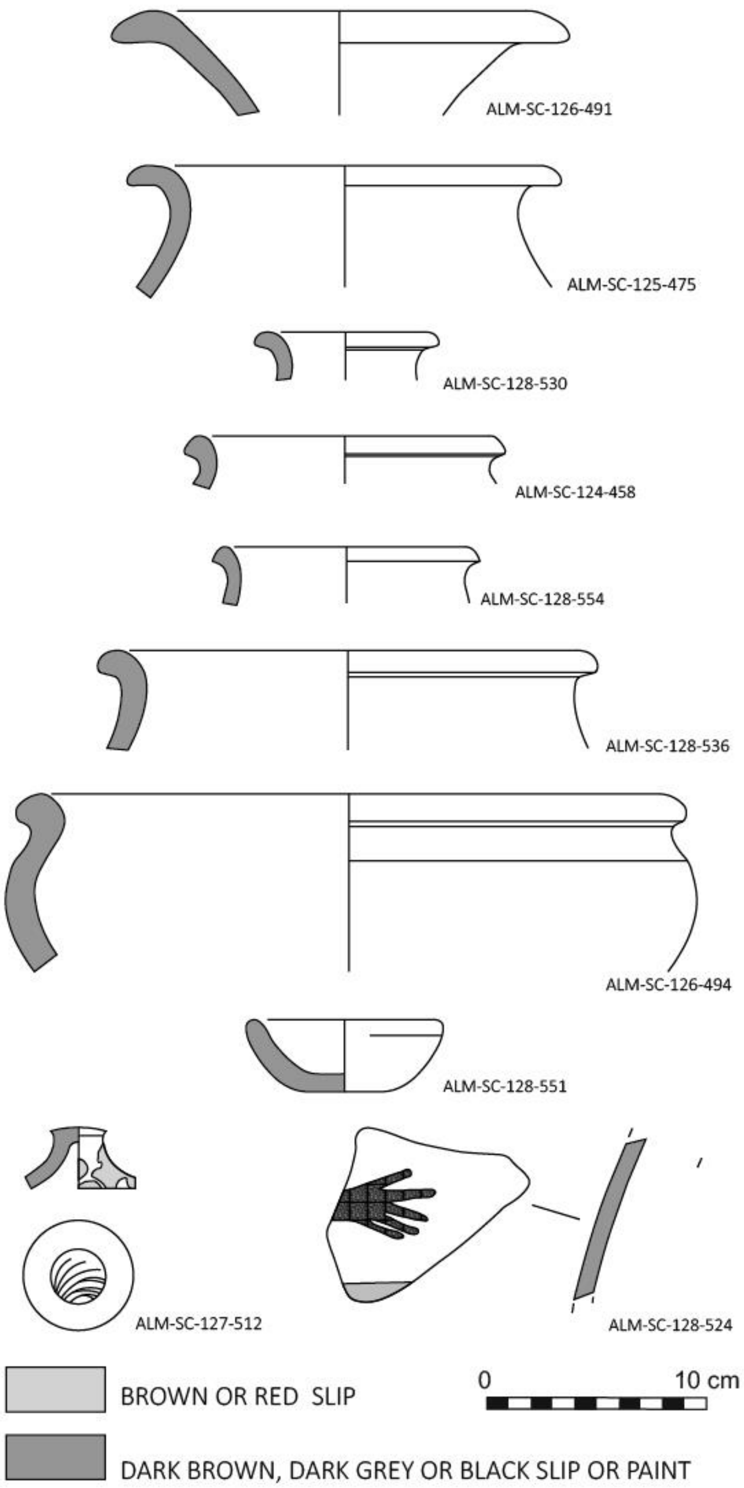


Plate XXX ALM-SC Period I-B, Phase 7



Appendix E: Certified values for reference materials

Note on accuracy and 'Soil Mode' calibration (see section 4.4.1): The performance of the Olympus Innox-X Delta Premium and the in-house calibration UCL Ceramics 1 pXRF calibration was compared to that of the manufacturers factory 'Soil Mode' calibration. The standards were also analysed with the pXRF machine in the Soil Mode using beam II for 120 seconds. The average accuracy over the 15 standards using the manufacturers Soil Mode (Table E2) reveals that accuracy varies considerably depending on the element in question, with an error of less than 10% for the trace elements Sr and Y and values of 100% or more for the minor elements Cu and Ti. Seven out of the 11 elements that were measured by the Soil Mode and present in the CRMs used for this assessment, had an accuracy 25% or better (Fe, Pb, Rb, Sr, Y and Zn). The in-house UCL Cal Ceramics 1 low calcium pXRF calibration afforded improvements for elements such as Fe, Ti and Zr but performed worse for Mn, Pb, Rb, Sr, Y and Zn. Due the in-house calibration recording several additional elements that were not present on the manufacturers Soil Mode beam II, the number of elements measurable with an error of ≦25% rose to nine (Co, Fe, Ga, K, Nb, Rb, Sr, Tb, Ti, Zr).

Table E1. Details of 14 certified reference materials used to assess the performance of UCL Cal 1 Ceramics 1 low calcium pXRF calibration in this paper/report/thesis. See Appendix 1 for certified values.

Code	Name
CGL 111	Rare earth ore
CGL 002	Alkaline granite
CGL 006	Nepheline syenite
CGL 007	Basalt
GBM306-12	Certified Ore Grade Base Metal
SARM 1	NIM-G Granite
SARM 41	Carbonaceous Shale
SARM 42	Soil
SARM 44	Sillimanite Schist
SARM 45	Kinzingite
SARM 48	Fluorspar Granite
SARM 50	Dolerite
SARM 52	Stream Sediment
SARM 69	Ceramic-1

Table E2. Average accuracy for 15 elements measured within 14 certified reference materials using the manufacturers Soil calibration and UCL Cal 1 Ceramics 1 low calcium pXRF calibration. Cal-culated using the percentage relative error based on a comparison of certified and measured values (Appendix E2) but disregarding the polarity of the individual accuracy calculations. The first two columns indicate the average over all standards for which the element was certified. The third and four columns presents averages based on only those standards whose concentration of the giv-en element falls within the range present in earthenware archaeological ceramics.

Element	Average accuracy all CRMs (%)		Average accuracy for ceramics range (%)	
	Manufacturers Soil Mode	UCL Cal Ceramics 1	Manufacturers Soil Mode	UCL Cal Ceramics 1
K	-	18.62	-	11.65
Sr	7.85	13.28	4.44	8.56
Zr	31.2	8.47	31.15	8.31
Ti	98.89	19.66	23.96	10.22
Fe	19.53	10.89	16.88	12.6
Ca	-	43.17	-	39.32
Zn	14.35	28.59	14.35	28.59
Rb	10.93	15.91	12.57	15.06
Mn	33.95	64.91	33.95	64.91
Nb	22.11	22.11	22.11	22.11
Ga	-	22.34	-	22.34
Co	-	25.53	-	25.53
Y	8.92	28.49	8.3	27.24
Pb	16.87	46.4	17.69	50.15
Cu	240.86	239.37	273.86	271.97

Appendix E1. Certified values for 13 reference materials used to assess the performance of UCL Ceramics 1 pXRF calibration and the manufacturers Soil Mode calibration. Values given in percentage weight.

Standard	Ca	Co	Cu	Fe	Ga	K	Mn	Nb	Pb	Rb	Sr	Ti	Y	Zn	Zr
CGL 111	18.23000	0.00325	0.01470	9.51000		0.75500	0.10800		0.11000	0.00430	2.24000	0.09000	0.09590	0.06000	
CGL 002	0.27700		0.00070	0.35000	0.00570	2.97000		0.00640	0.00630	0.23600	0.00123	0.01740	0.00230	0.00920	0.00400
CGL 006	1.63000	0.00100	0.00260	1.83900	0.00230	7.55000	0.10840	0.00400	0.01140	0.02070	0.17400	0.22200	0.00230	0.00980	0.06000
CGL 007	3.87000	0.00360	0.00320	6.88800	0.00230	3.31000	0.10070	0.00520	0.00090	0.00630	0.09270	1.26500	0.00200	0.01140	0.02870
GBM306-12		0.00225	1.49000	3.59500					2.70950	0.07200				2.06300	
SARM 1	0.56000		0.00120	1.40000	0.00270	4.14000	0.01600			0.03250	0.00100	0.05400		0.00500	0.03000
SARM 41	1.07200	0.00150	0.00530	2.96000	0.00200	1.15400	0.04600	0.00080	0.00300	0.00590	0.00540	0.33000	0.00170	0.00760	0.01460
SARM 42	0.63600	0.00350	0.00170	3.27000	0.00120	0.37300	0.07700	0.00080	0.00100	0.00220	0.00370	0.21600	0.00110	0.00440	0.01920
SARM 44	0.10000	0.00080	0.00100	1.44000	0.00550	0.14900	0.02300	0.00960	0.00300	0.00130	0.00050	1.09700	0.00840	0.02710	0.04060
SARM 45	0.55800	0.00410	0.00110	8.81000	0.00350	2.64000	0.07700	0.00270	0.00200	0.01420	0.00920	1.09100	0.00630	0.00740	0.03220
SARM 48	6.36000		0.00100	0.41000		3.54000	0.01500	0.02020	0.01350	0.02910	0.00290	0.06000	0.04360	0.00530	0.03000
SARM 50	7.72000	0.00400	0.00840	7.96000		0.51000	0.13200	0.00100	0.00250	0.00140	0.01950	0.51600	0.00230	0.00810	0.00860
SARM 52	0.26400	0.00810	0.02190	13.78000	0.00150	0.20700	0.20900	0.00110		0.00200	0.00250	0.77900	0.00200	0.02640	0.02500
SARM 69	1.69000	0.00280	0.00460	5.02000		1.63000	0.10000	0.00090	0.00140	0.00660	0.01090	0.46600	0.00290	0.00680	0.02710

Appendix E2. Comparison of certified and measured values for 14 reference materials used to assess the performance of manufacturers Soil Mode pXRF calibration. Accuracy calculated using the formula (measured-certified)/certified)x100 and given in percentage relative error.

Standard		Cu	Fe	Mn	Nb	Pb	Rb	Sr	Ti	Y	Zn	Zr
CGL 111	certified	0.015	9.510	0.108		0.110	0.004	2.240		0.096	0.060	
	measured	0.008	8.686	0.382	0.001	0.077	0.002	1.644	1.282	0.081	0.049	0.014
	accuracy	-47.347	-8.660	253.852		-29.909	-52.047	-26.624		-15.704	-18.933	
CGL 002	certified	0.001	0.350		0.006	0.006	0.236	0.001	0.017	0.002	0.009	0.004
	measured	0.008	0.252	0.096	0.006	0.008	0.256	0.001	0.144	0.002	0.011	0.006
	accuracy	1041.574	-27.977		-0.158	22.984	8.602	21.626	725.402	-15.826	15.304	41.300
CGL 006	certified	0.003	1.839		0.004	0.011	0.021	0.174	0.222	0.002	0.010	0.060
	measured	0.004	1.336	0.081	0.003	0.012	0.020	0.176	0.311	0.003	0.010	0.079
	accuracy	63.576	-27.328		-16.572	6.579	-5.188	1.356	40.081	15.565	-2.714	31.833
CGL 007	certified	0.003	6.888	0.101	0.005	0.001	0.006	0.093	1.265	0.002	0.011	0.029
	measured	0.007	6.340	0.092	0.004	0.001	0.006	0.087	1.092	0.002	0.011	0.036
	accuracy	119.665	-7.962	-8.620	-14.627	4.667	-10.032	-6.516	-13.696	-1.100	-2.140	25.631

GBM306-12	certified	1.490	3.595			2.710	0.072				2.063	
	measured	2.970	5.487	2.660	0.000	2.358	0.064	0.004	1.005	0.002	2.428	0.030
	accuracy	99.333	52.629			-12.983	-10.861				17.703	
SARM 1	certified	0.001	1.400	0.016			0.033	0.001	0.054		0.005	0.030
	measured	0.006	1.086	0.014	0.005	0.004	0.033	0.001	0.140	0.015	0.006	0.039
	accuracy	374.474	-22.421	-10.625			1.926	7.600	160.111		28.600	30.167
SARM 41	certified	0.005	2.960	0.046	0.001	0.003	0.006	0.005	0.330	0.002	0.008	0.015
	measured	0.015	2.642	0.041	0.001	0.001	0.006	0.005	0.393	0.002	0.009	0.019
	accuracy	183.861	-10.730	-10.304	-4.775	-61.933	-3.729	1.519	19.230	-0.588	12.632	28.260
SARM 42	certified	0.002	3.270	0.077	0.001	0.001	0.002	0.004	0.216	0.001	0.004	0.019
	measured	0.007	2.796	0.065	0.000	0.001	0.002	0.004	0.231	0.001	0.005	0.026
	accuracy	288.747	-14.489	-15.117	-60.495	-10.000	1.455	-1.838	7.102	3.636	20.045	34.240
SARM 44	certified	0.001	1.440	0.023	0.010	0.003	0.001	0.001	1.097	0.008	0.027	0.041
	measured	0.005	1.141	0.019	0.009	0.003	0.002	0.000	0.766	0.010	0.027	0.061
	accuracy	372.031	-20.757	-18.609	-10.818	-4.533	16.462	-10.000	-30.201	13.524	0.450	49.099
SARM 45	certified	0.001	8.810	0.077	0.003	0.002	0.014	0.009	1.091	0.006	0.007	0.032
	measured	0.003	9.170	0.077	0.002	0.002	0.013	0.009	1.201	0.006	0.008	0.039
	accuracy	196.354	4.084	-0.623	-8.390	-20.200	-6.577	-7.370	10.092	2.889	12.838	22.205
SARM 48	certified	0.001	0.410	0.015	0.020	0.014	0.029	0.003	0.060	0.044	0.005	0.030
	measured	0.004	0.289	0.016	0.010	0.015	0.027	0.003	0.122	0.047	0.007	0.040
	accuracy	330.690	-29.473	8.533	-52.351	11.452	-6.014	-2.345	103.400	8.353	40.415	32.940
SARM 50	certified	0.008	7.960	0.132	0.001	0.003	0.001	0.020	0.516	0.002	0.008	0.009
	measured	0.015	7.168	0.119	0.001	0.002	0.001	0.018	0.532	0.002	0.009	0.010
	accuracy	76.316	-9.946	-10.136	-48.212	-10.320	-18.000	-7.754	3.008	-0.435	8.000	11.721
SARM 52	certified	0.022	13.780	0.209	0.001		0.002	0.003	0.779	0.002	0.026	0.025
	measured	0.030	17.950	0.264	0.001	0.097	0.002	0.002	1.324	0.002	0.023	0.032
	accuracy	34.751	30.259	26.153	-26.215		11.400	-6.400	70.021	19.700	-12.576	28.464
SARM 69	certified	0.005	5.020	0.100	0.001	0.001	0.007	0.011	0.466	0.003	0.007	0.027
	measured	0.011	4.684	0.089	0.001	0.001	0.007	0.011	0.486	0.003	0.007	0.038
	accuracy	143.252	-6.685	-10.900	-0.559	6.857	-0.788	-1.101	4.292	9.724	8.559	38.568

Appendix E3. Comparison of certified and measured values for 14 reference materials used to assess the performance of UCL Ceramics 1 pXRF calibration. Accuracy calculated using the formula (measured-certified)/certified)x100 and given in percentage relative error.

Standard		Ca	Co	Cu	Fe	Ga	K	Mn	Nb	Pb	Rb	Sr	Ti	Y	Zn	Zr
CGL 111	certified	18.230	0.003	0.015	9.510		0.755	0.108		0.110	0.004	2.240		0.096	0.060	
	measured	10.530	0.002	0.011	5.506	0.000	0.478	0.136	0.001	0.065	0.005	1.007	0.000	0.043	0.042	0.016
	accuracy	-42.239	-43.083	-26.556	-42.104		-36.662	25.624		-40.926	18.750	-55.064		-55.531	-30.600	
CGL 002	certified	0.277		0.001	0.350	0.006	2.970		0.006	0.006	0.236	0.001	0.017	0.002	0.009	0.004
	measured	0.178	0.000	0.008	0.353	0.007	2.680	0.282	0.006	0.011	0.246	0.001	0.004	0.000	0.013	0.004
	accuracy	-35.709		1041.574	0.999	19.577	-9.755		-0.158	69.862	4.406	-2.691	-74.887	-100.000	45.063	-4.905
CGL 006	certified	1.630		0.003	1.839	0.002	7.550		0.004	0.011	0.021	0.174	0.222	0.002	0.010	0.060
	measured	0.850	0.001	0.004	1.601	0.002	7.515	0.189	0.003	0.017	0.017	0.159	0.173	0.002	0.011	0.054
	accuracy	-47.848		63.576	-12.933	-18.793	-0.460		-16.572	53.276	-19.022	-8.677	-22.221	-26.336	8.439	-10.203
CGL 007	certified	3.870	0.004	0.003	6.888	0.002	3.310	0.101	0.005	0.001	0.006	0.093	1.265	0.002	0.011	0.029
	measured	1.928	0.003	0.007	5.998	0.002	3.265	0.169	0.004	0.000	0.005	0.080	1.089	0.002	0.013	0.026
	accuracy	-50.173	-14.383	119.665	-12.928	-20.690	-1.356	67.592	-14.627	-69.225	-19.501	-13.591	-13.944	-24.108	12.331	-8.924
GBM306-12	certified		0.002	1.490	3.595					2.710	0.072				2.063	
	measured	0.508	0.001	2.970	4.395	0.001	3.231	4.655	0.000	2.409	0.040	0.003	0.182	0.016	2.555	0.017
	accuracy		-72.025	99.333	22.250					-11.092	-44.312				23.860	
SARM 1	certified	0.560		0.001	1.400	0.003	4.140	0.016			0.033	0.001	0.054		0.005	0.030
	measured	0.310	0.001	0.006	1.391	0.003	3.770	0.021	0.005	0.005	0.031	0.001	0.048	0.013	0.006	0.027
	accuracy	-44.664		374.474	-0.621	2.048	-8.940	33.146			-4.586	-15.969	-11.714		28.978	-9.049
SARM 41	certified	1.072	0.002	0.005	2.960	0.002	1.154	0.046	0.001	0.003	0.006	0.005	0.330	0.002	0.008	0.015
	measured	0.564	0.001	0.015	3.377	0.002	1.034	0.094	0.001	0.001	0.006	0.006	0.347	0.001	0.011	0.015
	accuracy	-47.418	-1.604	183.861	14.076	-3.760	-10.385	104.191	-4.775	-52.007	-0.401	6.390	5.045	-22.654	50.479	2.316
SARM 42	certified	0.636	0.004	0.002	3.270	0.001	0.373	0.077	0.001	0.001	0.002	0.004	0.216	0.001	0.004	0.019
	measured	0.337	0.002	0.007	3.422	0.001	0.257	0.159	0.000	0.000	0.002	0.004	0.244	0.001	0.006	0.020
	accuracy	-47.030	-48.991	288.747	4.650	-17.442	-31.076	106.570	-60.495	-63.956	-1.596	1.234	12.864	-20.078	29.950	5.365
SARM 44	certified	0.100	0.001	0.001	1.440	0.006	0.149	0.023	0.010	0.003	0.001	0.001	1.097	0.008	0.027	0.041

	measured	0.080	0.001	0.005	1.512	0.006	0.000	0.035	0.009	0.002	0.002	0.000	1.144	0.008	0.040	0.045
	accuracy	-20.157	-34.471	372.031	4.969	13.062	-99.896	53.690	-10.818	-39.555	27.929	-16.473	4.324	-6.483	48.684	10.537
SARM 45	certified	0.558	0.004	0.001	8.810	0.004	2.640	0.077	0.003	0.002	0.014	0.009	1.091	0.006	0.007	0.032
	measured	0.292	0.004	0.003	8.301	0.004	2.634	0.128	0.002	0.002	0.013	0.008	1.092	0.006	0.010	0.030
	accuracy	-47.676	5.879	196.354	-5.782	5.718	-0.211	66.118	-8.390	6.184	-7.453	-8.938	0.075	-11.767	30.558	-7.600
SARM 48	certified	6.360		0.001	0.410		3.540	0.015	0.020	0.014	0.029	0.003	0.060	0.044	0.005	0.030
	measured	3.300	0.000	0.004	0.364	0.002	3.328	0.017	0.010	0.020	0.024	0.002	0.018	0.038	0.007	0.025
	accuracy	-48.114		330.690	-11.113		-5.991	14.531	-52.351	50.243	-18.882	-19.668	-69.693	-13.897	27.466	-15.609
SARM 50	certified	7.720	0.004	0.008	7.960		0.510	0.132	0.001	0.003	0.001	0.020	0.516	0.002	0.008	0.009
	measured	4.118	0.003	0.015	6.516	0.001	0.474	0.219	0.001	0.001	0.001	0.016	0.439	0.002	0.010	0.007
	accuracy	-46.660	-20.572	76.316	-18.143		-7.085	65.702	-48.212	-52.355	-30.064	-15.525	-14.923	-22.960	17.570	-17.525
SARM 52	certified	0.264	0.008	0.022	13.780	0.002	0.207	0.209	0.001		0.002	0.003	0.779	0.002	0.026	0.025
	measured	0.178	0.007	0.030	13.543	0.000	0.155	0.398	0.001	0.095	0.002	0.002	0.737	0.003	0.034	0.026
	accuracy	-32.400	-13.456	34.751	-1.719	-100.000	-25.235	90.521	-26.215		20.766	-5.058	-5.422	29.469	27.227	4.750
SARM 69	certified	1.690	0.003	0.005	5.020		1.630	0.100	0.001	0.001	0.007	0.011	0.466	0.003	0.007	0.027
	measured	0.827	0.003	0.011	5.028	0.002	1.548	0.186	0.001	0.001	0.006	0.011	0.462	0.003	0.008	0.028
	accuracy	-51.057	-0.813	143.252	0.168		-5.042	86.292	-0.559	-48.059	-5.082	-3.370	-0.830	-8.538	19.078	4.883

Appendix E4. Comparison of certified and measured values for 14 reference materials used to assess the performance of manufacturers Soil Mode pXRF calibration over the range of concentrations found in earthenware archaeological ceramics. Accuracy calculated using the formula (measured-certified)/certified)x100 and given in percentage relative error. Ceramics compositional range determined using data from Quinn et al. (2010), Day et al. (2011), Trave et al. (2014) and Quinn and Burton (2015).

Standard	Cu		Fe		Mn		Nb		Zn		Zr
Ceramics min	0.0000		0.81		0.01		no data		no data		0.00317
Ceramics max	0.0334		9.92		0.24		no data		no data		0.0427
	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert
CGL 111	0.0147	47.347	9.51	8.66	0.1080	253.852			0.0600	18.933	
CGL 002	0.0007	1041.574					0.0064	0.158	0.0092	15.304	0.004
CGL 006	0.0026	63.576	1.839	27.328	0.1084		0.004	16.572	0.0098	2.714	
CGL 007	0.0032	119.665	6.888	7.962	0.1007	8.62	0.0052	14.627	0.0114	2.14	0.0287
GBM30612			3.595	52.629					2.063	17.703	
SARM 1	0.0012	374.474	1.40	22.421	0.0160	10.625			0.0050	28.6	0.0300
SARM 41			2.96	10.73	0.0460	10.304	0.0008	4.775	0.0076	12.632	0.0146
SARM 42	0.0017	288.747	3.27	14.489	0.0770	15.117	0.0008	60.495	0.0044	20.045	0.0192
SARM 44	0.0010	372.031	1.44	20.757	0.0230	18.609	0.0096	10.818	0.0271	0.45	0.0406
SARM 45	0.0011	196.354	8.81	4.084	0.0770	0.623	0.0027	8.39	0.0074	12.838	0.0322
SARM 48	0.0010	330.69			0.0150	8.533	0.0202	52.351	0.0053	40.415	0.0300
SARM 50			7.96	9.946	0.1320	10.136	0.0010	48.212	0.0081	8	0.0086
SARM 52	0.0219	34.751			0.2090	26.153	0.0011	26.215	0.0264	12.576	0.0250
SARM 69	0.0046	143.252	5.02	6.685	0.1000	10.9	0.0009	0.559	0.0068	8.559	0.0271
Average over ceramics range		273.86		16.88		33.95		22.11		14.35	

Standard	Pb		Rb		Sr		Ti		Y	
Ceramics min	0.0000		0.0001		0.0045		0.12		0.00	
Ceramics max	0.0099		0.0230		0.0579		0.73		0.02	
	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy
CGL 111			0.0043	52.047						
CGL 002	0.0063	22.984							0.0023	15.826
CGL 006			0.0207	5.188			0.222	40.081	0.0023	15.565
CGL 007	0.0009	4.667	0.0063	10.032					0.002	1.1

GBM30612										
SARM 1										
SARM 41	0.0030	61.933	0.0059	3.729	0.0054	1.519	0.3300	19.23	0.0017	0.588
SARM 42	0.0010	10	0.0022	1.455			0.2160	7.102	0.0011	3.636
SARM 44	0.0030	4.533	0.0013	16.462					0.0084	13.524
SARM 45	0.0020	20.2	0.0142	6.577	0.0092	7.37			0.0063	2.889
SARM 48										
SARM 50	0.0025	10.32	0.0014	18	0.0195	7.754	0.5160	3.008	0.0023	0.435
SARM 52			0.0020	11.4			0.7790	70.021	0.0020	19.7
SARM 69	0.0014	6.857	0.0066	0.788	0.0109	1.101	0.4660	4.292	0.0029	9.724
Average over ceramics range		17.69		12.57		4.44		23.96		8.30

Appendix E5. Comparison of certified and measured values for 14 reference materials used to assess the performance of UCL Ceramics 1 pXRF calibration over the range of concentrations found in earthenware archaeological ceramics. Accuracy calculated using the formula (measured-certified)/certified)x100 and given in percentage relative error. Ceramics compositional range determined using data from Quinn et al. (2010), Day et al. (2011), Trave et al. (2014) and Quinn and Burton (2015).

Standard	**Ca**		**Co**		**Cu**		**Fe**		**Ga**		**K**		**Mn**	
Ceramics min	0.2		0.0003		0.0000		0.81		no data		0.39		0.01	
Ceramics max	20.94		0.0087		0.0334		9.92		no data		4.59		0.24	
	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy
CGL 111	18.23	42.239	0.0032	43.083	0.0147	26.556	9.51	42.104			0.76	36.662	0.1080	25.624
CGL 002	0.277	35.709			0.0007	1041.574			0.0057	19.577	2.97	9.755		
CGL 006	1.63	47.848	0.001		0.0026	63.576	1.839	12.933	0.0023	18.793			0.1084	
CGL 007	3.87	0.173	0.0036	14.383	0.0032	119.665	6.888	12.928	0.0023	20.69	3.31	1.356	0.1007	67.592
GBM30612			0.00225	72.025			3.595	22.25						
SARM 1	0.56	44.664			0.0012	374.474	1.40	0.621	0.0027	2.048	4.14	8.94	0.0160	33.146
SARM 41	1.07	47.418	0.0015	1.604			2.96	14.076	0.0020	3.76	1.15	10.385	0.0460	104.191
SARM 42	0.64	47.03	0.0035	48.991	0.0017	288.747	3.27	4.65	0.0012	17.442	0.37	31.076	0.0770	106.57
SARM 44	0.10	20.157	0.0008	34.471	0.0010	372.031	1.44	4.969	0.0055	13.062			0.0230	53.69
SARM 45	0.56	47.676	0.0041	5.879	0.0011	196.354	8.81	5.782	0.0035	5.718	2.64	0.211	0.0770	66.118
SARM 48	6.36	48.114			0.0010	330.69					3.54	5.991	0.0150	14.531
SARM 50	7.72	46.66	0.0040	20.572			7.96	18.143			0.51	7.085	0.1320	65.702

SARM 52	0.26	32.4	0.0081	13.456	0.0219	34.751			0.0015	100			0.2090	90.521
SARM 69	1.69	51.057	0.0028	0.813	0.0046	143.252	5.02	0.168			1.63	5.042	0.1000	86.292
Average ceramics range		39.32		25.53		271.97		12.60		22.34		11.65		64.91

Standard	**Nb**		**Pb**		**Rb**		**Sr**		**Ti**		**Y**		**Zn**		**Zr**
Ceramics min	no data		0.0000		0.0001		0.0045		0.12		0.00		no data		0.00317
Ceramics max	no data		0.0099		0.0230		0.0579		0.73		0.02		no data		0.0427
	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert	Accuracy	Cert
CGL 111					0.0043	18.75							0.0600	30.6	
CGL 002	0.0064	0.158	0.0063	69.862							0.0023	100	0.0092	45.063	0.004
CGL 006	0.004	16.572			0.0207	19.022			0.222	22.221	0.0023	26.336	0.0098	8.439	
CGL 007	0.0052	14.627	0.0009	69.225	0.0063	19.501					0.002	24.108	0.0114	12.331	0.0287
GBM30612													2.063	23.86	
SARM 1													0.0050	28.978	0.0300
SARM 41	0.0008	4.775	0.0030	52.007	0.0059	0.401	0.0054	6.39	0.3300	5.045	0.0017	22.654	0.0076	50.479	0.0146
SARM 42	0.0008	60.495	0.0010	63.956	0.0022	1.596			0.2160	12.864	0.0011	20.078	0.0044	29.95	0.0192
SARM 44	0.0096	10.818	0.0030	39.555	0.0013	27.929					0.0084	6.483	0.0271	48.684	0.0406
SARM 45	0.0027	8.39	0.0020	6.184	0.0142	7.453	0.0092	8.938			0.0063	11.767	0.0074	30.558	0.0322
SARM 48	0.0202	52.351											0.0053	27.466	0.0300
SARM 50	0.0010	48.212	0.0025	52.355	0.0014	30.064	0.0195	15.525	0.5160	14.923	0.0023	22.96	0.0081	17.57	0.0086
SARM 52	0.0011	26.215			0.0020	20.766			0.7790	5.422	0.0020	29.469	0.0264	27.227	0.0250
SARM 69	0.0009	0.559	0.0014	48.059	0.0066	5.082	0.0109	3.37	0.4660	0.83	0.0029	8.538	0.0068	19.078	0.0271
Average over ceramics range		22.11		50.15		15.06		8.56		10.22		27.24		28.59	

Appenidx E6: Average accuracy for 15 elements measured within 14 certified reference materials using the manufacturers Soil calibration and UCL Cal 1 Ceramics 2 high calcium pXRF calibration. Calculated using the percentage relative error based on a comparison of certified and measured values (Appendix 2) but disregarding the polarity of the individual accuracy calculations. The first two columns indicate the average over all standards for which the element was certified. The third and four columns presents averages based on only those standards whose concentration of the given element falls within the range present in earthenware archaeological ceramics.

Element	Average accuracy all CRMs (%)		Average accuracy for ceramics range (%)	
	Manufacturers Soil Mode	UCL Cal Ceramics 1	Manufacturers Soil Mode	UCL Cal Ceramics 1
K	-	18.62	-	11.65
Sr	7.85	13.28	4.44	8.56
Zr	31.2	8.47	31.15	8.31
Ti	98.89	19.66	23.96	10.22
Fe	19.53	10.89	16.88	12.6
Ca	-	43.17	-	39.32
Zn	14.35	28.59	14.35	28.59
Rb	10.93	15.91	12.57	15.06
Mn	33.95	64.91	33.95	64.91
Nb	22.11	22.11	22.11	22.11
Ga	-	22.34	-	22.34
Co	-	25.53	-	25.53
Y	8.92	28.49	8.3	27.24
Pb	16.87	46.4	17.69	50.15
Cu	240.86	239.37	273.86	271.97

Appendix F: RA and SOP

Experiment or Procedure:

Document Archaeological Ceramic material (pottery);

Collection of Clay Samples;

Produce thin-sections and powder samples of ceramic pottery.

Locations:

Location of work: on site (excavation); BHU, Banaras Hindu University, Varanasi.

Distance from site: within 30-minute walk.

Transport requirements (foot, plane to BHU)

Potential risks: see the following Risks Assessments:

Risk Assessment for Producing thin-sections of ceramic pottery. Approved by Catherine Kneale, University of Cambridge, on the 22 Feb 2017

Risk Assessment, Student Fieldwork Form. Approved by Mrs Jessica Rippengal, University of Cambridge on the 22 Feb 2017

Following Contents:

Equipment

Pottery Analysis Critical Pathway

Phase 1a: Collection of pottery during fieldwork (Excavation)

Phase 1b: Clay Sampling (Exc-In-Situ; around the site)

Phase 2: Preliminary Analysis (Post-Exc-In-Situ)

Phase 3: Documentation, Thin-Sections and Pottery Powder.

Equipment for Pottery Analysis.

Ceramic Petrography and Powder Sampling

Dremel® cordless (8100/8200);
Dremel® 3.2mm Tile Drill Bit;
Dremel® diamond cutting wheel (sc545);
Tile cutter;
Plug adaptor;
Diamond needle;
UV 15 W Black Light;
Cover slides;
Rack/ grid;
Tempered glass for hand polishing;
Tweezers;
Sticks;
Mask;
Nitrile gloves;
Sandpaper (grit: 240 and 600);
Carbide paper and powder (grit 600).
Plasticine or modelling clay;
Filter paper;
Microscope slides;
Disposable paper cups;
Syringes;
Electrical Single Hot Plate/1500 Watt;
Lantelme 5831 Thermometer Analogue/Bimetal;
Tinfoil;
Lab safety glasses/ specs;
Plastic vial tube powder sample storage;
Laboratory coat;

Chemical substances:

Silicon Carbide Powder (600 Grit);
Acetone;
Speedex Universal Activator Paste;
Speedex Wash Light Body;
Bluher Epoxy Resin;
Bluher EpoThin Hardener;
Optical adhesive (Norland 61);
Industrial Methylated Spirit;

Clay Sampling

Geological maps;
Compass;
GPS;
Geological hammer;
Sample bags;
North arrow;
Black board and chalk;
Pencils and pens;

Morphological analysis:

Digital scale;
Pottery gauge;
Digital Caliper Gauge Micrometer;
Magnifying lens;
Diameter chart;
Millimetre drawing paper;
Translucent tracing paper;
Scale bar (5cm; 10cm; 50cm);
CameraTrax 24ColorCard-2x3 with white balance;
Sharpie;
Lables;
White and black background for photos;
Sharpener and rubbers;
Munsell color charts;
Measuring Tape;
Light Box Kit;
Tripod;
Laptop and external Hard Disk;
Camera (Reflex, Canon 7D);
Canon SD cards;
Extra Canon batteries;

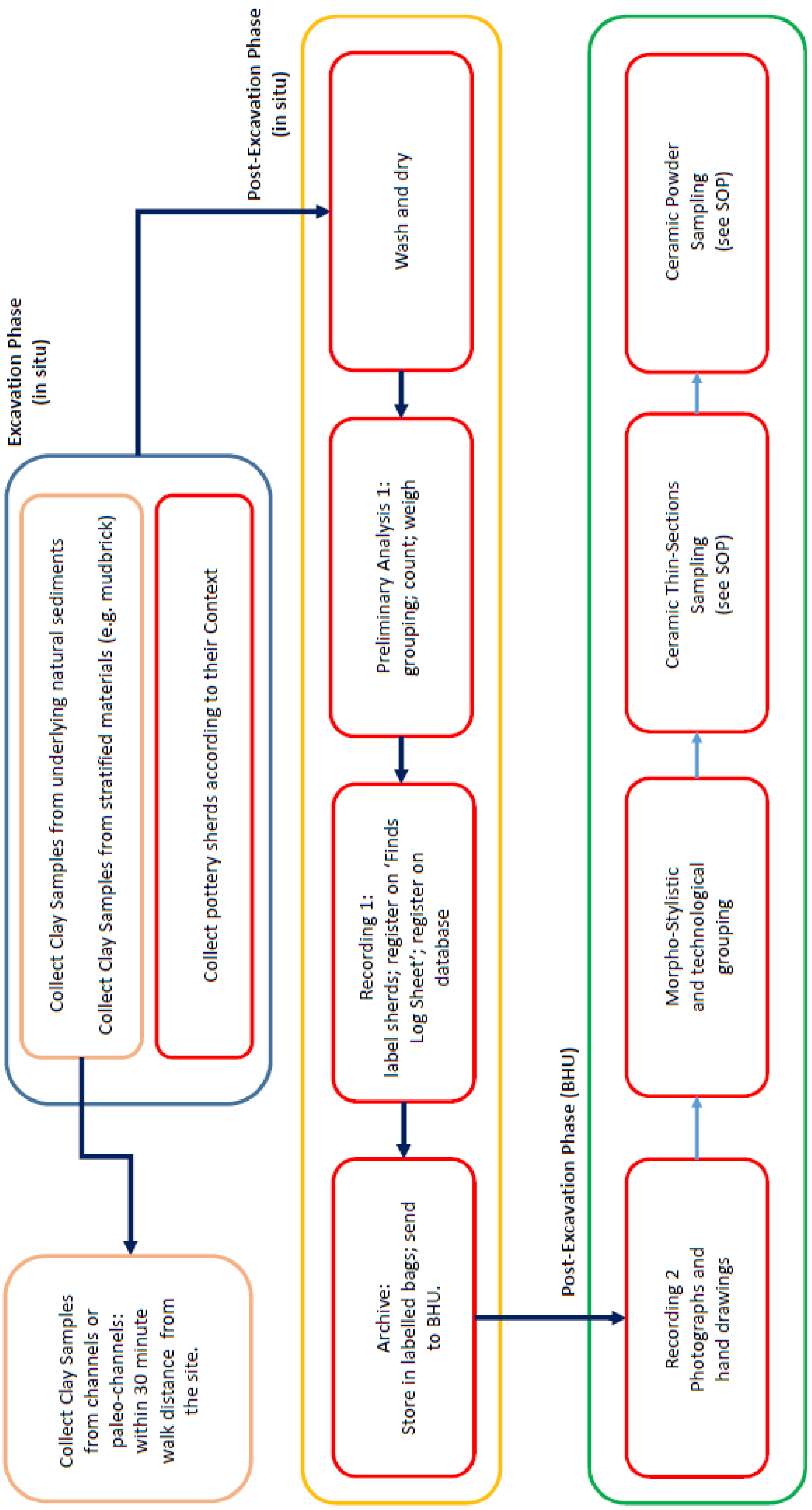
Software

FileMaker Pro (Database);
Photoshop CC;
Illustrator CC;
Lightroom CC (photos);
Agisoft Photoscan PRO;
MS Excel;

Geochemical Analysis

Portable XRF (pXRF);

Pottery Analysis Critical Pathway



Phase 1a: Collection of Pottery During Fieldwork (Excavation)

On-site retrieval and sampling: the all assemblage - all ceramics - from excavated area will be collected and temporarily – yet securely – gathered according to their context number. "The collection of pottery during fieldwork should be carried out in accordance with the methods and strategies set out in the project design. These may be modified in response to specific circumstances, such as the discovery of special deposits such as graves, or unexpected dumps of large amounts of kiln waste. The overall aim of collection and processing must be to produce a comprehensive, stable, well-ordered, pottery assemblage that can be easily accessed and analysed by specialists that are involved in the project and others that may conduct subsequent research" (PCRG, SGRP and MPRG 2016).

Phase 1b: Clay Sampling

Location of work: on site;

Distance from site: within 30-minute walk.

Transport requirements (foot)

Introduction

In order to obtain information about the occurrence and composition of clay sources, it is necessary to have a knowledge of local and regional geology, and conduct direct observations in the field, collect samples and study these in the laboratory.

Raw material prospecting or clay sampling involves travelling across the landscape looking for naturally occurring raw materials that might have represented suitable source of clay or temper for ancient ceramic manufacturer. This will be carried out on foot in close proximity to the archaeological sites. Important equipment includes topographic maps, a compass, a GPS, a geological hammer or a trowel, sample bags, camera, notebook and pencil.

Selecting Samples

When it comes to selecting samples, it is important to bear in mind that recent geomorphological processes and land-use changes may mean that different raw material sources were available to ancient potters. Therefore, five types of samples will be collected: unfired mudbricks chronologically/ stratigraphically associated to the ceramic assemblage (contexts; finds); clay sources available in close proximity to the archaeological site; samples from rivers or channels located in close proximity to the site; fired mudbricks, likely produced locally (finds); kiln lining.

Procedure

Promising outcrops or deposits of clay or possible temper sources should be investigated in the field by removing a sample and examining it by eye or with a hand-lens. Clay rich material should be wetted and worked by hand to check its suitability as a raw material for ceramic production. For instance, pinching and rolling out a coil of the wet clay gives an indication of its plasticity. When carrying out clay tests in the field, it is worth bearing in ming that potters could have modified what might seem to be an unpromising source of clay into something more suitable for ceramic manufacture by means of sieving, levigating, clay mixing and tempering. When collecting samples, it is important to photograph or draw the deposit, make a short description, mark it on the map or record the coordinates of the sampling site. Samples should be bagged and labelled clearly with a sample number, date and location. Field samples collected during an excursion or campaign of raw material prospecting need to be processed in the laboratory and prepared as thin sections for analysis and comparison to the ceramics under study.

Phase 2: Preliminary Analysis

Processing: all ceramics must be carefully washed. Pottery showing clear burnt residues and soot must be avoided.

Assessment: The assemblage must be evaluated to determine its potential in accomplishing the project aims. We will follow the guidelines proposed by *PCRG* (PCRG, SGRP and MPRG 2016) and identify: general ware group, e.g. 'flint-tempered wares', or ceramic tradition, e.g. 'Grooved ware'; quantity (number and weight of sherds); presence of vessel forms and other diagnostic pieces (preferably quantified); the chronological range (period) of the pottery in each contextual unit; the quantity of pottery in each contextual unit, usually derived from the bulk finds record.

Preliminary Analysis, Recording and Archiving: For each sherd, fabric, form, number, weight and attributes must be recorded prior to any further analysis and/or archiving. If, due to time limitation, this was not possible, then provide as much information as possible. A more detailed analysis will be done when the specialist visits the archives.

All pottery should be marked. Marking, bagging and boxing must utilise archivally stable materials. The assemblage can now be sent to the archive (BHU).

Phase 3a: Documentation and Thin-Sections Preparation

Thin section and ceramic powder sample preparation of archaeological ceramics using a portable kit. Preliminary documentation: Each artefact has to show a find and context numbers, as well as an analytical number or code. Label each sherd as follow: Site/Trench-#Context-#Sherd (e.g. Sherd number 1, from Bahola trench AB1, context 109, will be labelled as BHA/AB1-109-1). Assign an analytical number to each thin-section sample following this scheme: e.g. AlessandroCeccarelli-Thin-Section-#number (*AC-TS108*). Subsequently, take a photo of the interior and exterior of every sherd on a uniform background (*figure 1*); draw diagnostic and painted sherds on translucent tracing paper. record each sherd as entries on a database and select samples for thin-section analysis and/or X-ray analysis.

Figure 1. Sherd number 1, from Bahola trench AB1, context 109. The interior and exterior of every sherd is photographed.

Selecting Samples

A fragment of a ceramic artefact (c. 5 g in weight with a long dimension of 3 cm or more) is required for producing a thin-section. Handles, lids or fragments of applied decoration are generally not selected, since these may not represent the same technologies used for producing the whole vessel, and might follow a different method of production. Select a sherd where it is possible to produce a vertical section (rim to base) for better understanding of forming techniques and clay paste preparations. Ceramic building materials are not subjected to the above mentioned restrictions of sampling, since the orientation of the section is not necessarily relevant, unless different layers of ceramic pastes (plaster, daub or clay furnace linings) are visible; in this case, proceed sectioning across these features in order to understand their microstratigraphy. Put the samples on a plastic tray with plain paper on it. Write author's name, date and sample numbers, and draw a grid for hosting the samples on the paper.

Cutting

Cut the selected sherd or sub-sample in the chosen orientation and produce a small 'chip'. This chip is the ceramic core out of which the final thin section is produced. The chip has to be c. 2-3 centimetres thick. Use the Dremel® 8200-1/35 Cordless Multitool Li-Ion (10.8 V) and a Dremel® diamond cutting wheel (sc545) to perform the cut. Such device was selected for two main reasons: first of all, it is a cordless device, which allows to produce chips even where electricity is not constantly accessible; second, the lithium battery of Dremel® 8200-1/35 is waterproof, which allows to cut wet sherds in all safety and protecting the operator from getting electrocuted.

Gloves, mask and goggles have to be worn while operating the Dremel®. Perform the cut as straight as possible as this will form the surface of the final thin section. Is highly recommended to produce a platform of white plastazote, and design it to host and solidly support the Dremel® while cutting samples, in order to protect the operator from cutting fingers out. Afterwards, leave the chip and the parent sample to dry on the tray in the designated cell of the grid/tray, which was previously marked with its specific sherd label and sample number. Once dry, put back the parent sample into its storage bag and leave the chips on the tray, ready for the next stage of the preparation process.

Resin Impregnation

Thin-Section petrography is a process used for both hard rocks and softer materials, such as pottery. Nevertheless, the latter material needs to be to be impregnated to hold together during the thin-sectioning process. This is done by filling the fabric, pores or voids, with a transparent low viscosity two-part epoxy resin, either before or after the cutting process described above. Place the lower portion of the chip in a small clay ball (c. 2-4 cm diameter) on the tray, in order to keep it vertically erected, with the freshly cut surface parallel to the tray and facing upwards.

Turn on a hotplate (similar to Maple SHC-I Ceramic Top Stirrer Hotplate). This is covered with clean silver foil, and turned on and set at 3-4 (lower medium temperature) on the dial. Transfer the chip to the hotplate with cut surface facing downwards; place multiple chips in the same order/pattern as they appear on the grid drawn on the tray: this will help to avoid mixing up the samples. While the chips warm up, weight 2.5 grams of 'Epothin' resin and 0.9 g of 'Eposet' hardener and mix them using a paper resin cup on a digital scale (Smart Weigh SWS100 Elite Digital Scale 100 x 0.01g). Gloves, goggles and mask (3M 4251) have to be put on during this stage. Stir the resin/hardener solution. Do not stir energetically and avoid the formation of bubbles/foam.

Important: (1) do not use the same syringe or paper on the bottles and do not get the lids mixed up. This can lead to premature setting of the resin; (2) throw away the consumable tools in the hazardous waste bin.

At this point the chips are warm and ready to absorb resin more homogeneously. Pick up a chip using plastic tweezers and dip it face down in the resin/hardener solution for c. 10-15 seconds. Remove the chip from the solution and place it face upwards on the clay ball so that the cut and impregnated face of the chip is levelled. Discard cup, consumable tools and gloves into the hazardous waste bin. The resin impregnated chips take about a day to cure.

Grinding and polishing the impregnated chip

Before gluing the chip to the microscope slide, the resin-impregnated surface needs to be polished. Grind off the uppermost portion of resin layer, smooth and flat the surface. Carry out this grinding/polishing phase with either 600 grit carborundum or with a 600 grit grinding sand paper, rotating the chip face down on a glass plate in a slurry of grit and water (circular motion or in a figure-of-eight).

Frosting and Labelling Microscope Slides

Standard microscope slides (76 x 26 mm) will be used for producing thin-sections. Slides will be 'frosted' in order to improve bonding of the chip with the glass. Produce the frosting by rotating the microscope slide face down on a glass plate in a slurry of carborundum grit. Once frosted, wash and dry it with paper towel. Write or scratch the sample number onto the un-frosted side at the bottom with a diamond tipped pen and/or permanent marker.

Bonding Chip to the Slide

Gloves, goggles and mask (3M 4251) have to be worn during this stage. Wash the frosted side of the microscope slide in acetone to remove any grease. Use the UV-setting glue (Norland Optical Adhesive NOA 61) to bond the ceramic chip and slide (one to three drops of the glue on the slide). Gently place the flat polished surface of the chip on the slide and allow the weight of the chip to spread out the glue. Move the slide and chip above the UV light source (UV 15 W Black Light). Samples will take about 24-36 hours to dry and set.

Re-sectioning and Grinding Sample

After bonding the chip to the microscope slide, the sample needs to be re-sectioned and ground down almost to 30 µm. Perform the re-cutting on wet samples using a Dremel® 8200-1/35 Cordless Multitool Li-Ion (10.8 V) and a Dremel® diamond cutting wheel (sc545). Gloves, mask and goggles have to be put on while operating the Dremel®. Perform the cut as straight as possible on a platform made of white plastazote, designed to host and firmly support the Dremel® while re-cutting samples. As already mentioned, such device was selected for two main reasons: first of all, it is a cordless device, which allows to produce chips even where electricity is not constantly accessible; second, the lithium battery of Dremel® 8200-1/35 is waterproof, which allows to cut wet sherds in all safety and protecting the operator from getting electrocuted. Considering the physical feature of the drill and the diamond wheel, most of the chip will be re-cut and a sample of about 3-5 millimetres should be left on the microscope slide.

Final Hand Polishing

At this stage the thin-section is ready to be stored (*figure* 2). The final stage of grinding and polishing thin-sections down to 30 µm will not happen in situ, and will likely take place in a more controlled environment, e.g. Earth Sciences Department, University of Cambridge, UK, where a *Buehler PetroThin Machine* can be used following the departmental SOP. Once ground to c. 50 µm using either the PetroThin Machine, carborundum powder and/or sand paper, polish the samples by hand to bring them to the correct thickness of 30 µm. This is done on the glass plate with carborundum powder.

The proposed methodology and SOP has been tested (April 2016) by Alessandro Ceccarelli, and a total amount of 116 ceramic thin-sections have been successfully produced at BHU, Varanasi, from pottery unearthed at Alamgirpur, Uttar Pradesh, and Bahola, Haryana.

Phase 3b: Ceramic Powder Samples Preparation

For geochemical and mineralogical analysis of ceramic powder samples, at least 2g of powdered sherds need to be sampled.

1. Scrubbing

Cleaning of sample is essential so as to remove surface contaminants. Scrubbing pottery sherd follows a similar procedure described in the paragraph '*Thin-Sections SOP: 3. Cutting*'. However, *Dremel® 3.2mm Tile Drill Bit* will be used instead of the diamond wheel. Keep a sherd sample tightly in gloved non-dominant hand. Drill will be held in dominant hand, using the previously mentioned plastazote support for reducing risks of abrasion or cutting. Powder produced from the outer surface will be discarded. Gloves, goggles and mask (3M 4251) have to be worn during this stage.

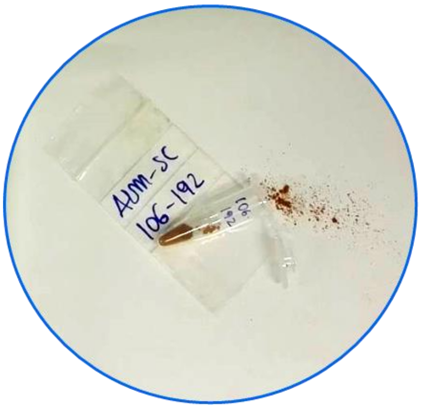


Figure 3. Ceramic powder samples produced by the author (April 2016) from pottery sherds unearthed at Alamgirpur trench SC, Uttar Pradesh.

2. Grinding

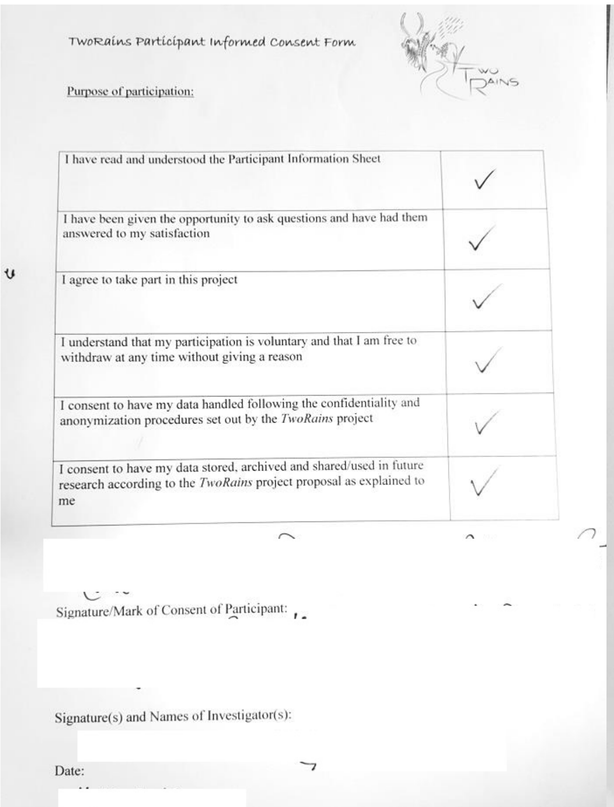
Place a small sheet of paper under the sherd. Drilling pottery sherd follows a similar procedure described in the paragraph '*Thin-Sections SOP: 3. Cutting*'. However, Dremel® 3.2mm Tile Drill Bit will be used instead of the diamond wheel. Keep a sherd sample tightly in gloved non-dominant hand. Drill will be held in dominant hand, using the previously mentioned plastazote support for reducing risks of abrasion or cutting. Gloves, goggles and mask (3M 4251) will be worn during this stage. Powder produced from the internal portion of the wall will be stored (c. 2g of powdered ceramic) in a *plastic vial tube sample storage (figure 3)*.

3. Cleaning:

The used drill bits will be cleaned with water first. Drill bits with then put in a beaker with Industrial Methylated Spirits (IMS) and placed in the water bath of an ultrasonicator.

Appendix G: Ethnographic study: consent forms, questionnaire and ethical approval

Participant informed consent form (examples):



TwoRains Participant Informed Consent Form

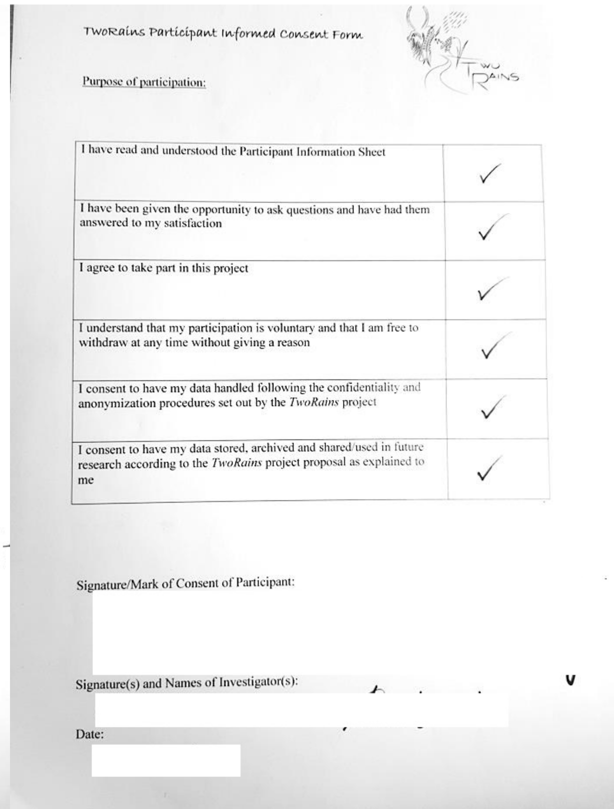
Purpose of participation:

I have read and understood the Participant Information Sheet	✓
I have been given the opportunity to ask questions and have had them answered to my satisfaction	✓
I agree to take part in this project	✓
I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason	✓
I consent to have my data handled following the confidentiality and anonymization procedures set out by the *TwoRains* project	✓
I consent to have my data stored, archived and shared/used in future research according to the *TwoRains* project proposal as explained to me	✓

Signature/Mark of Consent of Participant:

Signature(s) and Names of Investigator(s):

Date:



TwoRains Participant Informed Consent Form

Purpose of participation:

I have read and understood the Participant Information Sheet	✓
I have been given the opportunity to ask questions and have had them answered to my satisfaction	✓
I agree to take part in this project	✓
I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason	✓
I consent to have my data handled following the confidentiality and anonymization procedures set out by the *TwoRains* project	✓
I consent to have my data stored, archived and shared/used in future research according to the *TwoRains* project proposal as explained to me	✓

Signature/Mark of Consent of Participant:

Signature(s) and Names of Investigator(s):

Date:

Model of questionnaire:

Questions to ask potters

1. Where do you get the clay from? Is this always the same place? Did your grandparents and parents use this source(s)?
2. What else do you put into the clay?
3. How do you make pots? Is this how your grandfather made them?
4. How many people are involved in producing a pot?
5. How long does it take to make a pot?
6. What rotatory devices and tools you use to make pots?
7. What kiln, firing techniques and fuel you use to make pots?
8. In what season you prefer to craft vessels?

Ethical approval:

UNIVERSITY OF CAMBRIDGE
School of the Humanities and Social Sciences

Ethics Committee Secretary

Department of Archaeology
Free School Lane
Cambridge

15 December 2017

Dear ,

Ethical approval: Winter Rain, Summer Rain: Adaptation, Climate Change, Resilience and the Indus Civilisation (TwoRains – ERC consolidator grant)

The Chair of the Ethics Committee for the School of the Humanities and Social Sciences, acting on the Committee's behalf, has considered the documentation you provided, which followed the procedures concerning ethical approval of research.

I am able to inform you that approval, with respect to ethical considerations, has now been given to your project. Please note that this clearance is based on the documentation you have submitted. You must resubmit your application to the Ethics Committee should you subsequently make any substantive changes relating to matters reviewed by the Committee.

We are content for this letter to be forwarded to your grant sponsors, **ERC.**

Yours sincerely

Appendix H: Additional Tables

Table H.1 Simplified summary of ceramic technologies before the advent of urbanisation in the Indus zone. Four stages are identified. SSC: Sequential Slab- built ceramics; BBM: Burj Basket Marked; KGM / T-A: Kili Gul Muhammad and Togau A; SKT: Sheri Khan Tarakai; KLB: Kalibangan; and BR: Bara (see references in the above Tables 3.2, 3.3, 3.4).

Stages	Ceramic Tradition	Organic Temper	Fine Paste	Slab	Coil	Mould	Wheel-Fashioning	Wheel-Throwing	Applied Rustication	Monochrome or Bichrome Paintings	Polychrome Painting
Stage 1:	SSC	x		x							
	BBM	x				x					
Stage 2:	KGM / T-A	x	x	x	x	x	x			x	
	SKT	x	x		x	x	x		x	x	
Stage 3:	HW	x	x	x	x	x	x		x	x	x
	RW	x	x	x	x	x	x		x	x	x
Stage 4:	SS	x	x		x	x	x	?	x	x	
	KLB	x	x		x	x	x	?	x	x	
	BR	x	x		x	x	x	?	x	x	

Table H.2 Other forming techniques often associated with the production of Indus vessels.

Techniques	References (e.g.)
Coiling and wheel-coiling	Berg 2011; Rückl and Jacobs 2016; Vidale and Tosi 1996; Kenoyer 1994b:347; Mackay 1938; Miller 1999: 73; also see Rice 1987: 126
Sequential building and moulding	Dales and Kenoyer 1986: 65-66, 78-79, 83, 85, 216; Vidale 2000: 81; Wright 1991: 6.6; Kenoyer 1994b; Mery 1994: 477-478; Miller 1999
Paddle-and-anvil technique	Miller 1999: 77; Mackay 1938: 438, note 1.
Trimming and scraping	Rye 1981; Jenkins 1994; 2000; Mery and Blackman 1996; Mery 1994: fig. 41.2; Santoni 1989: fig 4; also see Anderson-Gerfaud et al. 1989; Miller 1999: 77; Dales and Kenoyer 1986: 66
Cord wrapping: strings and rope supports	Marshall 1931: 291; Casal 1964: Fig 71: 289; Dales and Kenoyer 1986: 67 Kenoyer 1994

Table H.3 Some of the most recurrent surface treatments found on Indus and Indus-like vessels during the Urban period.

	Type of Surface Treatment	References (e.g.)
Positive Treatments	Slip and Self-Slip	Dales and Kenoyer 1986: 43, 64; Mery 1994: 479; Dales and Kenoyer 1986: 43; Rice 1987: 149
	Wet Ware	Santoni 1989: fig 5
	Reserved Slip	Plenderlaith DATE; Dales and Kenoyer 1986: 44, fig. 7.3; Wright 1991: fig 6.4;
	Glazed Reserved Slip	Krishanan DATE Freestone DATE
	Applied Rustication	Rice 1987: 138
	Painting	Kenoyer 1998: 153; Rice 1987: 148
Negative Treatments	Smoothing, polishing and burnishing	Mackay 1938:212, 290; Rice 1987: 138
	Incisions, Combing and Striating	Dales and Kenoyer 1986:42-47; Santoni 1989: fig. 5; Dales and Kenoyer 1986: 423; Durrani 1981: 205; Rice 1987: 146, 139.
	Cutting and Perforating (see Cut Ware)	Dales and Kenoyer 1986: 423 ; Rice 1987: 147

Table H.4 Some firing structures and sites used as evidence for variability of pyrotechnologies during the Indus Urban period (after Miller 1997; 1999).

Type of Structures	Temperatures and Atmosphere	Sites (e.g.)	References
Bonfire	-	n/a	More data needed
"Open Air" Firing Structures	c. 750°C – 1000°C, oxidising	Mohenjo-Daro; Mehrgarh MR.C; Nausharo NS.K.	Jarrige et al 1995; Audouze and Jarrige 1979: 215; Mery 1994: 474, 479
Jar kiln and cylindrical firing structure	-	Harappa Mound E and F	Vats 1940: 470-472;
Oven	Oxidizing or reducing	Mehrgarh MR.F and K	Jarrige et al. 1995: 217, 427; Santoni 1989: 176
Pit Kiln	-	Harappa Mound E	Dales and Kenoyer 1991: 235, 1992
Sub-triangular structure with draft	-	Mohenjo-Daro DK-B,C	Pracchia et al. 1985; Pracchia 1987
Pear-shaped firing structures without pillars	-	Harappa Mound F Lothal Block E.	Vats 1940: 472-473;
Double-chamber updraft firing Structures (Kilns)	> 800°C, oxidising	Lal Shah, Mehrgarh Area 1; Mohenjo-Daro DK-G; Harappa Mound E; Balakot; Lothal Block E; Nausharo; Mohenjo-daro HR-B	Wright 1984; Pracchia 1985; Rao 1973, 1985; Dales 1974.
Double-chamber updraft kilns without pillars	> 800°C, oxidising	Balathal	V. N. Misra et al. 1997

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