Ceramics in Transition

Production and Exchange of Late Byzantine – Early Islamic Pottery in Southern Transjordan and the Negev

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Preface

This book is based on my PhD thesis entitled *Ceramics in Transition: A Comparative Analytical Study of Late Byzantine–Early Islamic Pottery in Southern Transjordan and the Negev*, completed in November 2010 at the Institute of Archaeology, University College London. Publishing this book was a lengthy process largely due to my post-doctoral research projects spiraling towards Scandinavian archaeology and my teaching commitments at the University of Helsinki. This book contains previously unpublished archaeological evidence and materials, especially ceramic data from the fascinating late Byzantine–early Islamic transitional period contexts in Jordan and Israel. Hence, it has been my desire for years to make this complete data set available for other researchers in the field, and I wish to thank David Davison at Archaeopress for his patience.

The regions of southern Jordan and Israel were closely culturally and politically connected in the Byzantine and Islamic times, however, it is not that often that archaeological assemblages from both sides of the modern political border are included in one research project. There are, of course, self-explanatory benefits for such research design. Furthermore, the application of archaeological science to ceramic studies in classical archaeology is still astonishingly rare. In my view, there is so much more in ceramics than chronological and stylistic attributes. The craft technologies, the choices made by the potters, the reasons behind those choices, the requests of their customers...there really is a plethora of evidence beyond the typo-chronological characteristics of pottery that we can try and reach via multi-disciplinary ceramic analysis. Even the most ordinary ceramics, cooking pots, plain domestic containers, can contribute to our knowledge of socio-economic structures and developments on communal and inter-communal levels, there is a chance that the pots were not 'just local production' without wider economic and cultural implications. Craft traditions can be surprisingly complex and multi-valued, and I hope this book can offer some insights to these topics.

I wish to express my sincerest gratitude to my PhD advisors Marcos Martinón-Torres, Thilo Rehren and Steven A. Rosen, who were always extremely supportive of me and my research. I also want to thank the examiners of my thesis, Alan Walmsley and Piotr Bienkowski for their criticism and advice, which greatly enhanced this work. Special thanks are due to Simon Groom, Kevin Reeves, Philip Connolly and Stuart Laidlaw on technical support in the IoA laboratory, and Margot Stout Whiting and Sarianna Silvonen for the English-editing. I also wish to acknowledge the archaeologists who permitted me to work on their excavation materials, Jaakko Frösén, Zbigniew Fiema, Mika Lavento, S. Thomas Parker, François Villeneuve, Zeidoun al-Muheisen, Steven A. Rosen, Isaac Gilead, Haim Goldfus and Peter Fabian. I wish to express warm thanks to the entire Finnish Jabal Harûn project team for their friendship. Thanks are due also to my research assistants Emmi Karvinen and Taika-Tuuli Kaivo.

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Chapter 1

Introduction

This book examines domestic and utilitarian coarse ware ceramic production and distribution patterns during the transitional, late Byzantine–early Islamic phase and the formative centuries of the Islamic culture, *c.* 6th–9th centuries CE in southern Transjordan and the Negev.[1] This book builds on ceramic data to examine the continuity, survival mechanisms, innovation and change in the southern economies and their ceramic craft traditions in particular during the transitional period. The geographical focus of this research covers the area of the Byzantine province of *Palaestina Tertia*, the southern areas of modern Israel and Jordan.[2] The areas were under the same administrative unit in the Byzantine period, but were separated in the early Islamic period administrative structure, the Negev being part of the provincial region of *jund Filastin* and southern Transjordan part of *jund Dimasq* (later *jund al-Sharah;* Aila possibly being part of *Misr*, the area of Egypt; see Haldon 1995: 389, 392, 407; Le Strange 1890: 25–36; Walmsley 2016; Walmsley 2008: 498–499; Walmsley 2007a: 75). Today, southern Transjordan and the Negev are divided by a modern political border, which has also largely segregated the archaeological research of the areas.

After the Muslim expansion into the regions in *c.* 630 CE, southern Transjordan and the Negev have very sparse references in the historical records (Avni 2014; King 1997: 271; King 1992; Schick 1998: 75; Schick 1994: 133–134; Walmsley 2007a). Recent historical and archaeological research, however, clearly demonstrates socio-cultural continuation and a peaceful transition under Islamic rule. Thus, the traditional view of dramatic decline and recession brought to the area by the Islamic invasion no longer holds (Avni 2014; Bessard 2018; Donner 2018; Donner 1981; Humphreys 2010; Kennedy 1999: 220; Kennet 2005; MacAdam 1994: 91; Magness 2010; Magness 2003; Petersen 2005b; Rosen 2000; Schick 1991; Taxel 2019; Walmsley 2016; Walmsley 2008: 495; Walmsley 2007a: 15–30; Whitcomb 2004; Whitcomb 2001b; among others; see Chapter 2 for historical background). It appears that the new ruling class of the Umayyad period was tolerant towards Christians and Jews living in its territories and the life of these communities continued uninterruptedly in the first centuries of Muslim rule. In general, the socio-political transformation was gradual, but multidimensional: a new ruling class, administration, official language and dominant religion were introduced, and the Muslim expansion also brought new people and customs into the area. It appears, however, that no immediate changes were introduced to the material culture traditions – at least not very radical ones – directly after the socio-political transition. This is particularly apparent in the case of the utilitarian and domestic pottery under scrutiny here. It has been suggested that innovations in the ceramic culture appear only a couple of centuries later, related to the established Islamic rule (Avni 2014; Gawlikowski 1986: 118; Kennedy 1999: 235; Walmsley 2008; Walmsley 1995b; Walmsley 1992b: 257; Watson 1992: 244).

Southern Transjordan and the Negev are located some distance from the new administrative centres of the Umayyad and ʻAbbasid period, situated in Damascus and Baghdad, respectively, which were the main sources of socio-cultural innovations in the Umayyad and ʻAbbasid periods (see Whitcomb 2001b: 505). In this sense, the economic role and importance of the southern areas, and particularly rural contexts, has sometimes been questioned (see, e.g., Avni 2014; Schick 1994, for discussion). The areas, located between Syria and Egypt, and serving as the initial bridgehead for the coming of Islam from the Arabian Peninsula, and the sites included in this project have, however, a strategically crucial position regarding the movement of people, goods and influences in the formative stages of Islamic culture.

This book focuses on ceramic artefacts from well-stratified Byzantine–Islamic deposits recovered at five archaeological sites and unique socio-economic contexts: the monastery and pilgrimage site of Jabal Harûn near Petra, the port of ʻAqaba/Aila on the Red Sea coast, the village of Khirbet edh-Dharih near the Dead Sea, the town and administrative centre of Elusa and the farmstead of Abu Matar in Beersheva (Figure 1.1; see Chapter 3 for more details; and Bertaud *et al.* 2015; Fiema *et al.* 2016; Fiema and Frösén 2008; Gilead *et al.* 1993; Goldfus and Fabian 2000; Lenoble *et al.* 2001; Parker and Smith 2016; Parker 2013; Villeneuve 2011; Villeneuve 1990 for excavation reports). Khirbet edh-Dharih, Jabal Harûn and ʻAqaba/Aila/Ayla are located on the Hajj, pilgrimage, route and the main north–south road of southern Transjordan, connecting them, for instance, with Amman, Jerash, Pella and Damascus, and the Red Sea, Fustat, al-Hijaz, the Arabian Peninsula and beyond.

[1] The term ʻlate Byzantine' is used in this book to refer to the pre-Islamic, 6th–7th centuries. Alternative concepts, such as ʻByzantine' or ʻlate Antiquity' can be seen as equally ambiguous in terms of chronology. All dates CE unless otherwise noted.

[2] Henceforth, ʻsouthern areas' refers to this geographical region.

The Negev sites, Elusa and Abu Matar in Beersheva, are connected by various routes continuing to Syria, Sinai, Egypt, Jerusalem, Gaza and the Mediterranean coast, the Dead Sea region, and across the Wadi ‘Arabah to southern Transjordan, al-Hijaz, and further (Al-Shorman *et al.* 2017; Avni 2014; Avner and Magness 1998: 39, 50; Frenkel 1996: 185–187; Taxel 2019; Walmsley 2009; Walmsley 2000: 300–305; Walmsley 1992a; Whitcomb *et al.* 2016; Whitcomb 1995; Whitcomb 1994). Jabal Harûn and Khirbet edh-Dharih are both associated with ancient holy sites, Jabal Harûn near Petra being one of the main holy sites in the region in the Islamic period. Khirbet edh-Dharih is also located in the vicinity of the macroeconomies of the Dead Sea and Karak areas (see Chapter 3 and e.g., Johns 1994; Tomber 2004; Walmsley 2016; Walmsley 2009; Walmsley 2008; Whitcomb 1989a; Zarins 1989).

This book aims to demonstrate that the ceramic traditions of the southern areas were not marginalised or regional by character (naturally, regional ‘micro-traditions’ also existed, see Sodini and Villeneuve 1992; Walmsley 2007a: 59; Walmsley and Grey 2001; Watson 1992: 246; for discussion), but instead form an analogy with the ceramic cultures in the regions of northern Jordan and Israel in the early Islamic period. The caravans and the Hajj pilgrims contributed to the movement of people and goods across the regions, provided direct flow of influence from the newly established Islamic centres to the southern regions, and benefitted local market systems and economies in the southern regions.

In the analytical section of this book (Chapter 6), selected ceramic artefacts from the five sites are subjected to geochemical, micro-structural and technological characterisation by energy dispersive X-ray fluorescence spectrometry with energy dispersive spectrometry (ED-XRF) and scanning electron microscopy with energy-dispersive spectrometry (SEM-EDS) (for recent applications of these methods in archeological ceramic studies, see Angeli *et al.* 2019; Bland *et al*. 2017; Beltrame *et al.* 2019; Holmqvist *et al.* 2018; Holmqvist 2017; Santacreu and Cau Ontiveros 2017; VanValkenburgh *et al.* 2017, among others). The aim of the ceramic analyses was to identify geochemical groups indicative of production clusters among the sampled assemblages, and to investigate inter-site and inter-regional patterns of ceramic transport, organisation of production, and adaptation of ceramic traditions according to the new Islamic influences.

In the sampling process, altogether 141 ceramic finds were selected from the five archaeological sites. An attempt was made to include ceramic artefacts representing typical ceramic forms and types in the assemblages (Bishop *et al.* 1982: 278–279; Rands and Bargielski-Weimer 1992: 34; Tite 1999: 197; see Chapter 6 for the sampling strategy). The sampled ceramics represent coarse wares of domestic and utilitarian nature, kitchen utensils and food and liquid containers. Different container forms, jars and amphorae, were sampled to examine their possible transportation and distribution networks. Additionally, examples of more exotic ceramic artefacts, macroscopically identified as possible imports, were sampled from each site. These examples included atypical container finds in the assemblages and glazed vessels. In addition, some architectural ceramics, and ceramic wasters from the Elusa workshop were sampled. The sampling was focused on loci associated with the 6th–9th centuries, the majority of the samples dating to the 8th–9th centuries.

There are no known ceramic production centres in southern Transjordan and the Negev that operated in the post-Byzantine period (excluding the ‘Aqaba kilns, see Melkawi *et al.* 1994; Whitcomb 2001a). The currently known ceramic workshops in the Byzantine period are also rare in the southern areas, and the identified workshops seem not to have been operating after the 6th century (see, for example, ‘Amr and al-Momani 1999). Further north, in Bet Shean and Jerash, ceramic workshops were established in the city centres in the early Islamic period, marking new industrial development and capital investments in the former Byzantine centres (Bar-Nathan and Atrash 2011; Bar-Nathan and Mazor 1993; Duerden and Watson 1988; Foote 2000: 33–34; Schaefer 1986; Walmsley 1992b: 256; Watson 1989). Similar evidence, however, is currently lacking from the south, and it is to this picture that this book aims to contribute.

The ceramic data presented in this book demonstrate that the communities mainly utilised local ceramic supplies. There were also regional and inter-regional exchange networks of ceramic products. The results show that mundane cooking and utilitarian pottery can offer valuable economic evidence of past societies. The cooking pots were not ‘just local products’, but also inter-regionally exchanged objects. Pots probably served as containers for other products or personal utensils of travelers, however, it appears that good-quality cooking pots were also exchanged as primary products. Economic activities of the communities and the characteristics of the locally available clay resources also affected the production profile and created specialised manufacture. Calcareous clays were used to make durable amphorae, whereas cooking pots were acquired from regions where non-calcareous clays were available. Aqaba-amphorae were transported to Jabal Harûn near Petra, Elusa in the Negev, and Khirbet edh-Dharih by the Dead Sea, thus for nearly 200 kilometers along the caravan routes. In turn, Petra cooking pots were transported in vast quantities to Aqaba. Amphorae-borne products were also carried between the Negev and southern Transjordan sites. The Negev sites Elusa and Abu Matar acquired cooking pots from the same regional supplier, unrelated to Elusa's industrial amphora production.

The ceramic data speak for wealthy rural economies in the southern regions during the transitional and early Islamic periods. The local ceramic traditions demonstrate a high-level of cross-regional assimilation and interaction, which underlines the importance of archaeological data and material comparison across the modern political border dividing these regions today. The potters adapted their practices and added new stylistic characteristics and vessel forms, possibly relating to changed dietary customs, to the local ceramic repertoires. For instance, paint-decorated, later 8th–9th century ceramics arrived to the southern regions as northern imports (e.g. from Jerash), but were also found in the 'local' Khirbet edh-Dharih and Jabal Harûn geochemical groups, providing evidence that this Islamic ceramic tradition was imitated by the southern potters. Imported Islamic cream wares and glazed wares, possibly of Baghdad origin, are also present in the assemblages.

Apart from the new forms and decorative patterns, only minimal changes took place in the operational chains of the potters and the ceramic recipes over these centuries and political alterations. The strong pattern of continuity of the material culture traditions into the early Islamic period has led to one of the key problems of current research: early Islamic material remains have been misinterpreted as Byzantine, or 'Abbasid period evidence as Umayyad, resulting in 'false gaps' in the settlement history of the regions, particularly in the southern areas. Misdated ceramic evidence has led to problematic interpretations of archaeological contexts and entire sites, ultimately affecting the picture of the settlement patterns of wider regions (Avni 2014; Avner and Magness 1998: 39; Falkner 1993–94; Haiman 1995a: 39–41, 45; Johns 1994: 8–9; Magness 2003: 1–2; Magness 1997: 485; Walmsley 2016; Walmsley 2008; Walmsley 2007a: 55).

The historical background, focusing on aspects affecting local industries and exchange networks, is discussed in Chapter 2. The archaeological sites are presented in further detail in Chapter 3. In Chapter 4, the key concepts of this book, ceramic traditions, technologies, style, provenance and exchange, and aspects such as technological variation, change and operational chains of the potters are reviewed. Chapter 5 presents the ceramic catalogue, typo-chronological categorisation of the ceramic samples, given with a comparative typological discussion including published ceramics from other relevant sites. The calougue aims to view shared stylistic traits between the ceramics from the sampled sites and those from a broader regional context, and, where possible, suggest refined chronologies. The reader should follow the catalogue using the illustrations of Appendix I, which includes drawings and photographs of each ceramic find sampled for analysis.

Chapter 6 presents the compositional and technological ceramic data obtained from the ED-XRF and SEM-EDS analysis, with the aim to geochemically and mineralogically 'fingerprint' the sampled pottery, and to distinguish compositional patterns and groups in the sampled assemblages from each site. An 'integrated' analytical approach will be employed: bulk chemical compositional categorisation of the ceramics based on their major, minor and trace elemental patterns by ED-XRF analysis will be supplemented by microstructural and mineralogical examination by scanning electron microscopy (SEM-EDS) (for integrated approach, see Arnold 1981: 33–34; Beltrame *et al.* 2019; Blackman 1992: 113; Buxeda i Garrigós *et al.* 2003: 14–15; Carvajal López *et al.* 2018; Day *et al.* 1999; Holmqvist *et al*. 2018; Montana 2017: 89–90; Tite *et al.* 2018; Tite 1999: 201; Stoltman *et al.* 1992; Tschegg *et al.* 2009).

In the ceramic analysis, ceramic provenance and local ceramic production at the environs of each site will be investigated by the so-called 'reference group' strategy, in which the largest compositional group in each assemblage can be considered local to the site in question (for reference group strategy, see, e.g., Baklouti *et al.* 2014; Bishop *et al.* 1982: 301; Montana *et al.*, 2018). The assignments of the samples to compositional groupings are based on statistical processing, cluster and principal component analysis of the bulk chemical ED-XRF results, supplemented by microstructural analytical results from the SEM analysis.

Furthermore, patterns of material exchange, e.g., shared ceramic production or ceramic trade between the sites, and distribution of ceramic products associated with a particular workshop will be examined by comparative data analysis. SEM-EDS was also used to examine the ceramic manufacturing techniques, surface treatments and other technological factors such as firing temperature (see, e.g., Beltrame *et al.* 2019; Bland *et al.* 2017, for similar approach). These analytical data were then investigated in comparison with the macroscopic examination of the ceramics and in light of the typo-chronological information available. In Chapter 7, the compositional groups and technological ceramic data are discussed particularly in correlation with the archaeological, typo-chronological evidence. Finally, Chapter 8 presents the conclusions of this research project and discusses the results in wider socio-economic and historical contexts.

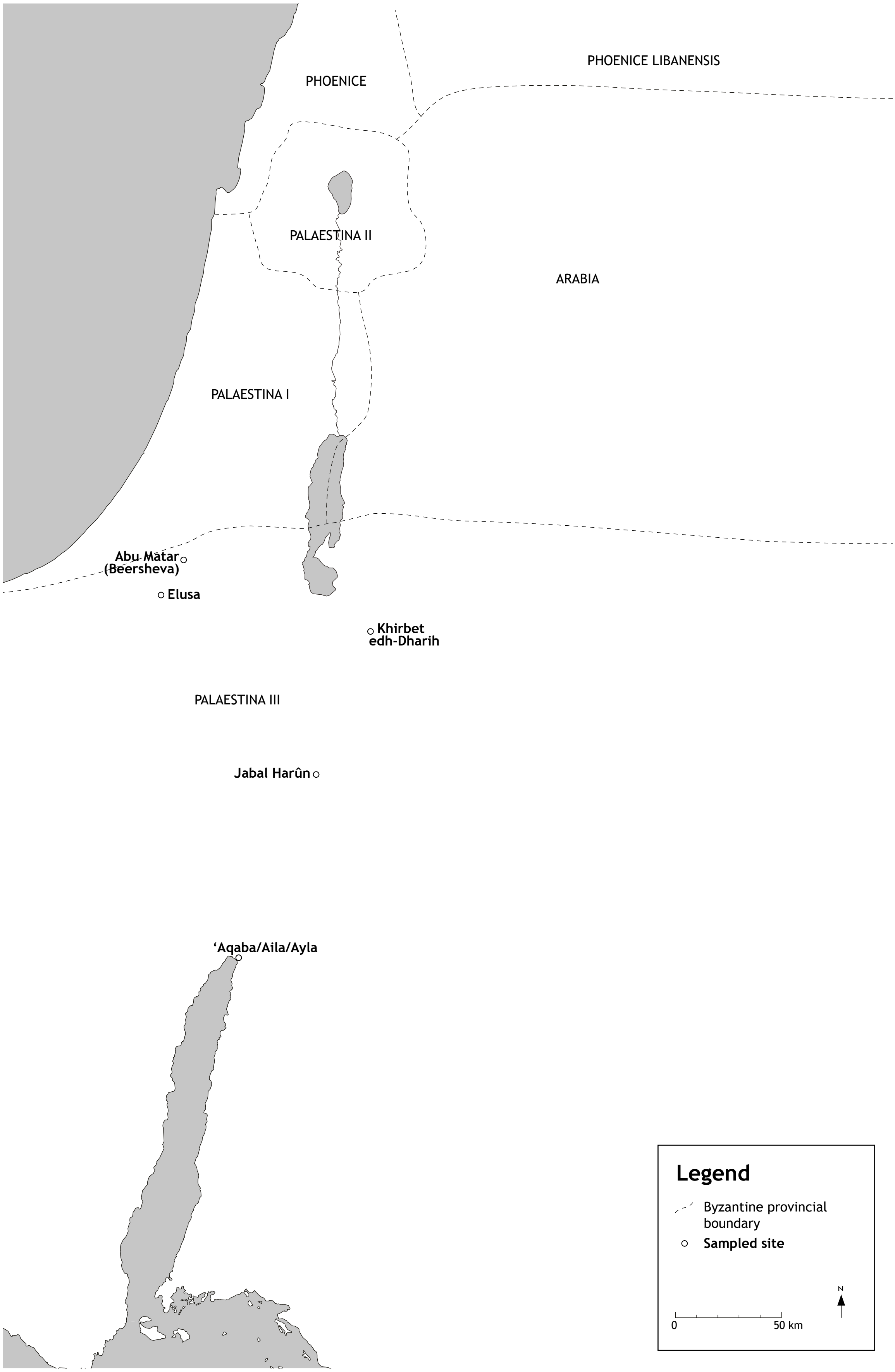

Figure 1.1: Locations of the archaeological sites included in this study. The Byzantine borders are approximate. For an illustration of the Islamic provincial divisions, see, e.g., Walmsley 2007a: 75, Fig. 7.

Ceramic analysis can serve as a starting point for further discussion on economic systems and relations. Evidence of ceramic exchange on local, regional or inter-regional levels can attest to shared economic structures, trade, transport and communication between different communities and locations. Domestic pottery in particular is often considered of limited economic value, although there is evidence of regional and inter-regional exchange systems of cooking vessels (see Adan-Bayewitz *et al.* 2009; Adan-Bayewitz 1993 for evidence from Roman Galilee), and cooking pot manufacture frequently required adaptations to specific demands, such as thermal shock resistance and cooking habits (see, *i.a.*, Sillar 2000; Sillar and Tite 2000; Tite and Kilikoglou 2002). In particular, ceramic exchange can link to the existence of rural markets, places where farmers, pastoralists and craftsmen exchanged their products, such as pottery, metal and other common goods, although it is difficult to find evidence for open-air markets by means of archaeology (Graf 2001: 230–232; Laiou and Morrison 2007: 37, 40, 81–82; see, e.g., Binggeli 2006–7; al-Muqaddasi 1994; Ibn Battuta 1956; for historical evidence). Comparative analytical ceramic studies can aid the study of these matters by offering material evidence of links and contacts between communities.

Chapter 2

Southern Transjordan and the Negev in the late Byzantine and early Islamic periods

This book deals with the period of cultural transformation following the Muslim expansion into the former Byzantine territory in the 630s, a period which has gained much scholarly interest. Today, the socio-political Byzantine–Islamic change can no longer be associated with decline and disruption but is rather identified as a political and cultural transition, characterised by a strong economic continuation into the early and middle Islamic periods (see Avner and Magness 1998; Avni 2014; Bessard 2018; Donner 2018; Donner 1981; Humphreys 2010; Insoll 2005; Kennet 2005; Lindstedt 2018; MacAdam 1994: 91; Magness 2010; Magness 2003: 215; Petersen 2005a; Petersen 2005c; Shahîd 2002; Shahîd 1995a; Shahîd 1995b; Shboul 1996; Silberman 2001; Taxel 2019; Vernoit 1997; Walmsley 2016; Walmsley 2008; Walmsley 2007a: 15–30; Walmsley 2001a; Walmsley 1992a; Whitcomb 2004; Whitcomb 2001b: 503, 505; among others).

The transition of the political power had, nevertheless, immense cultural significance and gradually influenced 'all aspects of society' such as the demography, politics, administration, religion and linguistics of the area (Kennedy 1999: 220). The archaeological sites where ceramic samples were included in this work, the monastery of Jabal Harûn, the village of Khirbet edh-Dharih, the port of 'Aqaba/Aila, the farmhouse of Abu Matar in Beersheva, and the town of Elusa, represent different socio-economic contexts, but in the same economic system. Successful economies require complex socio-economic contact networks, and particularly interaction between urban and rural contexts, agricultural and pastoral communities, and contacts with merchants, markets, and communities engaged in various activities in the society (see Johns 1994: 2–3).

It has become increasingly clear that the southern areas had 'an intimate relationship with broader cultural changes' taking place in the Islamic centres, such as Damascus and Baghdad (Whitcomb 2001b: 503–504; see also Walmsley 2009), and had a great importance for the early Islamic establishment, not least because of the control of the Hajj, the annual pilgrimage route to Mecca (see Figures 2.1 and 2.2). Recent archaeological research has also increasingly focused on non-urban areas, perhaps leading to a more balanced picture of the society in which the vast majority of the population lived in rural areas (see Broshi 1979: 5; Graf 2001: 219–223, 231; for discussion). Rather than being indicative of the demographic or economic situation of the southern areas, the paucity of Umayyad and 'Abbasid period written sources referring to southern Transjordan and the Negev may be explained by other factors, for instance, early Islamic historians concentrating on events taking place in the administrative centres (King 1997: 271; Schick 1998: 75).

The complexity of the ceramic finds from these periods, with Byzantine, Umayyad and 'Abbasid ceramics showing only gradual development of forms, has also contributed to the problems of archaeological research. As Johns writes, 'it is not that the pottery of these centuries is absent from sites in southern Transjordan, but rather that archaeologists have been – and still are – unable to recognize it for what it is' (Johns 1994: 8–9; for the Negev see, e.g., Avni 2014; Haiman 1995a: 39–41, 45; Magness 2003). Ceramic traditions will be discussed in further detail in Chapter 5, but it is essential to note here that craft traditions, such as ceramic and glass industries, appear largely unchanged until the 9th century, thus showing no immediate changes following the political transition (Brems *et al.* 2018; Freestone *et al.* 2015; Hoffmann Bartod *et al.* 2018; O'Hea 2001: 136; Phelps *et al.* 2016; Walmsley 2001b: 310; Walmsley 1995b: 660; Walmsley 1982; see also Gorin-Rosen 2000; Freestone *et al.* 2000; Henderson 1999: 238; Simpson 1997; and Chapter 5 for ceramic typo-chronologies).

Another aspect that may have had a negative impact on outcome of the archaeological research has been the practice of building demographic models on the basis of survey data (for this practice, see Frankel *et al.* 2001: 116–117; Geraty and LaBianca 1985; Miller 1991), although surface finds alone should not be seen as 'reliable indicators of rural demography and settlement density' (Johns 1994: 4; see also Walmsley 2005: 515). Relying on survey data and misinterpreted ceramic evidence has had a serious impact on the study of demographic and cultural development in the early Islamic periods, creating a 'false dark-age' in the 'Abbasid and Fatimid periods (Walmsley 2007a: 55, 90–110; see also Avni 2014: 31; Bienkowski and Adams 1999: 170–171; Johns 1994: 3–4; McQuitty 2005: 328; Walmsley 2016; Walmsley 2005: 513–515). These issues notwithstanding, survey can provide valuable archaeological evidence when caution is taken on the interpretive models based on surface data alone.

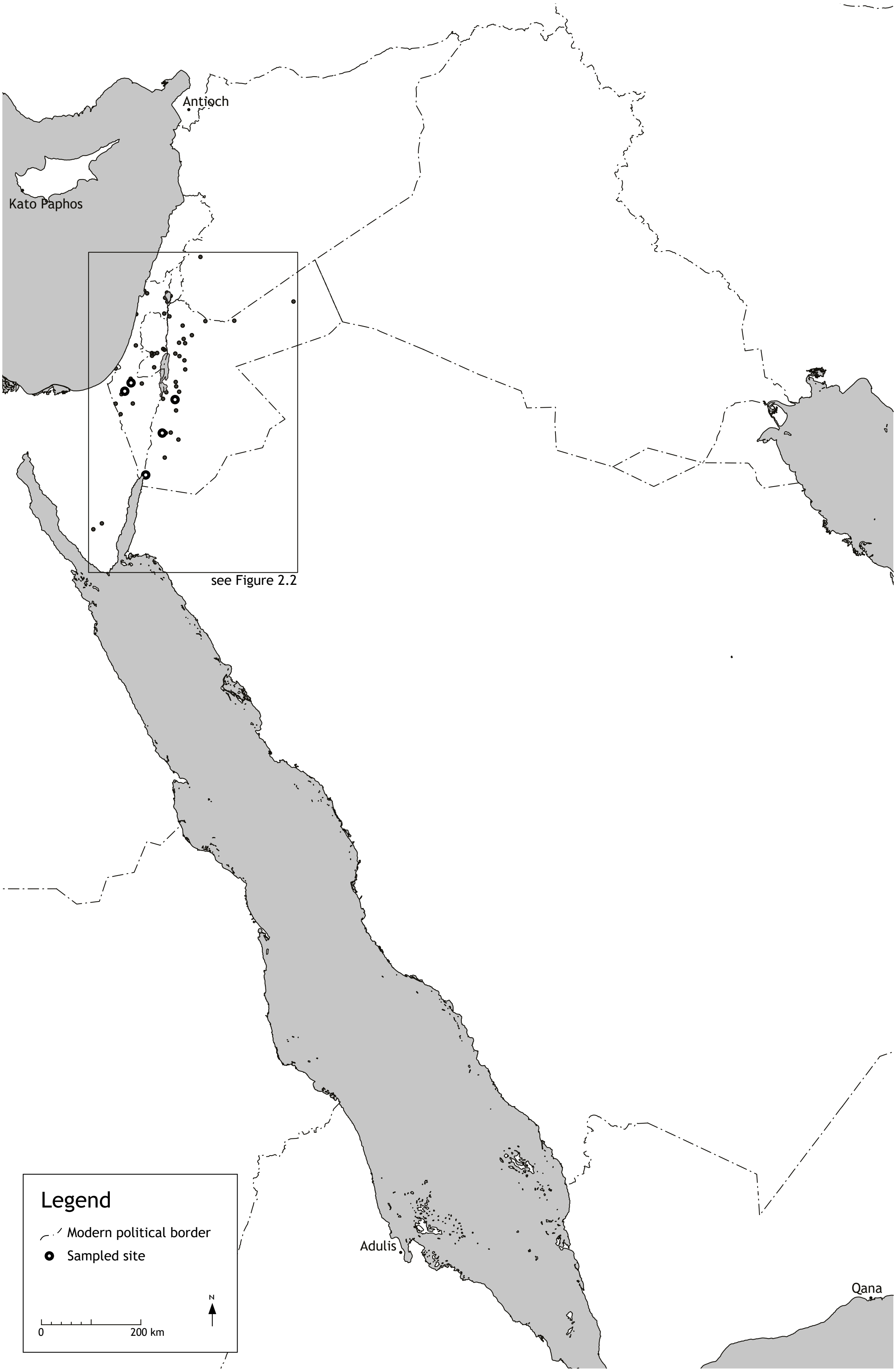

Figure 2.1: Map of sites discussed in the text.

Figure 2.2: Detail of Figure 2.1. Archaeological sites included in this study (Khirbet edh-Dharih, Jabal Harûn, ʻAqaba/Aila, Elusa and Abu Matar in Beersheva), and Byzantine and Islamic sites cited in the text.

Rural and urban contexts in Byzantine Palaestina Tertia

Prior to the Islamic expansion in the 630s, southern Transjordan and the Negev belonged to the same administrative unit, the Byzantine province of *Palestina Tertia* (see Figure 1.1 in Chapter 1). Thus, it is important to study these areas as 'a single unit, as part of the same socio-economic system' (Bienkowski and Galor 2006: 1; Bienkowski 2006: 20–22; Rosen 2017: 19), although the modern political border has also largely divided archaeological research. The Byzantine provincial borders were a reminiscence of a development from the 2nd century, when southern Transjordan and the Negev became a part of the Roman province of *Arabia,* which also included the southern parts of modern Syria, Jordan, Sinai and northwest Saudi Arabia. The northern part of the Negev belonged to the province of *Palaestina* according to Ptolemy (see, e.g., Bowersock 1983: 1–2; Sipilä 2009: 133–136; and Tsafrir 1986: 78 for further references). The province had a huge strategic importance for the Romans for control over the ports of Gaza and 'Aqaba/Aila, and routes connecting the Negev and southern Transjordan, with Sinai, Egypt, Judaea, Syria and the trade of Arabian Peninsula (see Adams 2007: 33–42, 205–234; Bowersock 1983: 2; Graf 1992: 256; Parker 2013; Parker 2003).

At this time, the most important road was the *Via Nova Traiana*, running through the province of Arabia, the city of Petra being a central point on the route from 'Aqaba/Aila to Amman (Roman Philadelphia) and Bostra in modern southern Syria (see, e.g., Avi-Yonah 1966: 183; Graf 1995: 264–265; Graf 1992: 254–256; Kennedy 1997: 71; Zayadine 1985; see also Crone 1987: 50; Erickson-Gini 2006; Graf 1978). The city of Petra had gained the status of a 'metropolis of Arabia' in 114 CE, and finally became a Roman *colonia* in the early 3rd century (Fiema 2002a: 60–62). It is likely that there were several east-west routes linking the Negev and southern Transjordan leading to Jerusalem, the Dead Sea, and further north and east, and to Sinai, Egypt, the Red Sea region, the Arabian Peninsula and beyond, although not much direct evidence exists for the road network. Ancient roads, often unpaved, are difficult to locate by archaeological means (Bienkowski 2003: 100; MacDonald 2013; MacDonald 2006: 85–87; see also Graf 1992: 259; Har-El 1981).

One of the identified east-west roads, however, is the old Petra–Gaza route leading from Petra through Wadi 'Arabah and the Negev, probably passing through Elusa and other locations in the Negev (Meshel and Tsafrir 1974–5: 104–105, Fig. 1; Graf 1992: 259). It has also been suggested that among the routes in the Negev road system, there was a route leading from the Wadi 'Arabah to Beersheva (Shereshevski 1991: 4).

At the end of the 3rd century, the provincial borders changed following Diocletian's reforms and the Negev, southern Transjordan and a part of Sinai were transferred from the province of Arabia to become part of *Palaestina* (Sipilä 2009: 149–152). Reorganisations continued and by the end of fourth century there were three Byzantine provinces of Palestine, *Palaestina Prima, Secunda* and *Tertia* (with Caesarea, Bet Shean and Petra as their respective capitals). The reorganisation described in the *Codex Theodosianus* in 409 CE confirms that the southern areas form *Palaestina Tertia* (Patrich 1995: 470; Sipilä 2009: 163–177; Tsafrir 1986: 79).

Although historical evidence on the actual borders of the new provinces is not very detailed, the northern border of *Palaestina Tertia* ran approximately through the middle of the Dead Sea, and the sites examined in this work belonged to this province (e.g., Tsafrir 1986: 79). Following the administrative reorganisation, a network of fortifications, *Limes Arabicus* (also known as *Limes Palaestinae*) was also built (Parker 2006c; Parker 2000a; Parker 1986; Sipilä 2009: 153–156; Tsafrir 1986: 77–84; see also Haldon 1990: 98–99; and Lenzen 1997: 238).

In Petra, the capital of *Palaestina Tertia*, churches had already been built in the 4th century, although the use of pagan temples also continued (Fiema 2002a: 60–65). At this time, there was already a substantial system of Christian pilgrimage routes with staging posts and hostels (Hunt 1982: 57), although historical records of pilgrims and other travellers through southern Transjordan and the Negev are scarce. The sparse contemporary documentation on the use of routes at this time may be due to most travellers being traders, as it appears that relatively few Christian pilgrims visited biblical sites in the Negev, such as Beersheva, preferring Jerusalem, Hebron and Mount Sinai (Mayerson 1963: 160). There were also numerous synagogues at least in Galilee, which seem to have been used throughout the Byzantine period, from the 3rd to the 7th century (Foerster 1992), if not later.

In terms of rural and urban economies in the Byzantine period preceding the Muslim expansion, between the 5th and early 7th century, urban communities flourished, and the rural countryside also experienced an 'explosive growth' of population in southern Transjordan and the Negev due to successful agricultural exploitation (Walmsley 1996: 150; see also Banning 1986; Johns 1994: 4–5; Kennedy 1991; Parker 1987a; Rosen 2000; Rosen and Avni 1993: 198). There were agriculture-based Byzantine towns in the Negev, such as Elusa, Beersheva and Nessana, and numerous farmhouses, hamlets and villages that continued to be inhabited at least into the 8th century (see Avni 2014: 259; Hirschfeld 2005: 523–531; Magness 2003: 177–194, 214–216; and Rosen 2000: 48).

In general, much of the wealth of the state was based on agricultural production and related taxes. The taxation system may have had a positive effect on the economic systems of the rural areas, agricultural products being transported in a large market and distribution network, while urban areas were also involved in production and trade (Greene 1986: 67; Kingsley 2001: 59; see also Adams 2007: 161–195). The Nessana papyri record cultivation of various crops in the area, such as wheat, barley, grapes, olives, figs and dates, wheat being the most significant crop (Mayerson 1962: 227, 231). Results of archaeological surveys and excavations have also demonstrated that although pastoralists are not described in the papyri, there was an extensive network of camp sites of pastoral nomads keeping sheep, goat, and possibly also camels and donkeys in the Negev during the Byzantine and early Islamic periods (Horwitz 1998; Rosen 2000; Rosen and Avni 1993: 192, 198; Rosen 1987a: 39; see also Adams 2007: 56–58; Banning 1986; Kennedy 1991; and Parker 1987a). The ceramic evidence from the camp sites illustrates contacts and trade between the camps and urban settlements (Avni 1996; Rosen and Avni 1997: 62–80; Rosen 1987a: 41).

In the Roman and Byzantine periods, the port of Gaza played a very significant role in the commerce within the Negev area. Literary and archaeological evidence imply that the Negev was the main producer for export from Gaza, wine being one of the primary products. Large wine presses have been identified at many Negev sites, including Elusa, and the production of the so-called Gaza jars is probably linked to this wine production (Mayerson 1992; Mayerson 1985: 76–78; and Chapter 5). Industrial agricultural structures at Shivta, including three wine-presses and an oil-press, indicate that its inhabitants were involved in commercial agricultural production, probably for markets in Gaza or in Elusa (Hirschfeld 2003: 408). Similar evidence is present at numerous other sites in the Negev, and the agricultural industries probably also supported other aspects of the local economic infrastructures, such as the road network, necessary for farmers and merchants travelling between fields and markets (Kingsley 2001: 58).

The trade of agricultural products was most likely a defining factor in the success of the rural economies (see Kingsley 2001: 57). In addition to the commerce in grapes, olives, wheat and ceramic containers as their possible byproducts, there are also other aspects of agricultural trade, such as the export of basalt millstones (Kingsley 2001: 44–45). Many studies have approached the question of whether the agricultural growth was made possible by extraordinary climatic conditions or increased rainfall in the Byzantine period Negev (see Hirschfeld 2004; Rubin 1989: 73–76; see also Kennedy and Liebeschuetz 1988: 71; Lucke *et al.* 2005; Walmsley 2007a: 132–136). It appears that instead of the overall rainfall amounts, the stability of the rainfall fluctuation has a more crucial effect on desert agriculture, and the rainfall fluctuation was possibly relatively stable in the Roman and Byzantine periods (Miller Rosen 2007: 168).

Changing socio-political reality of the 7th century

According to archaeological evidence, and documentary and literary sources, the Byzantine military presence was weakened from the mid-5th century the latest, although this impression may partly derive from changed garrisoning strategies and increased reliance on *foederati* (Parker 2016a: 17; Parker 2000a; Sipilä 2009: 200–205). Many of the forts were abandoned, including those of the *Limes Arabicus* positioned east and southeast of the Dead Sea, and there is no evidence of occupation during the 6th and 7th centuries in the watchtowers on the frontier. It is notable, however, that some of the military sites, such as Umm el-Jimal and Khirbet es-Samra, were turned into civilian sites and monasteries (Al-Shorman *et al.* 2017; Parker 2006c; Parker 2000a). Hence, the fortification system, initially designed by Diocletian, was largely neglected by the early 7th century, and barely used at the time of the subsequent Muslim expansion (Parker 2000a: 383–384).

The possible impacts of the Sasanian military activities in 614–628 CE on the southern areas are uncertain, but in general, the Negev and southern Transjordan were not involved in the main military operations (Haldon 1995: 406; Schick 1995: 20–48; Walmsley 2007a: 45–47). However, the Sasanian occupation did break the tradition of Byzantine political control and loyalties, making the region more susceptible to subsequent Muslim takeover. There is no evidence that the conquest affected Christian communities in the area, and although pilgrimage probably decreased during the time of the conquest, there are historical records that mention pilgrims visiting Jerusalem, Mount Sinai and the Jordan River during those years (Schick 1995: 18, 46–66; see also Walmsley 2016; Walmsley 2007a: 45). In the Negev, there is no archaeological evidence of destruction in any of the cities associated with the Muslim expansion in the 630s (Avni 2014; Rosen 2000: 52). Similar evidence of continuation is available for southern Transjordan: there are sources mentioning the peaceful capitulation of ‘Aqaba/Aila and Udhruh, and the peaceful transition to Umayyad rule is supported by archaeological data (Fiema 2001b: 431; Schick 1998: 76). It seems that the transition of political rule generally happened relatively ‘peacefully’, besieged towns surrendered and were promised safety and freedom of religion in return (Shboul 1996: 84–85).

Apparently, the socio-political transition had little effect on the lives of most of the communities, such as ‘Aqaba/

Aila, showing continuation and inter-regional trade into the late ‘Abbasid and Fatimid periods (Whitcomb 2001b: 510; see also Northedge 1991; Walmsley 2016; Walmsley 2008; Walmsley 1992a; Walmsley 1991). In the Negev, the economic activities of Nessana, Shivta and Beersheva seem to have continued at least into the 8th century (Avni 2014; Avi-Yonah 1958; Rosen 2000: 52–53). The archaeological evidence from numerous excavated sites in Beersheva, including Abu Matar, show continuity into the Umayyad and ‘Abbasid periods (Petersen 2005b: 46, 54, 115–116, Table 1). At the moment, evidence from Elusa dating to the early Islamic period is sparse. It may have had an administrative role in the early Islamic period, and early Islamic finds are recorded from the site, and thus its chronology appears to extend at least into the Umayyad period (Avni 2014: 259; Petersen 2005b: 58).

In the following administrative reorganisation, the areas of southern Transjordan and the Negev were segregated into different administrative and military units in the system of *ajnad*, the Negev belonging to the *jund Filastin* and southern Transjordan to the *jund Dimasq* (later *jund al-Sharah*), whereas Aila was probably part of *Misr*, the area of Egypt, although this is not entirely clear from the historical sources (see Haldon 1995: 389, 392, 407; Le Strange 1890: 25–36; Walmsley 2008: 498–499; Walmsley 2007a: 75). It has been suggested that some of the Byzantine administrative systems were retained by the Umayyad rulers, and Greek was the administrative language in the 7th century (Kennedy 1999: 221–222). There are, however, very few written sources discussing the very early stages of the Islamic state (see Hoyland 2006; Johns 2003; Walmsley 2007a: 72–76; for the taxation system, see Kennedy 1995).

Rural and urban economies in the early Islamic period

Following the turn of the socio-political era, changes were gradually introduced to the society, such as mosques replacing churches as religious centres, and also serving as places for public and political meetings and courts (Kennedy 1999: 231–232, Kennedy 1985: 4–5, 15–16; see also Magness 2004: 21; Walmsley 2007a: 34–39; and Whitcomb 2001b: 507–509). Mosques were built in Jerusalem and Damascus, but also in many former Byzantine centres, such as in Jerash, Amman and in ‘Aqaba/Ayla and at settlements founded by the Umayyads, such as Ramla and ‘Anjar in Lebanon (see Barnes *et al.* 2006; Guidetti 2013; Hillenbrand 1999; Northedge 1989; Walmsley *et al.* 2008; Walmsley and Damgaard 2005; for further references). Several mosques were also built in the Negev (see Avni 1994; and Rosen 2000: 54).

During the Umayyad period, the caliph’s residence was situated in Damascus, but there were also large caliph-sponsored building projects elsewhere, such as the Dome of the Rock and al-Aqsa mosque built in the late 7th–early 8th centuries in Jerusalem (Schick 1998: 76; see also King 1992, and Raby and Johns 1992). The importance of Muslim pilgrimage to holy places also increased in the 9th–10th centuries (Walmsley 2001a: 529, 533–538; see also Taxel 2019). The ‘Abbasid dynasty moved the capital to Baghdad in 762, but Damascus also continued as an important centre (King 1997: 271; Walmsley 1992a; Whitcomb 2000: 513). Muslim sources also record the foundation of Ramla in the early 8th century. The town became the capital of *jund Filastin* and an industrial and commercial centre, its activities including pottery production, and being a way-station on the route from Damascus to Fustat, and also well connected with Jerusalem (Luz 1997: 33–45). Other new towns were founded in North Africa and Iraq (Petersen 2005b: 29).

As under the Byzantine administration, urban trade and pilgrimage continued to play an important role in the local economies in many areas under Muslim rule (Kennedy 1985: 25). The major alteration of the urban structures at Pella seems to have taken place in between the mid-7th and mid-8th centuries, relating to the reformation of the commercial areas, such as combining central markets and *caravanserai*. New and extended market areas were established in former Byzantine centres in the north, particularly in the 8th century, indicating strong economic activities and the importance of markets in small towns in the early Islamic period (Walmsley 2016; Walmsley 2007b: 270; Walmsley 2000: 274–283).

According to Magness, the archaeological and historical evidence indicates notable growth and economic welfare from the mid-6th–mid-7th to the 8th–9th centuries, particularly in the coastal cities but also in some parts of the Negev, where there was a thriving economic system of agricultural villages in the Umayyad and ‘Abbasid periods, involved in metallurgy, mining, trade and pilgrimage, the port town of ‘Ayla being its commercial centre (Magness 2003: 215; see also Avner and Magness 1998: 39, 52; Whitcomb 1995; Whitcomb 1994). This conclusion is parallel to the evidence from the northern areas, where local economies show strong continuity at least into the ‘Abbasid period (see, for example, Northedge 1991; Walmsley 1992a; Walmsley 1991).

A scarcity of evidence affects the study of Islamic roads, and particularly those of the Umayyad period. Nevertheless, a network system for transportation, commerce and military functions must have been of great importance for the early Islamic administration (Walmsley 2009; Walmsley 2000: 299–300). Available archaeological and historical evidence clearly demonstrate that there was an ‘infrastructure conducive to trade' with a vibrant economic system of numerous, well-organised towns connected by communications networks from the late 7th and into the 8th century (Walmsley 2000: 304). There were probably several important routes, leading from Damascus to the provincial centres and the capitals of *al-Urdunn* and *Filastin*, Tabariyah and Ramla, and beyond to the Mediterranean coast, Fustat and to the al-Hijaz; in the 'Abbasid period, the routes also connected to the new capital in Baghdad and al-Raqqah and Fustat. There were also regional roads that connected 'Aqaba/ Ayla, Jerusalem, Jericho, Zughar, Udhruh (Walmsley 2001a: 518; Walmsley 2000: 300–305).

One of the most important routes was probably the Hajj, running from Damascus via Amman to 'Aqaba/ Ayla towards al-Hijaz and Mecca, and control of it was of great strategic and religious importance to both the Umayyad and 'Abbasid dynasties. The route, connected to various roads, ran through numerous locations, market places, and attractions. The caravans of pilgrims and merchants taking the route were major catalysts in inter-regional contacts, although contemporary sources on markets in the southern areas are sparse (Binggeli 2006–7; Walmsley 2009: 459–462; Walmsley 2001a; and references; see also, e.g., al-Muqaddasi 1994; Ibn Battuta 1956; Ibn Hawqal 1964; Ibn Jubayr 1952; Lopez and Raymond 1990).

Apparently, there were only minor changes in the road network in the southern areas between the 5th and 8th centuries, and the main north-south road was likely to follow the course of the *Via Nova Traiana*. There was also continuing traffic from 'Aqaba/Aila/Ayla to Gaza via Nessana and Elusa, and from Ayla to Sinai, and thus, the town continued to function as a central junction in the road network connecting Sinai, the Negev and Transjordan (Avner and Magness 1998: 50; Frenkel 1996: 185–187; see also Bienkowski 2006: 16; King 1987: 91; and Mayerson 1963). In addition, the distribution of early Islamic *qusur*, agricultural estates, along the roads, suggests investments in agriculture. King describes the *qusur* as way-stations or *caravanserai* 'as well as meeting whatever local role each *qasr* played' (King 1987: 100), perhaps they provided travellers with goods as well. There were also tax-benefits for Muslim inhabitants involved in agriculture in the Umayyad period (Kennedy 1999: 234–235; Kennedy and Liebeschuetz 1988: 66–67; see also Grabar 1993).

Regarding early Islamic agriculture, written sources from the 10th century onwards refer to many new crops introduced in the course of the early Islamic period. For example rice, previously cultivated only on a small scale, sugar cane and bananas became more popular (al-Muqaddasi 1994; Amichay *et al.* 2019; Ibn Hawqal 1964; Walmsley 2007a: 113–116; Watson 1983). New crops and other agricultural innovations may indicate socio-economic changes in the rural life in the 7th and 8th centuries, particularly in the Jordan Valley area, where the climate was most suitable for the new crops (Walmsley 2001a: 542–543; Walmsley 2000: 310; see also Amichay *et al.* 2019), although the distribution of the new cultivation regime to the Negev and southern Transjordan is less certain at the moment. For the Crusader period, however, 12th-century sources refer to successful cereal cultivation, trade of agricultural products and a dense network of villages around the southern end of the Dead Sea, with Karak, Zughar and Jericho as the main market places (see Brown 2016; Johns 1994: 1–14; Le Strange 1890: 479–480, 536; McQuitty 2005: 336; Politis 2013; Walmsley 2001a: 518–520; see also Ibn Jubayr 1952: 301; McCormick 2001: 32–35, 78).

In southern Transjordan, Humeima and Udruh apparently retained their economic and political statuses in the early Islamic period. It is possible that in addition to agricultural production, they were also places for local markets. Udhruh become the capital of the district of *al-Sharah*, and Humeima served as the base of the 'Abbasid family in 749–750 CE (Fiema 2002b: 237; Oleson 2016; Oleson and Schick 2013; Oleson *et al*. 2010). No early Islamic period ceramic production, however, has been associated with these sites. Geochemical analysis suggests that Humeima's ceramic corpus includes imports from multiple sources (Holmqvist 2013). There is, however, currently very little evidence concerning the situation of Petra during the Umayyad or 'Abbasid periods. It may have lost its urban character at this time, being an agricultural centre and probably a leading market place, and its economic activities were linked with the Jabal Harûn monastery nearby (Fiema *et al.* 2016; Fiema 2002b: 225, 241–242; Fiema 2001b: 432; Levy-Rubin 2003: 220–222). Fiema writes: 'Petra's position in the new political and economic reality of the Umayyad period is virtually unknown…it is never mentioned in the extant texts' (Fiema 2002b: 237; see also 'Amr and al-Momani 2011; Hamarneh 2013).

Future archaeological research may reveal early Islamic period evidence from the Petra region, particularly if further examinations are carried out not only in central Petra but also in its hinterland. The Petra Valley has been intensively examined, but there is a possibility that the early Islamic centre may have been elsewhere (see Fiema 2002b: 192–193, 220; Fiema 2001b: 429; Russell 1985: 42; and also Ross *et al.* 2007). As Northedge notes, 'the centres and occupied areas evidently tended to move over time…as not all sections would have been inhabited at the same time' (Northedge 2005: 119). One option may be that instead of Petra, the early Islamic activities concentrated in Wadi Musa, where middle Islamic settlement has been found, or another location in Petra's immediate vicinity (see Brown 1987; Graf 1995; Fiema 2001a: 121; and Walmsley 2001a: 518–522; see also Le Strange 1890: 536). 'Amr and al-Momani (2011: 306–307) note that there are several early Islamic sites identified on the al-Sharah Mountains overlooking Petra in addition to Byzantine sites showing continuation into the early Islamic period.

The lack of historical references as such is not unique to Petra, as there are also other Byzantine centres that have not received much attention from early Islamic historians. Bet Shean/Baysan/Scythopolis, the former capital of *Palaestina Secunda*, appears to have received few references in the early Islamic period records, although its archaeological record is uninterrupted until the 747/9 CE earthquake and later, when it was involved at least in the local market economy (Bar-Nathan and Atrash 2011; Khamis 2001: 159; Tsafrir 2009; Tsafrir and Foerster 1994: 111; Zeyadeh 1991). In addition to Bet Shean, the severe effects of the mid-8th century earthquake are clearly demonstrated by the well-preserved destruction deposits of Pella's public and domestic areas, and there is also evidence of destruction caused by the earthquake in other sites, such as the Amman citadel, Tiberias, Khirbet al-Mafjar, and it possibly also affected Petra (Bennett and Northedge 1977–8; Fiema 2002b: 235–236; Northedge 1984; Tsafrir and Foerster 1997: 136–137; Walmsley 2007b: 246–251; Whitcomb *et al.* 2016).

Prior to the destruction caused by the earthquake, the Bet Shean city centre functioned as an industrial and commercial area in the late Umayyad period. The evidence of industrial development at Bet Shean in the course of the Umayyad period includes a substantial pottery workshop with several kilns, indicating that it was a relatively large and wealthy settlement (Bar-Nathan and Atrash 2011; Bar-Nathan and Mazor 1993: 36–37; Khamis 2007: 445–469; Khamis 2001; Tsafrir 2009; Tsafrir and Foerster 1994: 112–113, 115). The shops originating from the Roman period were still used in the Byzantine and Umayyad periods, and the ceramics produced in the Umayyad workshops were mainly jugs and asymmetrical flasks of yellowish ware, these kinds of ceramics being typical of Umayyad contexts at the site (Bar-Nathan 2011a: 211; Tsafrir and Foerster 1997: 138).

There was also an extensive ceramic industry in the Jerash centre in the Umayyad period, where several kilns were constructed in the Roman period structures. The excavators date the ceramic production to the first half of the 8th century (Duerden and Watson 1988; Schaefer 1986: 411, 419–421; see also Kehrberg 2009; Pierebon 1983–4; Watson 1989). It has been suggested that the newly founded industrial activities, such as specialised production of high quality common wares, in the urban Umayyad contexts, demonstrate investments in these former Byzantine centres in the Umayyad period (Foote 2000: 33–34; see also Lichtenberger and Raja 2016). The 'Abbasid period industries in al-Raqqa and Alexandria also included production of glazed and unglazed ceramics (Heidemann 2006; Henderson *et al.* 2005: 138–141; Kubiak 1998: 381). In light of this evidence, although early Islamic ceramic workshops have not been identified in southern Transjordan or the Negev so far (excluding the 'Aqaba/Aila kilns, see, e.g., Melkawi *et al.* 1994; Parker 2014; and further discussion in Chapter 5), there is a strong probability that the local economies in the southern areas were also involved in ceramic manufacture during this era.

Christian communities under Muslim rule

In general, it seems that the Umayyad rulers were tolerant towards Christians and 'prepared to preserve the religious life of any community that had a scripture' (Fowden 1999: 98; see also Munt 2015), and were 'more interested in cultural and political conversion rather than religious conversion' (Shboul 1996: 89). Furthermore, in terms of the cultural transition, it is of enormous relevance that there were Arab tribes living particularly in the southern areas hundreds of years before the Muslim expansion, and Christian Arabs formed a large part of the Christian population in the Byzantine period and were closely integrated to provincial life. In fact, these Arabic or Aramaic speaking Christians, particularly the *Ghassanids*, and especially urban families familiar with Byzantine administration and traditions, were active in various aspects of society and played an essential role in the cultural 'interchange' of the early Islamic period (Shboul 1996: 77–79, 81; see also Edwell *et al.* 2015; Fisher *et al.* 2015; Haldon 1995: 403–406; Liebeschuetz 2000: 67–68; Shahîd 2002: 374–393; Shahîd 2001 and Shahîd 1995b). In fact, the Ghassanids had also political and military significance, as the Arabic sources imply that although they had previously supported the Byzantine state, they took the Muslim side in the 630s development (Haldon 1995: 403–414).

Many Christian tribes did eventually convert to Islam, often following economic and political contacts, but the increase in the Muslim population probably had more to do with migration rather than conversion, and the early Islamic period population was ethnically and religiously mixed (Shboul 1996: 85–88). The changed socio-political context probably engendered insecurity in the Christian communities, but they were not forced to convert to Islam nor was there a systematic conversion programme, and the majority of the population remained Christian throughout the early Islamic period (Shboul 1996: 75–77). The large number of Arabs, Christian and non-Christian, already living in the area had a great importance for the cultural development, not least because the *Ghassanids* also had close ties to other tribes and trade contacts with rural and urban communities and with the Arabian Peninsula (Haldon 1995: 415–423; Shahîd 1995a: 115–133).

Ecclesiastical activities continued and new churches were also built in the early Islamic period (Fiema 2001b: 431; Walmsley 1995a: 322). There even seems to have been an ecclesiastical building wave in the 7th century, and ecclesiastical refurbishment taking place in the 8th century, as is attested by a number of churches built in villages, such as Khirbet al-Samra and Umm al-Rasas (see Walmsley 2005: 516–520 and references). Apparently churches were also still being constructed in the 8th century, with renovation work possibly continuing to the 9th century in the Jerusalem area. In Cathisma, located on the Jerusalem–Bethlehem road, the southern part of the church was modified in the early Islamic period, and a *mihrab* was added for the use of Muslims while the rest of the building seems to have continued to function as a church (see Di Segni 2003: 247–250; see also, for example, Avner 2003 for Cathisma). Similar evidence is available from Shivta (Sbeita), located *c.* 40 kilometres southwest of Beersheva, where a small mosque was built next to one of the churches (Hirschfeld 2003: 395–396).

Many of the Byzantine monasteries continued to function during the early Islamic period although financial support from the Christian aristocracy had diminished and the Christian organisational structures changed (Di Segni 2003: 247–250; Levy-Rubin 2003: 204–207; Schick 1995: 96–97). There were organised Christian communities and Christian pilgrimage also continued, although at a reduced scale, as the Muslims did allow Christian pilgrims to visit the holy places in their territory (Levy-Rubin 2003: 214–217; Mayerson 1994: 242; Piccirillo 1984; Schick 1995: 109; see Munt 2015 for discussion). It is possible that Christian communities faced more unstable times and pressure to convert to Islam during the late ‘Abbasid period (Schick 1998: 77; Schick 1997; Schick 1991: 79; Schick 1995: 96).

It is clear that monasteries were of economic importance to local communities. Even though monasteries mostly relied on their own workshops and other activities they carried out themselves, it must still have been necessary for them to link with various producers in neighbouring villages to gain everyday supplies. Monasteries may have acted as economic centres and administrators in the movement of goods and people, the system financially supported by donations of visiting pilgrims (see Lebecq 2000: 129–131 for comparison). In some cases, the pilgrimage centre and its related economy became more important economically than the urban markets (Kennedy and Liebeschuetz 1988: 77, 87; Kennedy 1985: 24–25).

The Jabal Harûn monastery must have had an impact on the local economy in the early Islamic period (see Fiema *et al.* 2016; Fiema 2002b: 225, 241–242; Fiema 2001b: 432), and the prospect of trade with visiting pilgrims probably attracted local merchants and craftsmen to the monastery or its environs (see Holmqvist 2016b for early Islamic ceramic lamps probably brought to the site by visiting pilgrims). The pilgrim traffic likely contributed to the distribution of goods, such as agricultural products, possibly carried in ceramic containers (see Whitcomb 1992b: 116-117; see also Dembinska 1985). According to Hirschfeld, bread and seasonal vegetables, fruits and herbs were particularly important in the diet of monks living in the area of the Judean desert, some ascetic monks possibly eating only bread with salt and water. Thus, wheat was required in large quantities, and as the Judean desert is unsuitable for its cultivation, wheat was imported by camel caravans from the Dead Sea area (Hirschfeld 1996: 144–145, 150; Hirschfeld 1992: 82–83).

Remarks on ceramic trade, exchange and transportation

Regarding the ceramic trade in general, it is difficult to discuss actual figures of the ceramic trade as there are hardly any written sources discussing pottery (Greene 1986: 156). In addition to fine wares, the majority of the traded ceramic objects were likely containers exported as byproducts of other goods, and the actual products are often untraceable in the archaeological records (see Kingsley 2001: 58). Trade in domestic wares, however, is a crucial, although often overlooked, aspect of ceramic economies to consider. The caravans and other travellers probably also carried cooking utensils for their own use with them, and this may have contributed to the transportation of cooking pots, and to their exchange, as new vessels may have been required from time to time and purchased from local markets. Presumably, ceramic utensils, also domestic and utilitarian, were exchanged at market places, although not much evidence has been identified so far. Prices for common ware containers are listed in Diocletian’s price edict, and their pricing appears to be based on the sizes of the vessels, although it is difficult to ascertain the actual cost of the vessels (Young 1977: 212–214; see also Peña 2007: 27–31).

The minimum trade or exchange value would have to be added to the manufacturing, transporting and marketing costs, to make a profit (Anderson 1984: 168). Cooking utensils are generally associated with a relatively low value, although considering their performance requirements, this may not have been the case with good quality cooking wares (see Tite and Kilikoglou 2002; see also Mayerson 1995 for grain prices), although archaeological ceramic studies often concentrate only on the exotic and fine wares as plausible objects of inter-regional trade and distribution (see, e.g., Baklouti *et al.* 2014; Hayes 1972). Furthermore, the amount of exotic, imported fine wares is commonly considered to be indicative of the economic wealth of the community, although production and trade of utilitarian and coarse wares may also form a profound part of the economy, or indicate other economic activities, such as products transported in the ceramic containers. Lack of imported containers may also indicate that the society was self-sufficient in terms of agricultural production (Kingsley 2001: 57).

It should be noted here that coastal and inland sites are unlikely to have parallel ceramic records due to different trade realities, efforts and costs required for the transportation of products, each community and location having its individual 'physical limits of trade' (Greene 1986: 16–17; see also Dunn 2007; and Stathakopoulos 2007: 212). In general, the inland costs of ceramic transportation are considered considerably higher compared to sea-trade (Jones 1964: 841–842). According to the ancient figures obtained from Roman sources, the costs of inland transportation were estimated even 20 times higher, which would rule out profitable overland transportation of bulk, low value goods for 'any significant distances' (Greene 1986: 40, 169; McCormick 2001: 8, 83, 788; see Adams 2007: 3–8, 11–14, for discussion). Land transportation, however, may be seen as less dependant on seasons and weather (Laiou and Morrison 2007: 36).

Agricultural products were probably traded mainly on a local level, whereas wine, oil and perhaps other more specialised products were transported for longer distances (see Haldon 1990: 26; Stathakopoulos 2007: 211–217). The trade was likely based on the interaction of numerous regional economies, micro-regions and exchange of their products at rural markets, combined markets of nearby villages, as well as urban markets (McCormick 2001: 32, 782–798; see also Laiou and Morrison 2007: 37, 40). Urban populations were linked with agricultural and pastoral economies, producing goods for the urban population and for trade, the towns being central market places for rural products (Walmsley 1996: 126, 148–149).

Economic well-being means that communities are able to specialise their activities and also purchase goods from other producers. Farmers, pastoralists and craftsmen were able to gather and exchange their products, such as pottery, metal and other common goods at rural markets. Therefore, workshops of local craftsmen may also have been located in agricultural villages and not always in large urban contexts (Graf 2001: 230–232; Laiou 2005: 36, 46; McCormick 2001: 578). Laiou and Morrison suggest that local markets involved in 'local exchange' would have attracted people within a 50km radius, whereas goods of higher value were subjected to regional, inter-regional and long-distance transportation (Laiou and Morrison 2007: 81–82). On the other hand, it has been suggested that economic networks covered a radius of 100km, or a distance equivalent of three days travel (Walmsley 2009: 465; Walmsley 2000; see also Adams 2007: 44–45). Cooking wares can be regarded like any agricultural product of relatively low exchange value, and they were probably often exchanged to other products rather than being actually sold (Greene 1986: 46–47, 164–165). In addition to the local markets, there were larger, periodic fairs that attracted locals, foreigners and caravans, but it is difficult to identify these open-air markets by archaeological means (Graf 2001: 231; Walmsley 2001a: 543).

In addition to certain fine wares, amphorae are the principal ceramic category associated with long-distance distribution. These containers were used particularly in sea-borne trade to transport various agricultural products, such as wine, oil and fish products (Callender 1965: 39–41; Kingsley 2009; McCormick 2001: 92–114; Peacock and Williams 1986: 31; Rubio-Campillo *et al.* 2018; Van Neer *et al.* 2010). Many of the transported products, such as wine and oil, required special skills and environments to produce. Fish sauces were imported to inland communities, and different amphorae can presumably be linked with different products although not much evidence is available (Peacock and Williams 1986: 35-37; Van Neer *et al.* 2010; and also Callender 1965: xxii; for a papyrus discussing wine-jar production in Roman Egypt, see Cockle 1981).

Amphorae were likely traded at market places, although probably not transported over long-distances for their own value. Empty amphorae have been found in shipwrecks, but it is probably only because the seals have not survived in the underwater conditions (Bass 1982: 188). Preserved remains of organic materials in amphorae from archaeological contexts are generally rare, the few known examples including remains of wine, fish bones and olives (Heron and Pollard 1988: 429–430; Pecci *et al.* 2017; Van Neer *et al.* 2010; Van Neer and Parker 2008).

In the early Islamic period, it seems that the importance of wheeled transportation decreased. The preference for pack animals allowed narrower streets and affected the planning of urban areas (Bulliet 1975: 226–229; Kennedy 1985: 26; see also Adams 2007: 49–56, 65–69; Bagnall 1985; and Foss 1997). Although ceramic-borne trade may have benefitted from this development (assuming that ceramic containers were more often carried by pack animal than wheeled transportation), there is evidence from the 9th and 10th centuries that products traditionally transported in ceramic containers, such as oil, were being transported in large leather skins (Haldon 2000: 254–255). This may associate with the decrease in imported amphorae in some regions, reflecting not only a change in exporting and importing patterns, but also in forms of transportation (Haldon 2000: 254–255).

Prior to this, amphorae are still a common category in the ceramic assemblages of the 7th and 8th centuries, although the amount of imported fine wares and other exotica was gradually decreasing (Walmsley 2000: 322, 326–327). The chronology of amphorae, on the other hand, is very complex due to their chronology-defying characteristics and continuous reuse (see Pecci *et al.* 2017; Peña 2007: 47–56, 61–192). For instance, Late Roman 1 type amphorae have been associated with 8th–9th century contexts, and numerous alternative production centres for typologically linked vessels, such as the Gaza jars, have also been identified (see Armstrong 2009: 163–174; Kingsley 2009; Reynolds 2014; Reynolds 2005: 564–566, 573–578; see also Coto-Sarmiento *et al.* 2018; Majcherek 2004; Majcherek 1995; Tomber 2004 and Chapter 5 for further discussion).

Apparently, in the 8th century, there was a change in sea-trade from the state's bulk transportation to smaller-scale shipping of selected goods by independent shippers. At this point, the trade became characterised by 'small-volume, high-value' items rather than 'high-volume, low-value' goods, such as agricultural products (McCormick 2001: 102–103, 566–577; see also Dauphin and Kingsley 2003: 71; Haldon 2000: 247; Laiou and Morrison 2007: 41). The European and Islamic economies were intensively interacting from the late 8th century onwards fuelled by traders, travellers and pilgrims and these contacts continued into the 10th–11th centuries (McCormick 2001: 112–119, 782–797; see also Jacoby 2009: 386; Reynolds 2005; Wickham 1998).

Trade relations were also active with Egypt and Africa in the 8th–9th centuries, and Byzantine exports to Egypt are mentioned in Arabic texts dating to the 10th century, providing further evidence for trade between the Byzantine world and the Fatimid caliphate (see Jacoby 2009: 381; Laiou and Morrison 2007: 84; Sodini and Villeneuve 1992; Watson 1995; Watson 1992: 246; Whitehouse 1988; see also Majcherek 2004; Majcherek 1995; and Pringle 1985). In addition to the Red Sea and Fustat, 'Aqaba's trade links extending to al-Hijaz, the Indian Ocean and China benefitted the commerce of southern Transjordan and demonstrate that the 'Abbasids and Fatimids were part of an international trade network (Jacoby 2009: 381; Phillipson 2009; Sidebotham 2009; Tomber 2004; Walmsley 2001a: 541–542; Whitcomb 1989a; Whitcomb 1988a; Whitehouse 1988; Zarins 1989).

Chapter 3

Archaeological sites

The monastery of Jabal Harûn, the village of Khirbet edh-Dharih, the town of Elusa, the farmstead of Abu Matar, and the port city of ʻAqaba/Aila[1] are each representatives of individual socio-economic contexts with their unique microeconomic systems and contact networks (see Figures 1.1, 2.1 and 2.2 in Chapters 1 and 2 for the locations of the sites). Ceramic artefacts from these particular sites were selected for analysis based on their potential to provide evidence for ceramic manufacture and ceramic exchange on local, regional and inter-regional levels in the late Byzantine and early Islamic southern Transjordan and the Negev.

A comparative compositional study is required to examine ceramic provenance and possible exchange patterns between the sites, as most often hypotheses on ceramic transportation and common origin are based on typological grounds (see Chapters 4 and 5 for further discussion). Byzantine workshops have been identified near Petra and in Elusa (ʻAmr and al-Momani 1999; Bucking and Goldfus 2012; Goldfus and Fabian 2000), and ceramic production in ʻAqaba/Aila continued at least into the mid-8th century (Melkawi *et al.* 1994; Whitcomb 2001a), yet otherwise there is sparse evidence for ceramic manufacture in the southern areas, particularly in the early Islamic period. In the ceramic repertoires retrieved from Jabal Harûn, Khirbet edh-Dharih, Abu Matar, ʻAqaba/Aila, and also from Elusa to some extent, however, characteristics typical of Islamic periods are present. Hence, the provenance of these wares is puzzling, and a compositional study is necessary to examine their possible local origins and shared ceramic manufacture among the sites.

Furthermore, with regard to the economies of these sites in the early Islamic period, it is essential to investigate whether ceramic transport vessels or other ceramic imports can be identified in the assemblages. It is also important to study these ceramics to shed more light on their typo-chronological, functional and technical features. As a result, the ceramic analysis may provide insight into the socio-economic statuses of the sites, and the inter-site relations, such as economic links between rural and urban communities, and religious and other groups, which are of interest considering that the communities had their unique subsistence strategies, and specific requirements for domestic and utilitarian ceramic supplies.

It is likely that the inhabitants of the five sites mainly interacted in the macroeconomies of their immediate environments, but probably also required other, possibly ceramic-borne commodities, produced in other regions. The selected sites are linked by numerous routes crossing the southern areas in the regions. Khirbet edh-Dharih, Jabal Harûn and ʻAqaba/Aila are located on the main north–south route through southern Transjordan, following the course of the *Via Nova Traiana* and the Islamic Hajj route from Damascus via Amman to al-Hijaz and the Arabian Peninsula. The Hajj pilgrims, added to other caravan traffic, must have had a considerable impact on the movement of people, goods and influences. Elusa and Abu Matar are connected by the Negev roads, leading, for instance, to Sinai, Egypt, Gaza and the Mediterranean coast, Jerusalem, the Dead Sea region and further north, and to south to ʻAqaba/Aila, and east crossing the Wadi ʻArabah and joining other routes. Elusa is on the main Petra–Gaza route.

A few general observations can be made before each site is discussed in further detail in the following sections of this chapter. The monastery and the pilgrimage centre at Jabal Harûn probably had an important role in its local economy in the Petra region, since its community and the pilgrims increased the demand for foodstuffs and also ceramic utensils. Some goods may have been transported to the site, and its inhabitants may have visited markets in Petra, or, for instance, in Humeima or Udhruh (see Holmqvist 2013). In addition to domestic and utilitarian ceramic products, some of the other goods required by the community, such as wine, oil, and fish products, may have been transported in ceramic containers. The pilgrims may have brought ceramic items with them. No evidence that the monastic community was involved in ceramic manufacture has been found up to the present.

Khirbet edh-Dharih also had an agriculture-based economy in the vicinity of an ancient sanctuary, Khirbet Tannur. The village had an excellent location with regard to trade routes and the Hajj route, and its community probably collaborated in the village network of the Dead Sea and Karak regions. Significantly, the site is not too distant (*c.* 80km; see, e.g., Walmsley 2009: 465; and Laiou and Morrison 2007: 81–82 for suggested 50–100km distances in regional and inter-regional economic networks) from Petra for its people to have

[1] Modern ʻAqaba is known in the historical sources as Aila/Ayla/Wayla. In this work, the name ʻAqaba/Aila is used when referring to Roman and Byzantine period evidence or the Roman ʻAqaba Project's materials (see Parker 1996: 323), and Ayla is used when specifically discussing the Islamic contexts in ʻAqaba.

used the same markets as the Jabal Harûn inhabitants, but it is even closer to the urban markets located, for example, in Jericho and Zughar.

The Negev sites, Elusa and Abu Matar in Beersheva are located only *c.* 20km apart, thus, leading one to expect that they shared economic links and possibly employed the same local producers for various goods. Although the socio-economic natures of the two sites are remarkably different, Elusa being an urban site with industrialised agricultural and ceramic production, and Abu Matar a suburban farmstead of the neighbouring town of Beersheva with a more rural and private socio-economic role, they can be seen as part of the same local economic system – or at least units of the same macroeconomy.

The port city of ʻAqaba/Aila is most strategically located in respect to the other sites. The town had a wide international trade network; thus, its status is highly commercial and industrial, characterised at least by a fishing industry and mass-produced ceramic utensils (see below). For this reason, one might also expect the ceramics originating from ʻAqaba to show the most prominent pattern in the inter-site ceramic analysis.

A common aspect shared by all of the socio-economies of the sites is their involvement in agricultural production or trade. Therefore, trade and transportation of various goods, and the related ceramic utensils, are most likely to form material links among the sites. One hypothesis here is an analogy with areas further north, where Jerash was involved in industrial ceramic production and also supplied ceramic utensils to the neighbouring communities, such as Pella, where no evidence of local ceramic manufacture has been found despite its economic role. Hence, it has been suggested that Pella may have been a marketplace for goods coming from different production centres (see, e.g., Foote 2000; Duerden and Watson 1988; Schaefer 1986: 435; Walmsley 2000: 326–327; Walmsley 1995b; Watson 1989). Industrial and economic development and investment are apparent at many northern sites, such as Pella, the Amman citadel and Jerash, in the Umayyad and ʻAbbasid periods (see, e.g., Hoffmann Bartod *et al.* 2018; Lichtenberger and Raja 2016; Northedge 1991; Walmsley 1991), but parallel economic evidence is sparse from the southern areas. In the following, the archaeological sites and the respective excavation projects will be discussed. Locus numbers and context identification for each sample are given in the ceramic catalogue (Chapter 5). For the purpose of this book, I had the opportunity to study the entire ceramic assemblages from Jabal Harûn, Khirbet edh-Dharih, Elusa (Ben Gurion University excavation materials) and Abu Matar (the Aila materials were sampled by the excavator, S. T. Parker).

The monastery of Jabal Harûn (Mountain of Aaron) near Petra

The Jabal Harûn monastery is located *c.* 5km southwest of Petra, on a high plateau of Jabal Harûn, the Mountain of Aaron, known as the burial place of Aaron in Jewish, Christian, and Muslim traditions. The site was excavated by the Finnish Jabal Harûn Project (FJHP) of the University of Helsinki between 1997 and 2010, the project and its fieldwork was directed by Jaakko Frösén, Zbigniew Fiema and Mika Lavento (see Fiema *et al.* 2016; Fiema 2003; Fiema and Frösén 2008; Frösén *et al.* 2004; Kouki and Lavento 2013). The FJHP's site is a ruined architectural complex (see Figure 3.1.), identified as a monastery and a pilgrimage centre located on a plateau approximately 70 m below the peak of the mountain, and *c.* 1245m above sea level. The monastery complex, including a church, chapel, domestic buildings and rooms – interpreted as a pilgrims' hostel – was most likely built in the late 5th century and used as such perhaps into the 9th century (see Fiema *et al.* 2016; Fiema 2008; Frösén *et al.* 2004). Importantly, there is a sarcophagus located in a 14th century Muslim *weli*, a shrine at the peak of the mountain, which, according to tradition, contains Aaron's remains.

Most of the Jabal Harûn ceramics sampled for this study were retrieved from Trenches J and Z, excavated during the campaigns of 2000 and 2005, respectively, located in the domestic areas of the complex (see Juntunen 2016; Lahelma *et al.* 2016 for the contexts; see also Fiema and Frösén 2008; and Fiema *et al.* 2016 for the excavation reports; for the FJHP pottery reports, see Gerber 2016; Gerber 2008; Gerber and Holmqvist 2008; Holmqvist 2016a; Holmqvist 2016b; Silvonen 2013; Silvonen and Holmqvist 2013; and Sinibaldi 2016). The strata sampled for this study (mainly locus 58 in Tr. Z, and the sampled loci in Tr. J), can be associated with the later occupational stages of the site (Juntunen 2016; Lahelma *et al.* 2016).

Trench J is located near the narthex of the church, where the excavations revealed structures indicating several phases of remodelling, including an installation for water collection, a conduit and a channel. In the conduit, there were two rims of ceramic containers serving as its spout, leading to a ceramic container (Lahelma *et al.* 2016; see also Frösén *et al.* 2001b: 363). The loci where ceramics were sampled for this study are related to a later phase in this area, when the central room was used for storage and dumping. Loci 44 and 45 were ashy layers of sand with charcoal and large amounts of coarse ware ceramic finds deposited on a stone pavement (see samples JH001, JH004, JH006, JH013, JH014, JH018, and JH020 from locus 44; and JH015 from locus 45). There were also residues from lime burning mixed with the soil, indicating industrial activities.

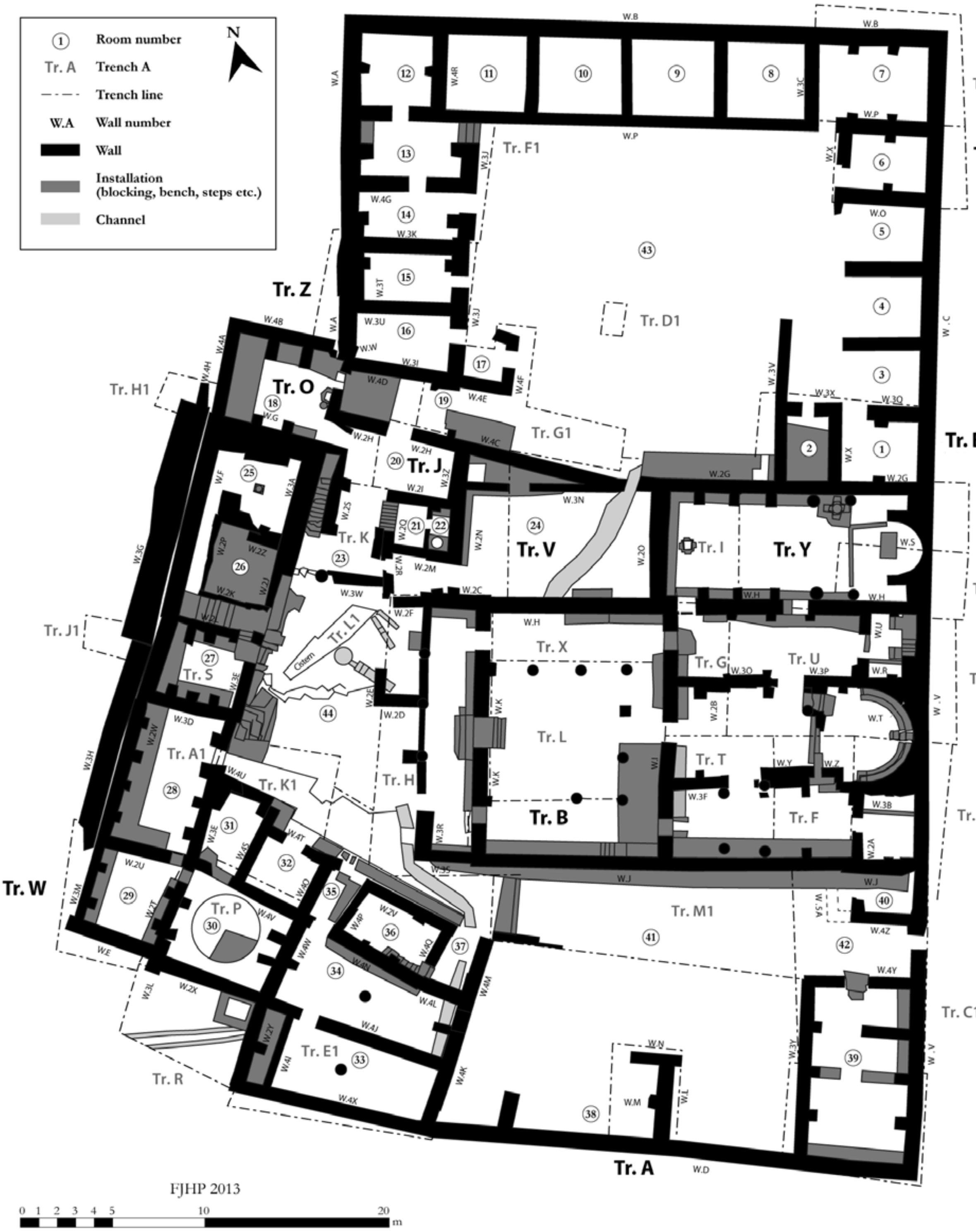

Figure 3.1: Jabal Harûn site and the sampled Trenches (adapted from Fiema 2016: Fig.1).

Locus 17 was a stratum of sandy soil accumulated in the south-western part of the trench, which contained ceramics, fish bones, eggshell fragments, ash and charcoal, indicating that the area was used for food preparation. Locus 20 was similarly a thick, sandy soil layer with plentiful ceramic finds (see sample JH026 from locus 17, and samples JH023 and JH035 from locus 20). Locus 21 (see sample JH002, see also JH015 from locus 10 in Tr. J) is related to the final collapse of the structures in this area, and the remains of a campfire suggest a temporary inhabitation in the ruined room (Lahelma *et al.* 2016; see also Frösén *et al.* 2001b: 365; the preliminary dates proposed by Gerber in Frösén *et al.* 2001a: 379 need to rejected as too early, see Chapter 5).

Locus 58 in Trench Z (located on the western side of the northern complex of the site, see Juntunen 2016) was a layer of collapse with a rich presentation of early Islamic ceramic types (see samples JH003, JH007, JH010, JH011, JH012, JH017, JH024, JH028 from this stratum). Furthermore, typologically interesting ceramics were sampled from certain contexts, particularly those of Trenches W and V, located in the western corner of the complex, and east of Trench J, respectively, although the stratigraphy of these deposits is less secure compared to Trenches J and Z (see samples JH009, JH016, JH027, JH029, JH030 for Tr. W, and JH036, JH037 and JH038 for Tr. V).

Petra is famous for its history as an economic centre, and although its role in the early Islamic period is not entirely clear, it may have still served as a regional market place (see Chapter 2 for discussion). The monastery site has provided evidence of continued inhabitation into the 10th century, and there are also historical accounts of monks living on the mountain in the 12th century (see Fiema 2008: 94–95; Mikkola *et al.* 2008: 159; see also al-Muqaddasi 1994: 99–100; Runciman 1952: 98). Apparently, Wadi Musa, its springs, and Jabal Harûn were among the main Muslim holy sites in the region in the 13th–15th centuries, and the mountain is still visited by pilgrims (Frösén and Miettunen 2008: 13–15; Walmsley 2008: 502, 513, 519; see also Stanley 1868: 302). Caravans are also known to travel through Petra until relatively recent times (see Roberts 1855: Pl. 95 and text; Stanley 1868: 28, 85–92; see also Bienkowski and Chlebik 1991; McKenzie 1991; Walmsley 2008: 498–500).

Therefore, the people living at Jabal Harûn and those visiting the mountain have had a very long-lasting impact on the local economy. The monastic role of the site has various socio-economic implications, as it increased demands on the local market, and probably also required goods from other regions. With regard to ceramic transportation, it is of importance here that abundant amphorae finds have been retrieved from the site. Some of these amphorae might link to the fact that the majority of fish remains found at Jabal Harûn originate from the Red Sea. Fish was an important part of the Byzantine diet, and parrotfish (*scaridae*) in particular appear to be common in monastic contexts, especially those with a pilgrimage presence (see Fiema 2003: 354; Studer in Frösén *et al.* 2001a: 385). Fish scales are also present in the later occupational layers of the site, which might suggest that at least some of pilgrims visiting the monastery area after its ecclesiastical role can no longer be substantiated followed the traditional diet (Fiema 2003: 354). Evidence of Red Sea fish remains found at inland sites also exists from the Negev (Lernau 1986). Considering the diet at the monastery, a large number of sheep and goat ribs indicates that racks were also brought to the site (Studer in Frösén *et al.* 2001a: 385). The botanical samples from Jabal Harûn provide evidence of basic plant foodstuffs, barley, olives, lentils, dates and grapes, olive stones and barley also representing possible contents of a jar found in Trench J (Tenhunen 2016; Tenhunen in Frösén *et al.* 2001a: 386–387).

It should be underlined here that a monastic context as such is not necessarily associated with numerous amphora finds. From the monastery of Khirbet ed-Deir, for instance, only one amphora sherd was recorded. It has been suggested that the lack of amphorae at Khirbet ed-Deir may indicate consumption of local wines instead of imported ones (Calderon 1999: 138). On the other hand, petrographic analysis of ceramics from the monastery of St Lot (Deir ‘Ain ‘Abata) at the southeast end of the Dead Sea, have demonstrated imports, possibly originating from Cyprus, northern Syria and Gaza, to the site (Joyner and Politis 2000). Furthermore, the Deir ‘Ain ‘Abata evidence shows that although catering for pilgrims must have required pottery, little or no pottery was manufactured at the monastery site itself. Instead, it appears that the ceramics, especially cooking wares, were manufactured ‘relatively locally’, while imports were more common in other vessel categories (Joyner and Politis 2000).

The village of Khirbet edh-Dharih in southern Jordan

The excavations at Khirbet edh-Dharih (*Mohafazah* of Tafileh) in southern Jordan are carried out as a joint expedition of the Institute Francais d’Archaéologie du Proche-Orient (IFAPO/ Ministry of Foreign Affairs, France), Yarmouk University and the Department of Antiquities of Jordan. The excavation project, Mission Franco-Jordanienne de Khirbet edh-Dharih, started in 1984 and is directed by François Villeneuve (l’Université de Paris I) and Zeidoun al-Muheisen (Yarmouk University). The Khirbet edh-Dharih site is located *c.* 80km north of Petra, and approximately 7 km from the Nabataean sanctuary of Khirbet Tannur, on the southern bank of Wadi al-Hesa in the Wadi Laaban, near the southern end of the Dead Sea and Karak. The site (see Figure 3.2) is mostly known for its Nabataean structures, including a village, sanctuary, necropolis, and agricultural and hydraulic installations, and Byzantine period settlement layers continuing into the early Islamic period (Bertaud *et al.* 2015.; Durand 2015; Durand and Piraud-Fournet 2013; Lenoble *et al.* 2001; Villeneuve 2011; Villeneuve and al-Muheisen 2000; Villeneuve 1990: 367; Waliszewski 2001).

The partial destruction of the site has been associated with the earthquake of 363 CE, after which the village was resettled by a Christian community. The Byzantine and Umayyad period village is located mainly in the necropolis and temple areas, which continued to be inhabited at least until the end of the 8th century. The excavators associate the end of the village occupation with another earthquake, the date of which cannot be established. It is also uncertain whether the community of Khirbet edh-Dharih converted to Islam. The temple area may have again been occupied in the Mamluk period and the 16th–18th centuries, when houses were built at this area of the site (see Lenoble *et al.* 2001; Villeneuve and al-Muheisen 2000: 1558–1561; Villeneuve 1990: 368–369).

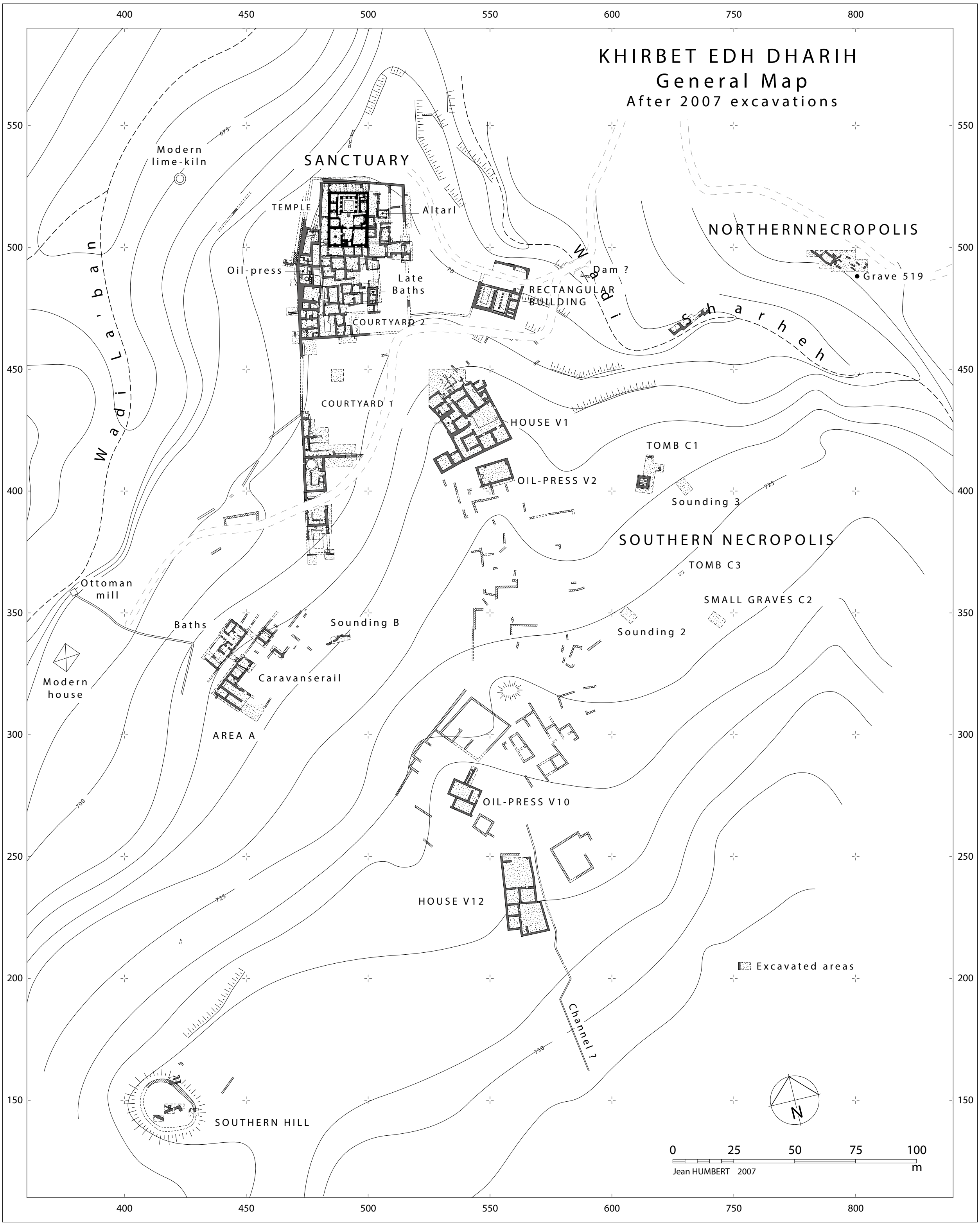

Figure 3.2: Khirbet edh-Dharih site general plan (Jean Humbert, Dharih Jordanian and French Archaeological Project, 2007).

The late Byzantine–early Islamic period ceramics were retrieved mainly from surface layers and unsealed deposits. Thus, the opportunities for intra-site stratigraphy based ceramic chronology are weak, and the ceramics need to be dated according to parallel evidence from other sites. Waliszewski suggests that forms similar to those included in this study date mainly to the 7th and 8th centuries (see Waliszewski 2001; see also Durand and Piraud-Fournet 2013; and Chapter 5 for typo-chronology). Loci that appeared to present a uniform typo-chronological ceramic repertoire were selected. Particularly loci S10C023–4 (samples DH001 and DH003), S2DD1–5 (samples DH013, DH020, DH021, DH037 and DH038) and S2KK1–2 (samples DH015, DH016, DH017, DH018, DH040) appeared chronologically homogenous including mainly early Islamic forms, while locus S1H12 was clearly a Roman period context, sampled for examination of chronological variation (samples DH004–DH007; see Chapter 5 for loci information on the samples).

In general, the Khirbet edh-Dharih excavations have provided a wide repertoire of common ware pottery, mainly jars and cooking pots, many of which are stylistically and morphologically parallel with the Jabal Harûn ceramic finds. Up to the present, no indications of late Byzantine or early Islamic ceramic production have been found at Khirbet edh-Dharih, or in its immediate environs. An analytical ceramic study is required to establish whether the stylistically related forms share a common provenance.

The city of Elusa in the Negev

Elusa (Haluza, al-Khalasa) was first settled in the Nabataean period, in the 3rd century BCE, when it apparently served as a station on the caravan route from Petra to Gaza (Negev 1993a: 379; Negev 1976: 359). The importance of Elusa increased in the course of the late Roman and Byzantine periods – it was the only Negev town that gained the status of a *polis*. It gradually became a major Christian settlement (there was possibly a pagan majority until the early 5th century) and it was the administrative centre of the Negev, with historical references to its bishops. Elusa is also listed as one of the towns in *Palaestina Tertia*, and is repeatedly referred to in the Nessana papyri (Negev 1993a: 379–380). There is a reference to the city from the late 7th century, indicating that it still had an official status in the early Islamic period. There are also records of pilgrims stopping at the site on the way to Mount Sinai (Mayerson 1983: 253; Negev 1993a: 379; Negev 1976: 360; Shereshevski 1991: 84; see also Le Strange 1890: 30). Throughout its history, Elusa had a commercial role, it was one of the wine producers in the Negev, served as an urban market, and caravans stopped there on their route to other commercial centres, such as Petra, Gaza and ʻAqaba/Aila (see Chapter 2; and Avni 2014: 259; Graf 1992: 259; Hirschfeld 2003: 408; Kingsley 2001: 57–58; Mayerson 1992; Mayerson 1985: 76–78; Meshel and Tsafrir 1974–75: 104–105).

The ruined architectural remains of Elusa (see Figure 3.3) are located in the northern Negev, *c.* 21km southwest of Beersheva, and 10 km northeast of Rehovot (Ruheiba). The site was originally excavated by the Colt expedition in the 1930s and by A. Negev in the 1970s (see Mayerson 1983; Negev 1976; Negev 1989; Petersen 2005b: 57; Shereshevski 1991: 82–90). Since 1997, the site has been excavated by the Archaeological Division of the Ben Gurion University in the Negev under the direction of Haim Goldfus and Peter Fabian (see Goldfus and Fabian 2000). The remains of the site cover a *c.* 48ha area including Nabataean period buildings, and Byzantine urban structures, such as a main street running in north-south direction, a theatre and at least two churches (Negev 1993b; Petersen 2005b: 57–58). During the Ben Gurion University excavations, from which ceramics were sampled for this study, the theatre and the pottery workshops, surveyed by A. Negev, were excavated.

The theatre (Area T) appears to have been built in the 2nd–3rd centuries CE, and while its structures were unearthed, the floor of the orchestra, built of limestone slabs, was recovered after the removal of *c.* 2m of accumulated soil (Goldfus and Fabian 2000: 93–94). During the excavation of the northern *cuneus*, it became apparent that most of the seats had been removed, but two staircases, one of them almost undamaged, were recovered in their typical places. In addition, a wide entrance, presumably built after the construction of the theatre, was found in the middle of the enclosure wall. In addition, further restructuring was identified in the theatre, such as blockages built in the northern part of the *proscenium*. The walls of the stage were ashlar-built, while the floor of the stage, probably a wooden structure, was not preserved (Goldfus and Fabian 2000: 93). The layers excavated in the stage area contained Roman and Byzantine sherds (ceramic samples from loci 2007, 2046, 3021, 3027, 3043, 3100, 3111, 3119, 3138, 3531 of the site were sampled, see samples E001–008, E0011, E013–014), indicating that the terminal date for the use of the theatre area did not exceed the 6th century (Goldfus and Fabian 2000: 94).

Area K, the ceramic workshops, was located *c.* 50m southeast of the theatre on the edge of the Byzantine city. The industrial area was walled by fieldstones, and included two rectangular structures. The walls of these structures were only partially preserved, the lower parts being of limestone and chalk blocks, and the upper sections of unbaked mud-brick. The southern ends of these structures were divided into smaller units, probably used as a ceramic storage and

Figure 3.3: Site plan of Elusa (adapted from Bucking and Goldfus 2012: Fig. 2; and Negev 1993a: 379).

shops, and also for drying the vessels before firing. In the northern end of the workshops, there were three small kilns. Large quantities of unsuccessful ceramic products, some unfired, were encountered in the area west of the workshop. These layers of misshapen vessels appeared discarded in the courtyard (loci 3017, 3055, 3091, see samples E015–020). Another, rounded kiln was excavated south of the courtyard. According to the excavators, the workshops were active at least until the 6th century (Goldfus and Fabian 2000: 94; see also Bucking and Goldfus 2012; Fabian and Goren 2002).

For this study, common ware sherds and wasters from the pottery kilns were sampled (see Chapter 5 and Appendix I for the ceramic catalogue). Most of the samples may be of late Byzantine date, although it is difficult to assign a secure terminal date for the forms. Ceramics typical of the early Islamic period, such as high-necked jars and basins, were not numerous in the Elusa assemblage studied and sampled for this project, and they were often unstratified surface finds (see, for example, samples E010 and E012). Negev reports early Islamic finds at the site, but gives few details. He associates the removal of ecclesiastical marble decorations with the early Islamic period, and suggests that this activity took place 'probably not much later than 700 C.E.' (Negev 1993b: 291; see also Avni 2014; Magness 2003: 194; Petersen 2005b: 58). Thus, one might expect the ceramic chronology of Elusa to extend at least into the 8th century, and possibly later, but the later phases are not necessarily well represented in the ceramic repertoire of the recently excavated areas, since the early Islamic activities may have been concentrated in other parts of the site, such as the cathedral area.

The farmhouse of Abu Matar in Beersheva

Beersheva is a large, multiperiod site located in the northern Negev. The Roman, Byzantine and early Islamic city centres were located in the area of the modern city established by the Ottomans in 1900, and there have been numerous archaeological excavations resulting from modern building activities in recent decades. Many recent excavations in Beersheva show an uninterrupted settlement pattern from the late Byzantine period into the Umayyad and ʿAbbasid periods (see Petersen 2005b: 54–57 for further references). The Abu Matar (Bir Abu Matar, Horvat Matar, Figure 3.4) site, located west of the modern Beersheva city centre, was originally excavated in the 1950s by Jean Perrot, working on the Chalcolithic settlement (Perrot 1955). The site was excavated as a salvage project in 1990–1991 under the direction of Isaac Gilead and Steven A. Rosen from the Ben Gurion University in the Negev and Peter Fabian of the Antiquities Authority and the Ben Gurion University, and extensive materials from Byzantine and early Islamic periods were revealed.

During the excavation of Area B, which provided most of the ceramics sampled for this project, Byzantine and Islamic period structures were recovered built on the remains of Chalcolithic settlement. The Byzantine structure, interpreted as a church, monastery or a villa, was of substantial size (*c.* 400m^2) with some ashlar-built plastered walls, and remains of red painted decoration and mosaics. The floors of the building were constructed of flagstones and plastered. In addition, the building was characterised by columns and benches along some of the walls. The building phase of the Byzantine building is likely to date from the late 5th–6th centuries, but it was re-modelled around the late 6th–early 7th centuries (Gilead *et al.* 1993: 97–98; for ceramics from the Byzantine contexts, loci 3045 and 2065, see samples AM001, AM007). In addition, a tombstone with a Greek inscription with a date of 537–538 CE, probably in secondary use, was found at the site (Ustinova and Figueras 1996).

The Islamic period settlement, identified as a farmstead, was built partly on the Byzantine structures 'not before the end of the 7th century' (Gilead *et al.* 1993: 98; there was also an early Islamic squatter's phase, pre-dating the farmstead, S. A. Rosen, personal communication, 2009). The inner walls of this building survived to a height of *c.* 50cm. The finds from the early Islamic structure included ceramics, mainly domestic and utilitarian coarse wares, dating to the late Byzantine and early Islamic periods (Gilead *et al.* 1993: 98; for Byzantine–Islamic contexts, loci 3453, 3494, 3532, see samples AM008, AM010, AM016, for Islamic contexts, loci 3078, 3090, 3156, 3179, 3350, 3377, 3407, 3453, see samples AM002–003, AM005, AM010, AM014, AM017–AM020). There were also sherds of moulded Islamic cream ware with floral imprints ('Khirbet al-Mafjar ware', Gilead *et al.* 1993: 98). These cream wares can be dated to the 11th century (see sample AM019; and Chapter 5 for typo-chronologies). In addition to the ceramics, finds encountered in the rooms of this building included ovens, stone objects and bones (Gilead *et al.* 1993: 98).

It appears that villages and farmsteads in the Negev, such as Abu Matar, flourished throughout the Umayyad and into the ʿAbbasid period (Rosen 2000), and it has been suggested that Abu Matar was probably part of a suburb of Beersheva rather than being an isolated rural settlement (Petersen 2005b: 46, 57). Ceramic samples analysed for this study include domestic utilitarian wares, cooking pots, jars and basins, from the late Byzantine and early Islamic occupational layers of the site.

The port city of ʿAqaba/Aila/Ayla on the Red Sea coast

Modern ʿAqaba has a long history as an international commercial centre on the northern coast of the Red Sea. The history of the port city, also well linked with caravan routes, goes back to the Nabataean and Roman periods, to the 1st century BCE. Ceramic samples from the Roman ʿAqaba Project excavations, directed by S. Thomas Parker from North Carolina State University, were included in this study. The 1994–2003 excavations have revealed large areas of the Roman and Byzantine city, including domestic quarters and a church (Parker and Smith 2016; Parker 2013; Parker 2006a; Parker 2003; see Figure 3.5).

The archaeological evidence shows that the town also maintained its commercial and international role throughout the early Islamic period into the late ʿAbbasid and Fatimid periods (Avner and Magness 1998: 39, 50–52; Parker 2013; Walmsley 2000: 300–305; Whitcomb 2001b: 510; Whitcomb 1995; Whitcomb 1994). The town had a significant, politically important, status in the Islamic period, as its control was essential for the Hajj route. There are historical records describing tribal actions challenging the ʿAbbasid rule of the city in the 9th century, and later battles in the 10th and 11th centuries. The town was badly damaged by an earthquake in 1068, after which there is very little historical evidence of its situation. It is mentioned, however, in 12th century sources, and in the 16th century it came under Ottoman rule (Petersen 2005b: 49–50; Whitcomb 2006; Whitcomb 2001b: 510).

The town is also of particular interest in terms of ceramic exchange: a specific type of transport vessel, the so-called ʿAqaba/Aila amphorae locally produced at ʿAqaba

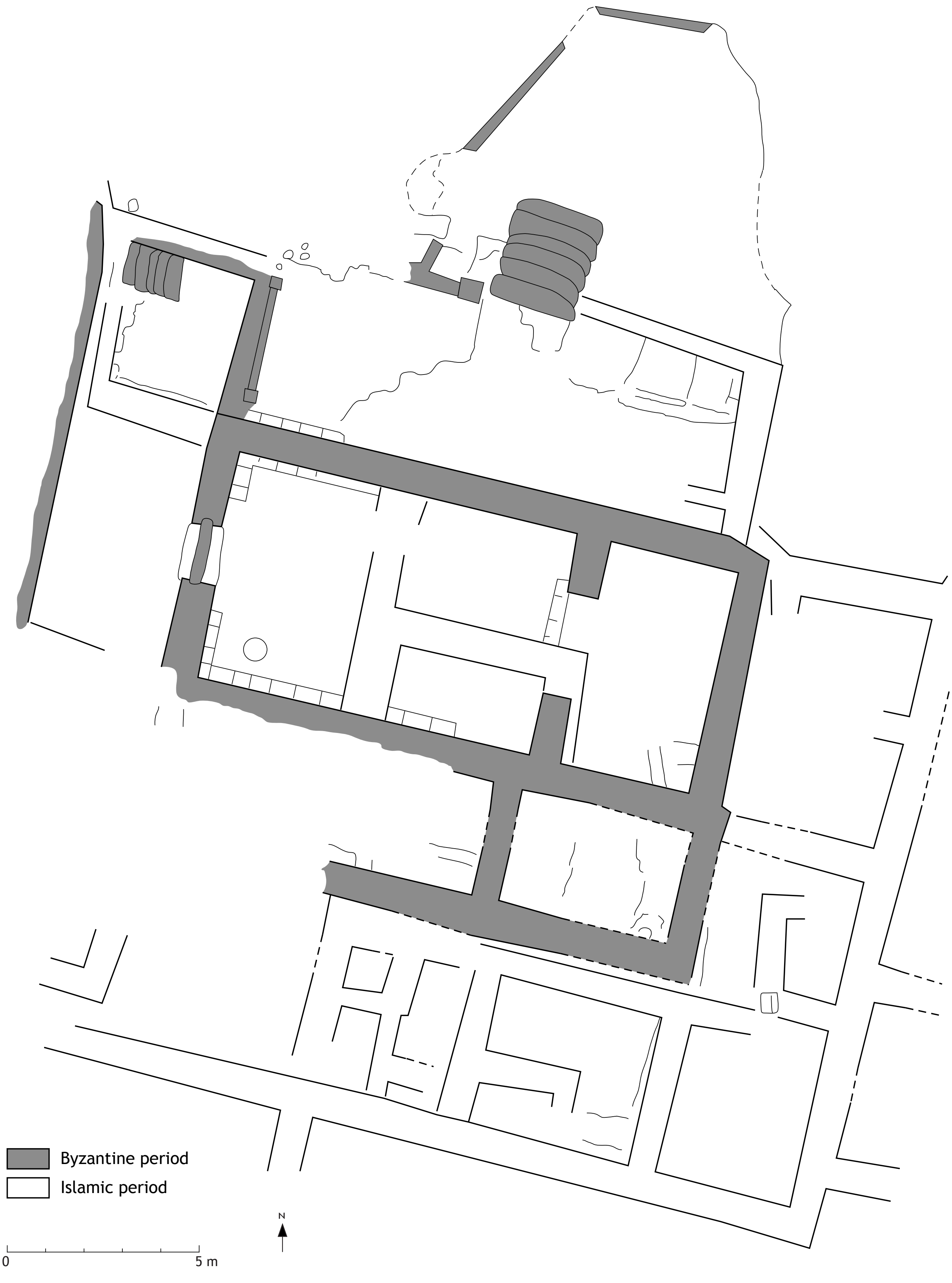

Figure 3.4: Abu Matar, Area B (after Gilead et al. 1993: 98, Fig. 114).

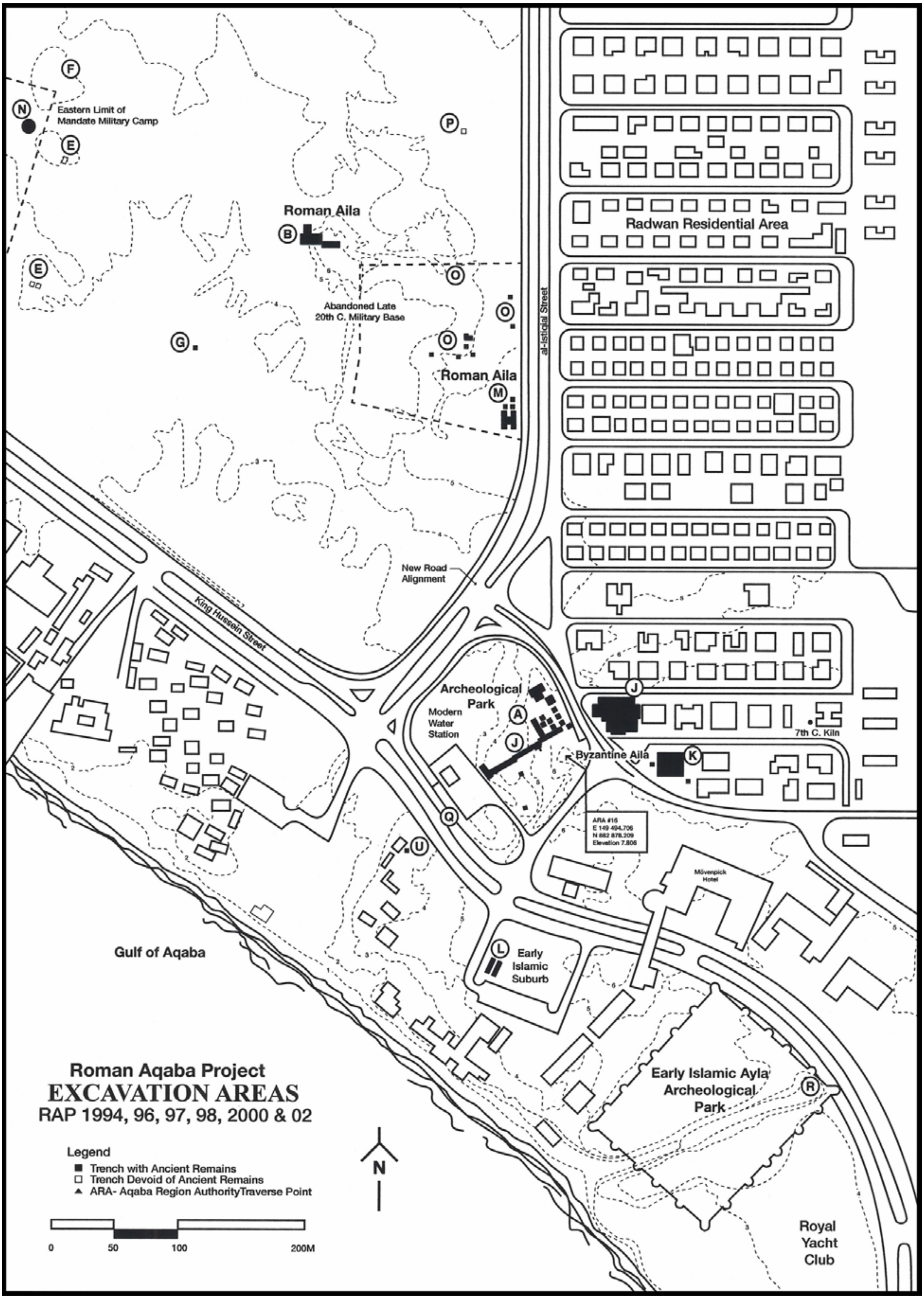

Figure 3.5: Locations of the areas excavated by the Roman 'Aqaba project discussed in the text (after Parker 2014: Fig. 5).

at least from the 6th–mid-8th centuries (Parker 2013; Melkawi *et al.* 1994; Whitcomb 2001a). These amphorae were traded particularly in the Red Sea environs, probably for their contents. Although the products transported in the vessels cannot be identified in most cases, there is, however, evidence of high quality *garum* (fish sauce) found in a Roman period jar at ʻAqaba/Aila. Hence, it appears that the amphora transport may have been linked with the export of fish products (Van Neer *et al.* 2010; Van Neer and Parker 2008). It is likely that the Red Sea fish products found at other places in southern Transjordan and the Negev were produced in ʻAqaba/Aila or at least transited through the town (Parker 1998b: 391). This hypothesis might explain the high number of both amphorae and Red Sea fish scales at Jabal Harûn, and a similar pattern may also be found at other sites in southern Transjordan and the Negev. The locally produced amphorae have been associated with the repacking of land-transported goods for sea trade (Melkawi *et al.* 1994: 463–464; Whitcomb 2001a: 299; see also Pecci *et al.* 2017). ʻAqaba/'Aila amphorae have been found in Petra and Humeima (ʻAmr 2001b; Holmqvist 2016a; Holmqvist 2013). Transport of these amphorae to the inland sites suggests that they were also used for the overland trade, and also that there were economic ties between the inland sites and the port city (see fish diet discussion in relation to Christian communities above). These issues will be further examined by analysing typical ʻAqaba/Aila amphorae sherds found at ʻAqaba in Byzantine and early Islamic contexts in comparison with amphorae with related stylistic and fabric characteristics found at the other sites.

To summarise the archaeological evidence from the contexts sampled for this study, the occupation in area A appears to have continued from the late Roman period into the early Islamic period. In this area, a cemetery was found, apparently abandoned in the 4th century (see sample A012 from locus A.10:21.93, a possible 4th century context), after which there were domestic quarters south of the cemetery in the late Byzantine period, 6th–early 7th centuries. This domestic complex was later reoccupied in the late Umayyad–early ʻAbbasid period, in the mid-8th century (Parker 2002: 412–418; Parker 2000b: 381–383; Parker 1998b: 381).

Domestic structures of the 1st–early 2nd centuries were unearthed in Area B, and there was also a second, late Roman, occupational phase from the late or mid-2nd century into the 4th century, and possibly later, when the usage of this area was characterised by baking activities – several ovens and remains of flour mills were found (Parker 1998b: 378–379). Thick natural clay beds with evidence of exploitation were also encountered, possibly being a clay source for ceramic manufacturing in the early Roman period (Parker 1998b: 378). Among the pottery finds from the site, there is an extensive number of imported vessels, particularly of Egyptian origin, but also Gaza jars, in addition to thousands of local ʻAqaba/Aila amphorae (Parker 1998b: 388–389). The evidence from the site shows an undisturbed transition into the early Islamic period, the Byzantine city continuing to be occupied throughout the Umayyad period into the ʻAbbasid period. However, the excavated areas seem to have been abandoned by the 10th century (Parker 1998b: 391; for samples from this area, see A004 from early Roman/Nabataean context B.1:18.13; A007 from 4th–5th century B.1:10.74; A008 from 1st–2nd century B.1:O.74; A009 from late Roman B.1:5.12; and A010 from B.1:0.69, A016 from B.2:56.59; and unstratified A002, A003, A005 and A015).

In Area J, the trench J.1–3 revealed a substantial mud-brick structure dating to the early Byzantine period, 4th century, and the Byzantine city wall was built partly on this building in the late 4th–early 5th century (see samples A014, A017 and A018 from 4th–5th century/early Byzantine contexts J.1:50.119, J.8:2.7; J.21:9:38, respectively). It is possible that the mud-brick building, tentatively identified as a very early Christian basilica on the basis of its orientation, general plan, finds such as glass fragments (oil lamps) and the vicinity of the cemetery (Area A), was destroyed by the 363 CE earthquake. There are also records of a bishop of Aila from 325 CE, attesting that there was a Christian community in Aila at this early stage (Parker 2000b: 383–390; Parker 1998b: 381–385; Parker 1996: 243). In Trench J.23, mud-brick walls belonging to late Byzantine/Umayyad domestic quarters were excavated (see sample A020 from a 7th century Umayyad context J.23:117.169). Possibly one of the gates of the city wall was blocked when these domestic quarters were built, and Umayyad ceramics were found in the blocking wall. The city wall went out of use in the late Byzantine period, around the 6th/early 7th centuries, and it was damaged by robbing in the Umayyad period, probably for the building of the early Islamic settlement, Ayla (Parker 2003; Parker 2002: 419–421, 427; Parker 2000b: 387, 390).

The starting date for the use of Area M was probably in the early Roman/Nabataean period, continuing into the late Roman period with possible disruption in the occupation. The late Roman structures in this area were mud-brick walls, and four ovens were also found. This area also yielded ceramic wasters indicating that there was an early Roman/Nabataean and late Roman period local ceramic industry near the excavated area (Parker 1998b: 379–380; see also Parker 2003; Parker 2002: 412–418; Parker 2000b: 378–381; see samples A001 from 2nd–4th century context M.1:14.31; A011 from late 1st–2nd century M.4:45.80; A013 from Roman/Nabataean M.1:14.31; and A019 from 1st–2nd century M.1:15.27). In area O, domestic structures were recovered, dating from the early Roman/Nabataean period (Parker 2000b: 377–378; see also Parker 2002: 409–412; see sample A006 from 1st–2nd century context O.1:8.21).

Chapter 4

Ceramic technologies, provenance and exchange

Ceramic traditions, styles and variation

Thematically, this work deals with ceramic traditions (*sensu* Franken and Kalsbeek 1975: 21), using typo-chronological ceramic categories, compositional characterisation and technological investigation to address issues of exploitation of raw material sources, ceramic manufacturing techniques, and ceramic provenance and exchange. Ceramic material cultures are multidimensional and complex systems, and to approach them one should apply multidisciplinary methodology and draw from archaeological, historical, environmental, ethnographical, experimental, technical and compositional evidence in order to assess factors possibly contributing to, and affected by, the specific nature of the *ceramic tradition* in question (see, e.g., Jones 2004; Kolb, 1989; Matson 1984; Tite 1999; Wright 1984; see also Binford 1962; Duistermaat 2017; Matson 1965). In an ideal situation, the entire ceramic research project would be tailored with analytical and archaeological knowledge hand in hand right from the beginning of the project planning (see Franken 1978/9: 78; Franken and Kalsbeek 1975: 26–27; Schneider 1995).

As discussed earlier, Byzantine and early Islamic written sources on ceramic production, exchange and trade are practically nonexistent. Hence, the understanding of ceramic systems of these periods needs to rely primarily on archaeological data, and interpreting ceramic artefacts and technologies in their unique social, ideological, political, economic and environmental contexts (for the development of the discussion, see for example, Dobres 2000; Hodder 1981; Peacock 1977: 23; Rathje 1979: 17, 19; Renfrew 1977: 3; Rice 1984b: 52; Sillar and Tite 2000; Skibo 1992; Tite 1988: 13; van der Leeuw 1984b: 59; Whitbread 2001: 449–450; see also Conkey 2006).

Ceramics can easily be seen as mass-produced items, but nevertheless, it is important not to focus solely on the strictly technical side of things (see Kingery 1982: 38-41). To quote Sillar and Tite, 'it is crucial to consider how the technology under study was embedded within wider environmental, technological, economic, social, and ideological practices' (Sillar and Tite 2000: 17). Ceramic manufacture is an act carried out in a specific socio-cultural context, in response to a certain demand presented by the community or user group. The conscious, and unconscious, choices made by a potter during the production process are influenced by these social, ideological, economic and political factors (David and Kramer 2001: 138; Mahias 1993: 177–178; Sillar and Tite 2000: 4; van der Leeuw 1993: 244). The formal and material properties of an object inform us about its technical history, but also symbolise the broader structural and perceptive dimensions of the society that produced and used it (Jones 2004: 335–336).

The applications of archaeological science methods continues to grow, but this tendency is perhaps not well reflected in classical and Near Eastern archaeology and particularly in the ceramic studies of these fields. There is still an apparent disparity between 'classical' ceramic studies (and indeed, even more so, in classical archaeology) concentrating on stylistic aspects and typo–chronologies and techno-compositional studies of ceramics. The latter is often seen as completely separate from traditional ceramic research (De Atley and Bishop 1991; Hamilton 2004; Jones 2004: 327; Rathje 1979: 19–21; van der Leeuw 1993: 238; Whitbread 1995; Widemann 1982). To quote Schiffer and Skibo (1997: 27): 'perhaps in our debates over style and function...we have all lost sight of the past artisan striving to create products that embodied causal factors respecting no modern theoretical and analytical boundaries.' The main focus of ceramic studies in Near Eastern archaeology still largely relies on typo-chronological analysis, although our understanding of ceramic traditions, production and distribution systems simply can no longer rely solely on typological evidence.

Typological classifications, as any method, should be carefully tied to the research context and questions, and treated as a research tool rather than an outcome (see, for example, Bortolini 2017; Hurcombe 2007: 55–60; Rice 1996a–b; van der Leeuw 1984a: 710–718). The typology debate is not new to artefact studies, and the discussion on the topic has been ongoing for decades (see Adams and Adams 1991; Bortolini 2017; for discussion). Hill and Evans (1972: 231–233) noted already almost half a century ago that 'classification is simply an extension of the recognition of differences and similarities among phenomena', type being a 'specific class of phenomena, characterised by a non-random cluster of attributes'. Similarly, the meaning and usefulness of a typology depend on the variables that were used (Whallon 1982: 127). It is impossible for an archaeologist to comprehensively conclude which typologically classifiable variables of the objects were useful and meaningful when the artefacts were produced and used. This poses problems related to variable selection in typological analysis (see Hodder

1999: 72–79; Jones 2002; see also Adams and Adams 1991; Hancock 2000; and Wheat 1991).

Archaeologists often work with sherds of broken objects, which provide only limited information of the original form or function of the artefact. In addition, detailed typologies and possible over-classification can produce data that are difficult to relate to other aspects of cultural behaviour (see Arnold 1985: 5). Hence, typologies are artificial and subjective categories created by the classifier. Furthermore, the archaeological record is created by finds that have survived and been found, kept and selected for further analysis. In this respect, even the starting point is already biased and offers very limited information, which is further altered by interpretations filtered through the individuals processing the finds and interpreting them (see Holtorf 2002: 62; Hurcombe 2007: 14–22, 49–53; Jones 2002: 39–62; Schiffer 1987: 3–11; Shennan 1988: 298–301; on formation processes of archaeological contexts, see, for example, Buxeda i Garrigós and Madrid i Fernández 2017: 30–42; Schiffer 1972; and Buchli 2004: 184; for further reading, see also Hodder 2005; Hodder 2004).

One major difficulty in the stylistic analysis of ceramics is to distinguish which characteristics, such as vessel form, surface treatment, rim or handle forms, and their variations, can be considered sufficient to differentiate ceramic styles and to identify regional variation or distinct ceramic traditions. In turn, the question remains what extent of variation can be accepted as belonging to the same stylistic and cultural tradition. The types we create are biased by our own concepts of utility and economy (Jones 2002: 95). Stylistic transmission and other similarities in ceramic traditions can result from various and complex social, economic, political or religious factors, depending on the nature of the society in question (Cullen 1984: 77–79; Hill and Evans 1972: 252–253; Hodder 1993; Hodder 1991; Plog 1978: 151, 178; Shepard 1956: 245–248). Stylistically similar objects may originate from various workshops, and on the other hand, very different forms and styles might have been produced at the same time in the same area or workshop (see Bar-Nathan 2011a: 211, for the Bet Shean evidence).

Keeping the subjectivity of ceramic classifications in mind, when dealing with an area that belongs to the same cultural context (e.g., southern Transjordan and the Negev in Byzantine and early Islamic periods), but includes different regions and local sub-traditions of material culture (as is apparent from the five assemblages sampled for this study), it is of importance to also see the wider material culture trends (i.e., stylistic similarities in ceramics published from southern and northern parts of today's Israel and Jordan), possibly shared by the cultural area before indulging in further interpretations on cultural regionalism based on local ceramic traditions.

As an example, open-form cooking pots typical of late Byzantine and early Islamic ceramic assemblages (characteristics discussed in more detail in the ceramic catalogue) seem to display minor variation in rim forms, handle placement or surface treatment in different regions, but share the general morphology. Although it is difficult to establish which characteristics of the cooking pots were the most meaningful for their producers and users, similar general morphology is usually taken as an indication that they were used similarly, for example, placed similarly upon the fire, used to cook similar dishes, thus being part of the same cultural matrix. The variation in the vessel details between the southern and northern areas can be used as evidence of separate material culture traditions, but the characteristics shared by the vessels from different sites and regions may equally indicate similar influences followed by local potters.

Common principles with regional variation in ceramic traditions might indicate 'regional micro-styles', where variation in stylistic expression occurs despite cultural connections and shared technological and functional choices (see Gosselain 1992: 560–561; for further references). Franken writes on the definition and variability of tradition that 'a tradition may be confined to few workshops…on the other hand a tradition may be found spread over large areas and be applied in many workshops…' (Franken 2005: 15; Franken and Kalsbeek 1975: 21). In addition to the possibility of similar stylistic trends being followed in the production of separate workshops, there is also the possibility that similarly styled ceramics in different sites and regions are the result of travelling potters manufacturing vessels in similar styles but exploiting local raw materials at different locations (travelling brick workers at building sites have also been suggested, see Peacock 1982: 35; see also David and Kramer 2001). General trends in compared ceramic traditions can be as significant as apparent variation, for instance, size, shape and decoration may vary, but 'certain characteristics appear repeatedly throughout the set even though no single one is necessarily present on or diagnostic of all pots' (David and Kramer 2001: 139). These potential similarities occurring should be considered at least as important as the differentiating factors between the assemblages and traditions.

Subtle variation in the details might merely reflect variation between different potters, possibly even within the same workshops, as known from ethnographic studies. Technological variation can appear between different workshops, but also in the products of the same workshop or the same potter (Blackman *et al.* 1993: 76; see also Roux 2017; Roux 2003). Thus, there is a risk that variation in ceramic artefacts, used by archaeologists to define styles, traditions and embedded cultural connotations, can merely be a result of variation in manufacture (see discussion in Sillar and Tite 2000: 11–12). For these reasons, one should not expect a 'regular change' in correlation with the chronology (Lucas 2005: 103–104), or link technological variation with chronological changes (Franken and Kalsbeek 1975: XV). Changes in ceramic manufacture can happen for a number of reasons, for example, because of other economic needs of the community, requiring specialised products (Hodder 1979: 451, see also Hodder 1993; and Hodder 1991).

The concepts of style and technology fuse together and are dependant on one another, form complex relationships and influence each other in a cultural context (Jones 2004: 331; Wright 1984; see also Cumberpatch 1997; and Sackett 1977: 371). The potter was required to produce ceramics that were stylistically and socially acceptable, and functional within the limits of the technology and raw materials provided. In order to understand the stylistic attributes, one needs to comprehend the technological choices available for the potter, and the ways they might alter ceramic typologies (Gosselain 1992: 561; Shanks and Tilley 1987: 137–155; see also Lechtman 1977; and Miller 2007: 36–39, 191–195 on 'technological style' and symbols in style and technology).

Chaîne opératoire and technological change

One of the most prominent concepts in the interpretation of material culture in archaeology is that of the 'operational chain' or *chaîne opératoire*, which Schlanger defines as 'the range of processes by which naturally occurring new materials are selected, shaped and transformed into usable cultural products' (Schlanger 2005: 25, for the theoretical background of the term, see Dobres 1999; Dobres and Hoffman 1994: 237–239, 245; Miller 2007: 29–30; Roux 2017; Schiffer 2004; Schiffer 1995: 55–66; Schlanger 1994: 144–145; Sillar and Tite 2000: 3–5; and Whitbread 2001: 455–456). In ceramic material culture, this sequence is attested by the actions of the potter, by selecting and mining clay sources, manipulating the clays by mixing or washing them and adding tempers, forming and shaping the vessel, decorating it and applying surface treatments and firing the vessel. These actions leave 'material traces' and 'by-products' that can be traced in the archaeological record, in order to reconstruct the various stages of the material operations and technical choices, and their links and effects, leading the way to further socio-cultural interpretations of their meanings (Schlanger 2005: 25–27). Importantly, the concept of *chaîne opératoire* entails not only a methodological procedure – arranging the information in a sequence of actions from raw materials to finished products – but also a theoretical commitment to integrate these actions in the context that ultimately explains why and how those actions took place (see Roux 2017; Roux 2007: 164–166; see also Courty and Roux 1995; Franken and Kalsbeek 1975; Loney 2000; Neff 2001; Rice 1991: 263–266; Roux 1989a; Roux 1989b: 69, 144; Schiffer *et al.* 2001).

The availability and suitability of raw materials is obviously an important constraint in the development of ceramic production, and the lack of suitable resources may in some cases explain the lack of production in a society. However, this could be an oversimplification of the matter, as there is ethnographic evidence of the long-distance transportation of raw materials for ceramic production (Arnold 1985: 20). Ethnographic studies have shown that although raw clays are most often transported only a few kilometres, there is evidence of raw clay transportation for distances as far as 50 kilometres, the distances of paint and slip materials transportation rising to hundreds of kilometres (Arnold 1985: 39–49). Another resource-based argument often used against the existence of local ceramic production in arid areas such as southern Transjordan and the Negev is the availability of fuel. There is however evidence of ceramic mass production at sites such as 'Aqaba/Aila, where the source of the enormous amounts of fuel required for this kind of industrial production remains uncertain (Parker 2014: 214). It is possible that fuels were also transported or acquired from other sources not necessarily visible in the archaeological record. For example, there is ethnographic evidence for the use of agricultural waste as a fuel in ceramic manufacturing (Peacock 1982: 25). The use of discarded organic materials as a fuel might also be the case in the 'Aqaba/Aila ceramic production.

Although materials can be transported, the available raw materials in a way condition the production methods, and the ways potters select and mix raw materials (clays and tempers) determine the characteristics of the 'end product' (Rye 1981: 16–19, 36–40; Henderson 2000: 115–142). Nevertheless, it should not be assumed that the potters are limited by the available raw material sources, since they are able to manipulate the available materials in order to gain the desired result (Sillar and Tite 2000: 3; see also Sillar 2000). Raw materials are the essence of any artefact production, but the technologies would not exist without social, cultural and practical meanings (Dobres and Hoffman 1994: 213–214; see also Costin 2000; and Silva 2008). Thus, in addition to raw materials and technical skills, socio-cultural and economic factors, such as organization of the production, also contribute to the nature of ceramic industries (e.g., Sillar and Tite 2000: 7; see also David and Kramer 2001: 165).

Notwithstanding the socio-cultural and environmental influences outlined above, artefacts were produced with a certain purpose and performance in mind, thus, also the intended performance and usability of the finished object required modifications of the raw materials and techniques used. For example, characteristics like thermal shock resistance, fracture resistance and cleaning possibilities are essential for a cooking-pot (Kilikoglou *et al.* 1998: 261; Kingery 1996: 195–200; Müller *et al.* 2016; Tite and Kilikoglou 2002; Tite 1988: 11–13). Variability, such as the 'technological choices' made by the individual involved, the potter, is an essential factor in ceramic production, and therefore one should not anticipate identical end products in detail, even when the same production, potter, raw material and manufacturing sequences is applied (see Schiffer and Skibo 1997: 27–30). Different appearance, such as the colour of the fabric of a finished ceramic object, does not necessarily mean that vessels with different characteristics were produced from different of raw materials, or originate from different production and sources. Franken and Kalsbeek (1975: XV) underline that 'shape and color can be very misleading if not seen within the framework of the potter's routine' (see also Bar-Nathan 2011a: 211). Ceramics produced using the same technology and materials can have different paste colour and vitrification, resulting from slight variations in the firing conditions, such as the fuel used, duration and temperature of the firing, and oxygen supply (see Blackman *et al.* 1993: 67; Bland *et al.* 2017; Quinn 2013: 188–203).

The design of a vessel is also determined by its composition and the desired mechanical performance. For example, the general form, uniform thickness of walls, and absence of sharp angles in the form add to the resistance to thermal shock. Certain paste compositions may help to minimise the breakage of items during transportation or when heated. The selection of inclusions also has an affect: calcite, plagioclase, and various heavy minerals have a similar thermal expansion to fired clay (see Bishop *et al.* 1982: 313; Bronitsky and Hamer 1986; see also Bronitsky 1989; and Feathers 1989). Experimental studies have illustrated that the combination of a low temper concentration and a high firing temperature produce pottery with high tensile strength, increasing the vessel's strength (Bebber 2017; Tite *et al.* 2001: 321; see Feathers 2003 for discussion). On the other hand, a high temper concentration combined with a low firing temperature improves pottery's toughness and thermal shock resistance, characteristics that are fundamental for cooking utensils, although the tempers differently affect calcareous and non-calcareous clays due to different thermal expansion of the clay types (Barone *et al.*, 2012: 20–21; Tite and Kilikoglou 2002; Tite *et al.* 2001: 321). Shell and limestone temper can also be used to reduce the thermal expansion of the clay and to stop crack propagation caused by thermal or mechanical stresses (the firing conditions should be monitored with care to prevent spalling, lime blowing, and the temperature should not exceed *c.* 650°C in an oxidising atmosphere or *c.* 750°C in reducing atmosphere; Bebber 2017; Tite and Kilikoglou 2002; Tite *et al.* 2001: 322).

High porosity and permeability of the vessel wall caused by the high temper concentration and low firing temperature can decrease the heating effectiveness of the vessel. This problem can be overcome by adding an impermeable surface treatment on the interior of the vessel, although this can reduce the thermal shock resistance (Tite *et al.* 2001: 322). Large voids, achievable by using organic temper, increase the thermal shock resistance, although slip might be needed to control the permeability (Rye 1981: 27). Studies have also demonstrated that quartz temper increases the toughness of cooking pots and amphorae in particular (see Vekinis and Kilikoglou 1998). Toughness, linked with vessel portability, is an important characteristic for a container, but also porosity, to keep the contents cool, and strength to carry the weight are essential technological qualities for transport vessels (Bebber 2017; Kilikoglou *et al.* 1998: 274). Interior and exterior treatments can affect the resistance to thermal spalling and thermal shock cracking in cooking pots, and exterior texturing can particularly help to prevent thermal cracking (Schiffer *et al.* 1994: 209; Schiffer 1990: 380; see also Pierce 2005: 124–154).

Ceramic provenance and exchange

Technical studies of ceramics typically focus on processing, production, structure, properties, applications and performance of ceramic artefacts and their raw materials (Kingery 1996: 175, 195–200; see also Vandiver 2001), with a view to reconstructing the provenance, distribution channels and trade of the ceramics (Tite 1988: 9), and go from there to address questions of broader archaeological relevance. In general in the field of ceramic studies, a positive increase can be seen in the number of experimental studies of cooking vessels, concentrating, e.g., on their performance characteristics. Studies related to economic aspects, however, such as exchange and distribution, typically deal with fine wares (see Baklouti *et al.* 2014; Tite *et al.*, 2018; Rice 1984c: 45). This pattern of neglecting the cultural and economic values of common wares and their role in exchange systems has led to a biased research outcome where domestic wares and their socio-economic connotations are nearly invisible. In addition to the practical level, much of the theoretical discussion concerning the concept of exchange in archaeology has similarly focused on 'high value commodities' (Riley 1984: 57).

Provenance analyses of pottery aim to study the distribution of workshops, movement of people, cultural influences, trade networks, and other relationships between sites (Kilikoglou *et al.* 1988: 37). There are different approaches to provenancing archaeological ceramics. First, ceramics of known provenance, such as kiln wasters, can be analysed in comparison with ceramics from other locations. Second, large quantities of ceramics from a single site can be analysed in order to establish compositional groups, of which the largest group is assumed to be local. Third, chemical compositions of ceramics can be analysed in comparison with natural clays in the area to pinpoint clay sources (Kilikoglou *et al.* 1988: 37). In this book, a combination of the first two approaches are employed.

The comparison of archaeological ceramics and potential raw material sources, entails some important complications: potters manipulated their clays and tempers, the composition of the ceramics also varied in the firing and was possibly affected by post-depositional conditions. The approach has been criticised, for example, by Wilson and Pollard, who state that 'it is fair to report that very few chemical studies of pottery have successfully and unambiguously linked vessels with raw material sources, or even attempted to do so' (Wilson and Pollard 2001: 511). The core of the problems related to sampling possible raw material sources for ceramic provenance analysis lies on the human factor behind ceramic manufacture: pottery making does not rely only on the right geology of raw materials, but it is a craft in which clays were washed and mixed, water and tempers were added and the products were fired (see Arnold *et al.* 2001: 70–71; Buxeda i Garrigós *et al.* 2003; Frahm 2018; Hein and Kilikoglou 2017; for discussion; and Henderson 2000: 110–142 on ceramic production procedures and the alteration of clays in the manufacturing process).

Due to these cultural practices, the actions of the potters that affect the elemental concentrations of ceramics, ceramics cannot be compared to clays and tempers in a 'one-to-one manner'; thus, the composition of pottery is actually the sum of the various chemical and cultural components (Arnold *et al.* 2001: 87–88). Correspondingly, pottery produced using the same raw materials, technology and by the same community should have the same chemical composition. In other words, the groups made based on ceramic analysis will correspond to different 'recipes', but not necessarily to different geological sources. If comparisons with raw material sources are attempted, the ways potters manipulated the raw materials, e.g., adding tempers, mixing clays from different sources and purifying clays should be taken into account and the analytical data should be corrected according to the pottery manufacturing practices, for example, the raw clays should be purified and fired before comparisons (Adan-Bayewitz and Perlman 1985; Henderson 2000: 117; Kilikoglou *et al.* 1988: 37, 45; Quinn 2013: 154–171).

Problems can arise even when ceramics produced using the same clay are analysed since different added amounts of common tempers, such as sand and lime, affect the element concentrations, and the samples are likely to be categorised differently in multivariate statistical analysis (Frahm 2018; Mommsen *et al.* 1988: 47). This stresses the pertinence of combining chemical and microstructural studies. Compositional comparisons of ceramic artefacts and raw materials are based on several assumptions, namely that the chemical compositions of the raw materials are unchanged or predictably comparable in the finished product, the chemical 'fingerprint' is different between sources and can be analytically characterised in the object with precision allowing discrimination between different potential raw material sources. Furthermore, it is assumed that there is no mixing of raw materials in the production or it can be recognised, there is no post-depositional variation or it can be identified analytically, and that the observed patterns of exchange can by explained by human behaviour (Wilson and Pollard 2001: 507–508).

If the pottery manufacture does not include drastic manipulation, mixing of clays or adding tempers, it may be possible to successfully match raw clay sources and ceramic chemical compositions for provenancing purposes (see Wieder and Adan-Bayewitz 2002). Geological literature and maps may be used as additional tools in ceramic provenance studies, although they generally do not tend to have information on clay deposits. However, geological surveys and maps can offer information on the possible origins of the tempers (Howard 1981: 7). Although provenance studies by sampling clay sediments can be successful, this approach, requiring intensive geological surveys, falls outside the scope of this book and practical constraints. However, the analytical data and methods of this study will be presented in a way that allows future studies, perhaps covering clays, to be compatible with this work, and available geological information will be referred to in the interpretation of the analytical data.

Lacking analyses of geological clays, many of the provenance attributions made in this study will rely on the use of 'reference groups' and the hypothesis that the largest compositional group is local to the site in question. This assumption is based on the 'criterion of abundance', according to which 'a ceramic unit strongly represented at a site is presumed to be of local manufacture, scarcely represented pieces being of nonlocal origin...according to the basic assumption, a greater proportion of locally produced pottery is consumed locally than is disseminated to any other single site' (Bishop *et al.* 1982: 301; see also Baklouti *et al.* 2014; Montana *et al.* 2018; Santacreu and Cau Ontiveros 2017). As any assumption, this approach is not without its risks, however, for sites with long occupational sequences, such as those studied for this project, but the hypothesis seems reasonable and, as argued later, coherent with the economic model inferred.

There are further possible problems related to the 'reference group' approach where the main compositional group is considered to be local to the site in question. Problems may arise if the results are based only on bulk chemical data, and the clay paste composition and mineralogical inclusions are not analysed. The reference groups are based on the assumption that there is less variation within a single clay or temper source than there is between different sources. However, the variation of coarsely tempered ceramics produced in the same workshop using the same raw materials may, in some cases, result in their categorisation to different groups in statistical analysis unless the clay paste composition is taken into consideration (Buxeda i Garrigós *et al.* 2003). It has been demonstrated that even samples prepared from the same vessel might be assigned to different groups in bulk chemical analysis due to chemical variation caused by tempers. Thus, it is essential to selectively analyse the paste composition in ceramic provenance analysis, as it is more directly linked to the original clay source than the possibly processed ceramic fabric (Buxeda i Garrigós *et al.* 2003: 14–15). Considering the issue of raw material sources, it should also be noted that more than one production centre may have exploited the same source areas, that one production centre exploited more than one source area, or that there was material exchange between the producing areas (Bishop *et al.* 1982: 301; see also Mommsen 2001 for discussion; and Stoltman *et al.* 2005 as an example of two way regional exchange of ceramics).

Considering all the above problems, the 'integrated approach', where bulk chemical analysis is combined with microscopic analysis, such as scanning electron microscopy or petrographic microscopy, is considered preferable over relying solely on compositional groups formed on the basis of bulk chemical data. In addition to the bulk chemical composition of a ceramic sherd, the ceramic paste and mineralogical inclusions can be analysed separately, and the question of intentionally added non-plastic, coarse-grained materials should be considered in order to form meaningful compositional groups for provenance studies (Arnold 1981: 33–34; Blackman 1992: 113; Buxeda i Garrigós *et al.* 2003: 14–15; Carvajal López *et al.* 2018; Tite *et al.* 2018; Tite 1999: 201; Stoltman *et al.* 1992; Tschegg *et al.* 2009; see also Day *et al.* 1999).

As a note for sample preparation for bulk chemical analysis, the sample size should correlate with the coarseness of the ceramics, i.e., larger samples should be used in cases of coarser materials, in order to provide a representative and homogeneous sample of the ceramic sherd, to also allow elements that tend to distribute heterogeneously, such as manganese, to be represented. A non-homogeneous sample can lead to elemental variation that is not representative of the original sherd (Bishop *et al.* 1982: 292–293). Mommsen notes that in cases where no additional information on the production technology or the ceramic paste is needed, chemical analyses alone may be adequate for ceramic provenance studies when certain guidelines are followed, such as representative samples, sufficient number of measured elements and high experimental precision (Mommsen 2004: 267–270). This book combines chemical and mineralogical approaches in order to obtain information on ceramic technology, not just provenance, and to facilitate future comparisons by other scholars.

The chemical elements that are meaningful for provenance analysis can vary depending on the analysed ceramic materials. In some cases, variation in one element can be considered adequate to identify a difference in the raw material utilised, but generally several elements should be considered, preferably showing clear differences of concentrations in different ceramic types, and relatively small differences in ceramics of the same type. The correlations between different elements should be studied by statistical methods, such as cluster analysis, in order to identify compositional groups (Wilson 1978: 222–223, 226–233, see further discussion of statistical methods used in this study below). In addition to interpreting the analytical data, it is important to review which archaeological questions, concerning, for example, the provenance, technological procedures and dating, can be answered and with what level of certainty (Kingery 1982: 41–43).

Moreover, different cultural and environmental processes might have affected ceramic artefacts during their use and after they were discarded, and these processes should be carefully considered in the examination of the physical properties of the objects (Tite 1999: 183). In addition to the alteration of raw materials in the course of ceramic production and the possible use-effects during the life-span of the object, the burial conditions might also affect the chemical compositions of archaeological ceramics.

Burial conditions can cause variation in the elemental concentrations of ceramics, affecting the near-surface part of the sherd, or its entire body (Freestone 2001; Heimann and Maggetti 1981; Schwedt *et al.* 2004: 89–96). For example, Schwedt *et al.* have shown in their NAA study, in which they compared samples taken from the surface and the core of the sherds, that the samples taken from the surface of the sherds, more affected by the burial conditions, showed reduced concentration values of Ca and alkali metals Cs, Rb, K and Na compared to the core samples of the same sherds (Schwedt *et al.* 2004: 89–96).

Ceramics were produced for a certain reason. A demand for products may depend on factors such as the needs for vessels in the community, utilitarian and technological needs for certain vessel forms, life-span of ceramics, and population size and density of the society (Arnold 1985: 127–128; see also Costin 2000: 396–397). Ethnographic studies have demonstrated that market conditions and demand for new styles are the factors that most alter pottery production (see Foster 1965), ceramic craft being 'essentially an economic activity, whether practised at a household or factory level' (Peacock 1982: 6). In addition to demand and the market situation affecting ceramic production, the degree of centralised administrative control over economic issues and trade can be reflected as competition between producers; different degrees of control can also result in regional differences in ceramic production and exchange systems (Feinman *et al.* 1984: 302–303). The power of demand and markets over ceramic production systems can also be seen in potters operating in modern tourist markets where changes can be introduced to the products quite rapidly in response to the requests of the tourists (see Rice 1984a: 250 for further references).

Cooking utensils and other domestic ceramics are often considered of less economic value, as common ware pottery transport is usually linked to the trade of agricultural products (see, for example, Pucci 1983: 110–112; Riley 1984 and further discussion in the previous chapter). However, even in regional contexts, compositional analyses are required to ascertain that domestic ceramics of similar morphologies originate from the same production site and share the same technological and raw material characteristics. Archaeological research on exchange cannot not be based on suspected value alone, especially as there is evidence that coarse wares, including cooking pots, were also subjected to inter-regional trade and exchange (see, for example, Adan-Bayewitz *et al.* 2009; Adan-Bayewitz 1993). To quote Renfrew (2004: 30): 'the transport facilities, the very kitchen utensils, the containers and storage facilities, it is these which constitute much of the engagement with the material world for the individual and for the community'. Smith (1999: 114) also writes that '"ordinary" goods are the principal products turned out by industrial manufacturing apparatus'.

Without direct evidence, it is difficult to evaluate the economic value of coarse ware ceramics. On a more symbolic level, changes in the value systems of the society might make the ceramic traditions more open to innovation and new influences. Ceramic industries, as any economic activity, would be affected by a change in the economic or political environment, for instance, changes in power structures of the community. A new ruling class may have particular demands concerning ceramic forms and styles (Rice 1984a: 248–249). Ceramic traditions may also reflect asymmetries of political power, in which case the individuals with higher political power dominate the ceramic tradition according to their needs, whereas the requirements of the lower classes, for example, for performance or design of the vessels, do not have similar weight, although the latter might be the actual user-group of the products (Schiffer and Skibo 1997: 43). Political changes often affect economic organisation and the 'productive capacity' of the community, and this kind of economic stress can make neighbouring groups more reliant of each other (Hodder 1979: 450).

Certain changes in circumstances might have a more direct effect in ceramic manufacture than other activities. For example, changes in the availability of resources, such as fuel, might force the potters to search for new resources and alter their technologies accordingly. Introduction of new diets and dishes, or decline of consumables, or crop failures, might eventually lead to the development of new food preparation methods and new cooking vessel forms (Rice 1984a: 245–247). Cooking practices, what is cooked and for how long, how often, and with which fuels, vary, and these variations are reflected in the required vessel properties, morphology and performance (Schiffer 1990: 374). Changing circumstances and increased demand for ordinary goods, such as oil (and pottery used to transport oil) might rapidly raise their market value, changing the economic relationships between luxury and common goods (Smith 1999: 114; see also Hayden 1998 for 'prestige' and 'practical' goods in archaeological contexts). Ideally, one should study the exchange of not just one artefact category, such as ceramics, but to compare the exchange patterns of different artefact categories, such as ceramics and metals, or preferably the full range of artefacts and other products that play a role in the trade and exchange system in question (Tite 2001: 447; Tite 1999: 195).

In order to understand ceramic distribution, one should aim to establish whether the ceramics were distributed directly from the production centre or via a market place. This kind of evidence is not easily drawn from the archaeological data, but different models of production and distribution networks can be sought based on ethnographic studies. For example, exchange of large quantities of ceramic objects and wide distribution areas usually indicate trading at market places instead of workshops (Spriggs and Miller 1979: 26). Locations near large cities and connections to transportation networks were often essential for large ceramic production centres (Arnold 1985: 165). In addition, potters tend to cluster in urban environments, in the vicinity of consumers, but there are also examples of rural production, sometimes specialised in the production of certain vessel types, far from commercial centres (Peacock 1982: 38–43; Peacock 1981: 190–191).

Production beyond the need for self-sufficiency and for exchange may in some cases indicate specialised production, and distinctive skills that have market value (Rice 1991: 266). In addition, a good location of the production centre, particularly in the vicinity of coastal areas allowing low-cost and low-effort transportation of the products, can be to the advantage of some centres (Spriggs and Miller 1979: 26–27). In addition, also the technological choices in pottery manufacture, the technological properties of a vessel affect its exchange and transportation possibilities. The shape and strength of the vessel affect its breakability in transportation and suitability for packing, hence, potters are likely to try and facilitate the specific requirements of the planned use of the vessel in their production (Sillar and Tite 2000: 7–8).

Communities that are self-sufficient in terms of ceramic production can be active members of ceramic exchange networks and also receive ceramics produced elsewhere, even if their own production would be adequate to respond to the demand within the community. Ethnographic studies have shown that households and communities that had their own ceramic supply and production were actually more likely to have received pottery produced elsewhere as a gift or via exchange (Costin 2000: 397). Some ethnographic studies have shown that only the highest quality of local ceramics were traded at market places whereas other local wares were used and distributed mainly in their production areas (Spriggs and Miller 1979: 26). Peacock writes that 'pottery distributed through periodic urban markets or fairs would produce a rather distinctive archaeological pattern...a concentration in the town and a thinner scatter in the countryside around' (Peacock 1982: 156).

High transportation costs and difficulty in transportation are often considered to have had a negative impact on inland transportation networks of ceramics, particularly at a long-distance level and in the case of coarse ware ceramics. In this sense, there is intriguing ethnographic evidence from Spain (Vossen 1984), where large ceramic containers, mainly used as water jars, were manufactured in centralised and specialised production centres and transported for long-distances, even hundreds of kilometres, to seasonal markets. This evidence is particularly interesting here, as it shows that the traditional way to transport the pottery over the long-distances was by donkeys. The large vessels were tied to the backs of the animals or piled in carts. The pack animals enabled the transportation despite the poor condition of the roads, and the long-distance trade was made profitable by the centralised production and high demand for efficient water jars in dry and hot areas. Outside the jar trading season, the tradesmen were involved in the trade of agricultural products (Vossen 1984: 343–360).

Chapter 5

Catalogue of the analysed ceramic artefacts

This chapter is a descriptive catalogue of the ceramics sampled for the techno-compositional ED-XRF and SEM-EDS analyses. The total of 141 ceramic sherds sampled for this study includes 38 sherds from the Finnish Jabal Harûn Project excavations (sample code JH), 43 from the Khirbet edh-Dharih (sample code DH), 20 from the Roman ʻAqaba Project excavations (sample code A), 20 from Elusa (sample code E) and 20 from the Abu Matar excavations (sample code AM).

The ceramics are presented in morphological and functional categories, including discussion on their style, chronology, context and examples of published parallels (for drawings and photographs of sampled ceramics, see Appendix I; for context descriptions, see Chapter 3). Regarding assigning forms to the sampled ceramics, it should be noted that vessel forms and sizes can only be tentatively identified when dealing with sherds, and it is not possible to know the uses of an archaeological object with certainty (see Orton *et al.* 1993: 76–80 for discussion). Sampling fragmentary vessels was inevitable, as the analytical methods required invasive sampling. In addition, it should be underlined here that in terms of typo-chronological ceramic analysis, the total number of 141 samples from five sites allows only limited possibilities for intra and inter-site study.

In the study area, many excavations have concentrated on urban sites, resulting in a biased socio-economic picture of material culture in a region where the majority of the population was likely to live in rural areas. During recent decades, however, a shift in archaeological research interest can be seen, and an increasing number of surveys and excavations are concerned with rural, pastoral and agricultural sites. Many archaeological reports are disadvantaged by the limited number of published ceramic finds, representing only a very restricted and artificially selected proportion of the assemblage retrieved from a site.

A comparative chronological study based on critical evaluation of published ceramic evidence is necessary to provide insight into the general chronological framework of specific ceramic types. This is often the only method of approaching the question of chronology of finds when dealing with contexts with few datable finds other than ceramics. Relying on published ceramic data presents us with problems, such as perpetuating flawed chronologies and out-of-date data. In this chapter, possible comparanda published from relevant sites are given to illustrate how the sampled ceramics fit in the ceramic material culture of late Byzantine–early Islamic southern Transjordan and the Negev and in the wider geographical context.

To form a picture of the ceramic traditions relevant to this study, one is forced to draw from numerous separate site reports, although their varying standards do not always offer an ideal basis for a comparative typo-chronological analysis. Dates in site reports suggested for ceramics of these periods can often be ʻconfusing or contradictory' (Stacey 2004: 11; see also Avni 2014: 31). It is not always clear from the ceramic report, whether the chronological assignments are based on intra-site data or dates of parallel finds from the literature. If the contexts are dated on the basis of other finds, such as coins, glass or ceramic lamps, one should also consider the chronological issues related to these find categories, such as coins being used for centuries after their minting (see Magness 2003: 205).

Primary excavation data and ceramic collections are rarely open for researchers to tackle these questions. As a consequence, it can be nearly impossible to suggest anything other than relatively wide chronological margins with any certainty for ceramics found at sites where absolute dates are not easily associated with the stratigraphy. The lack of coin finds, for instance, is typical of the southern sites during these centuries, making ʻsecure site chronologies next to impossible' (Walmsley 2007a: 59; see also Avni 2014: 31).

For this book, the ceramic samples were primarily selected from well-stratified deposits that contained stylistically and chronologically consistent ceramic corpora. However, the lack of securely datable objects affects all of the archaeological contexts under scrutiny here, limiting the possibilities for an intra-site absolute chronology for the deposits and finds. Available stratigraphic data were employed to sample ceramics primarily from late Byzantine and early Islamic period contexts with some earlier or later exceptions to examine chronological variation (see Chapter 6 for sampling strategy). The sampling was carried out in well-stratified loci identified by the excavators, yet full records of the stratigraphy and other finds were not always available for evaluation due to unfinished processing of the excavation data. The lack of information of other datable finds in the contexts naturally affects the possibilities of assigning an absolute chronology to the finds and it is therefore necessary to rely on published parallel data for chronological purposes.

Prior to the sample selection, a thorough examination of the entire ceramic assemblages from the excavations was carried out (excluding the Roman 'Aqaba project samples selected by the excavation director, S. Thomas Parker) to gain samples representative of the nature of the ceramic collections. Nevertheless, the selected objects can, in any case, form only a very limited representation of the vast ceramic assemblages recovered at the sites. Thus, it is hoped that the sampled ceramic artefacts, and the broader review of published comparative material, will provide a useful framework for the contextualisation and interpretative models of the acquired techno-compositional ceramic data.

Following the sample selection, the samples were examined macroscopically and described, photographed and drawn. In the catalogue, descriptions of the ceramic samples include interpretations of their function, stylistic details and chronology, and these aspects will be discussed in light of comparative ceramic information from other relevant sites. The descriptive classification is primarily based on vessel forms and functions, the main emphasis being on ceramic description rather than actual typological categorisation in a traditional sense. In my view, ceramic typologies are useful tools in ceramic research, and play a necessary role in artefact processing, but typological classes are most useful when formulated in concordance with materials science studies of ceramics. The compositional groups are compared and discussed in relation to the typo-chronological information presented in the descriptive catalogue. The interpretation of the data, in any case, relies on the combination of the data sets, both archaeological and techno-compositional.

At current, the understanding of the typo-chronologies and the development and survival of the late Byzantine–early Islamic utilitarian and domestic ceramic traditions in southern Transjordan and the Negev still requires scholarly efforts. Sauer and Magness (1997: 475) noted two decades ago that Islamic ceramic studies have traditionally concentrated on art historical studies of glazed vessels 'at the expense of the fragmentary and often unglazed material recovered on excavations' and this still applies today. Such research focus is unfavourable for the study of economic systems of rural communities, especially as glazed wares typically form only a small minority in excavation assemblages, thus, it is time to focus more on 'the vast uncharted seas of everyday wares' (Johns 1998: 84).

Scientific provenance analysis of utilitarian and domestic Byzantine and early Islamic ceramics in this region are also still rare, and suggested source and distribution areas of specific ceramic products are often based on stylistic characteristics, although typologies and macroscopic investigations are inadequate to distinguish actual material exchange from cultural diffusion and assimilation of craft traditions.

The questions of the flow, direction and origin of influences are of huge importance especially when dealing with a period of major socio-cultural shift but these phenomena are difficult to examine on the basis of archaeological evidence, especially in a chronological context. The same applies for material exchange, it can be challenging to quantify the exchange and securely identify products exchanged in the same system and timeframe, based on the fragmentary archaeological data alone.

Traditionally, the southern and northern ceramic traditions have been seen as separate, with strong regional features and little shared characteristics or material exchange. However, evidence for north-south contacts can be drawn from more recent research and this interpretation no longer seems reliable (Stacey 2004: 21, 89; Sodini and Villeneuve 1992; Walmsley 2007a: 59; Watson 1995; Watson 1992: 246; see Gerber 2016: 168 for the traditional view). In this book, the typo-chronological ceramic analysis builds on a hypothesis that there can be an analogy in craft traditions of different, yet related regions, such as the southern areas, and areas further north (see Whitcomb 1989c). While looking for shared cultural trends in ceramic traditions, one cannot expect to find identical ceramics at different sites and regions, as there are manufacture-related factors that affect the appearance of the vessel, even in the products of the same workshop, hence, certain level of variation needs to be accepted within a common tradition (see Chapter 4).

For instance, according to the evidence from Gharandal, located *c.* 50km north of Petra, it is stated that 'often the ceramics of the Early and Middle Islamic periods in southern Jordan have been regarded as very distinct and separate from those of the north... there are indeed differences, but [the excavations at Gharandal] have also shown that some contact and/or cultural influence from the north is represented in the ceramic assemblage' (see Walmsley and Grey 2001: 162). As an example, early Islamic red-painted jars and bowls that appear in 8th–9th century contexts have been considered to be a phenomenon restricted to the northern areas (Sauer and Magness 1997: 476–477; Schick 1998: 90). However, excavations have also revealed red-painted early Islamic ceramics found at sites in central and southern Jordan (see, e.g., Alliata 1991; Waliszewski 2001; Walmsley and Grey 2001, and research materials of this study), although in small quantities.

The presence of painted vessels at southern sites is of particular interest as it has been suggested that these wares were produced at Jerash (see Schaefer

1986), although alternative sources are also possible. In the following chapter, the source areas of the sampled painted sherds will be investigated in order to establish whether they are northern imports or, in fact, geochemically linked with southern ceramic manufacture, reflecting imitation of the northern ceramic tradition. There are, of course, ceramic micro-traditions and traditions that are clearly restricted to a certain locality or region, and apparently distributed only in a limited area (see Freestone *et al.* 2001 for the Deir ʻAin ʻAbata evidence).

It is probably inestimable how long it would have taken for a ceramic innovation to travel, for example, from Jerash to Petra. It could have been anything from a couple of days (to transport a fashionable pot across the country) to years (to bring a change to a traditional craft tradition). A traveller might have seen or purchased a new ceramic product and requested similar products, styles, or performance from his local potter. Travelling potters and merchants probably brought competition to regional markets, compelling local producers to alter their products in response. Trade is a powerful force in cultural transmission, and it has been suggested that merchants likely were among the primary converts to Islam (Insoll 1996: 494–496). New food preparation practices eventually materialise in food-related craft-traditions. Alteration in ceramic traditions not demanding major technological change but attainable using existing technology and readily available raw materials was likely faster for the potters to adapt, compared to changes requiring technological development.

One aspect that has contributed to the image of ʻregionalism' in southern ceramic traditions is that the published ceramic research displays two sub-regions, created by the modern political border dividing the archaeological research of the Negev and southern Transjordan, as well as more northern areas on both sides of the border (see Bienkowski and Galor 2006 for further discussion). It is not uncommon for a ceramic report to cite literature only from one side of Wadi ʻArabah, although this division is archaeologically completely artificial and inhibits establishing a comprehensive picture of the ceramic traditions and inter-communal contacts in the regions.

In the following, comparative ceramic evidence will be reviewed also from relevant sites in northern Israel and Jordan. There is a need to go even further, and cover modern Syria, Iraq, Egypt, the Arabian peninsula and other culturally related areas to look for combining factors in ceramic traditions, although not much evidence for coarse wares during these periods is available (see, for example, early Islamic common ware ceramics from Nippur, Iraq, see Ciuk 2000; see also Rousset 2001 for the Basra area; for Umayyad ceramics from north Syria, see Konrad 2001 and Tonghini 1995 and for 5th–6th century ceramics from Libya, see Dore and Keay 1989).

This approach is necessary considering that in the Islamic periods, the Hajj, the annual pilgrimage route to Mecca, must have had a huge role in the movement of influences and people in the area. According to 9th–10th century sources, the pilgrim route ran from Damascus via Amman to ʻAqaba and al-Hijaz, and was connected to east-west roads coming from Egypt, Gaza, Syria and Iraq along the way (Binggeli 2006–2007; Brown 2006: 382–384; Parker 2016a: 19–20; Parker 2002: 423–425; Walmsley 2009; Walmsley 2008: 498–501, 519–521; Walmsley 2001a; Whitcomb 1989b: 165–166; Zarins 1989: 245). The pilgrimage, added to commercial and administrative communications, demonstrates inter-regional movement of people in the area in the early Islamic period. People taking these routes inevitably transmitted influences and goods; thus, it would not be unlikely to see influences from Damascus, Amman, al-Hijaz, Egypt or other destinations connected to these routes emerge in the material culture of regions along the way.

Accordingly, the ceramic evidence from the sampled sites might show evidence for imports or influence diffusion originating from al-Hijaz, Syria and Egypt, the Mediterranean coast and further (for ʻAqaba's links to Egypt, the Red Sea and Arabia, see Parker 2002: 423–424; and Whitcomb 1998b). Cream wares and the so-called Khirbet al-Mafjar style mould-made ceramics imitate silver vessels produced in Iraq in the 8th century (Walmsley 2007a: 54; see also Whitcomb *et al.* 2016), but also southern influences, particularly those originating from the Arabian Peninsula have been identified in the ceramic traditions. ʻAqaba's ceramic record illustrates its extensive international trade contacts with Egypt, al-Hijaz, Iraq, Syria and China in the ʻAbbasid period. There are also imports originating from Samarra and Egypt found at the site (Tomber 2004; Whitcomb 1989a–b; Whitcomb 1989c: 274; Whitcomb 1988a; Zarins 1989; see Majcherek 2004 for Alexandria's commercial links with the east; and Northedge *et al.* 1990; Northedge and Falkner 1987 for Samarra ceramics, see also Matin *et al.* 2018; and Sarre 1925).

The so-called *Kerbschnitt* or engraved ceramic bowls imitating steatite vessels manufactured in al-Hijaz illustrate influences from the Arabian Peninsula. Several of these stone vessels were found in ʻAbbasid strata at ʻAqaba, so it is likely that the town was a significant link in the chain of flow of these influences and possible imports towards north, Amman, Jerash, Pella and other locations (Kisnawi *et al.* 1983; Magness 1994: 203–204; Walmsley 2007a: 68–69; Walmsley 1995b:

668; Whitcomb 1987: 262–266). Ceramic finds from early Islamic pastoral camps in the Negev suggest contacts with Sinai, Egypt and other parts of the central Negev, whereas no material links with Arabia were found (Rosen and Avni 1997: 95). Moreover, the possibility of the southern origin of the middle Islamic hand-made painted wares has also been discussed (for HMGPW, see below and, for example, Brown 1992; Johns 1998; and Walmsley and Grey 2001: 162).

In this light, it would not be surprising to find also that utilitarian products made by local manufacturers were affected by changing cultural influences and market preferences diffusing from early Islamic centres. Ceramics were probably transported by travellers and pilgrims as their personal items, imported by merchants as primary trade objects, or as containers for other goods.

Chronological problems and misdated Byzantine and early Islamic ceramics have been discussed by many scholars. Walmsley writes that the repeated misdating of 'Abbasid ceramics as Umayyad 'has had a profoundly negative impact on the writing of a social, especially urban, history of the early Islamic period' (Walmsley 2001b: 306). Whitcomb states that problematic early excavations and historical suppositions have led to the misinterpretation of ceramic finds: 'much which archaeologists have labelled "Byzantine"' has a high probability of being early Islamic, Umayyad and often 'Abbasid' (Whitcomb 1998a: 493; see also Avni 2014: 31; Walmsley 1982; and Whitcomb 1992a: 385).

Ceramics have been commonly misdated as too early (9th century ceramics have been thought to date to the 8th century, 8th century ceramics to the 7th/6th century) leading to a missing ceramic record for the 9th and 8th centuries, used as evidence for the decline following the 7th century Muslim conquest (Avner and Magness 1998: 39; Magness 2003: 1–2; Magness 1997: 485; see also Falkner 1993–94 for a critical view of ceramics as a chronological tool for early the Islamic periods). The evidence from Gharandal has provided similar indications, with secure later 8th to early 9th century contexts providing ceramic forms which in previous studies have been categorised as Byzantine (Walmsley and Grey 2001: 162).

The chronological problems also relate to other find categories. Coins were used for centuries after minting. Thus, 'Abbasid ceramics are often found with Umayyad coins (more common in archaeological contexts than their 'Abbasid counterparts), often resulting in misdating ceramics in these contexts as Umayyad (Magness 2003: 205). According to Magness, misdated ceramic finds and the reliance on numismatic data have caused historical and chronological misinterpretations. 'In many cases the pottery and coins provide a broad *terminus post quem* instead of the actual date of the associated phase or remains' (Magness 2001: 11). Ideally, one should also refrain from using political terms or dynasty names in ceramic chronologies (Grabar 1973; Pringle 1981: 46–47; Sauer and Magness 1997: 475; Schick 1998: 80; Whitcomb 1992a; Whitcomb 1989b: 172).

Crucially, the fact that there appear to be very few changes between late Byzantine and early Islamic ceramic traditions has contributed to the chronological complexity of these artefacts. According to Walmsley, the 7th century ceramic assemblage at Pella displays traditional, pre-Islamic forms, which continue into the early 8th century. There is 'a period of accelerated change' from the end of the 7th century into the mid-8th century, and a 'rapid and systematic' alteration of ceramic traditions in the later 8th and throughout the 9th centuries, when some traditions became extinct and were replaced by 'external' ones (Walmsley 2007a: 48–69; Walmsley 1995b: 668; Walmsley 1992b: 256). Likewise, Gawlikowski writes on the Jerash ceramic record that 'there is no change to be observed with the advent of the Islamic government nor later with the rise of the 'Abbasids, the development of ceramics being, as it should be expected, independent of political events of the time' (Gawlikowski 1986: 118).

The 9th century changes, with Iraqi/Samarra-style cream ware ceramics taking over the ceramic market, and the addition of engraved (*Kerbschnitt*) and glazed wares of Iraqi or Egyptian styles, reflect a 'cultural reorientation' and adaptation to the Islamic culture but this is not an immediate response to the political situation (Walmsley 2007a: 58–59, 65–66; see also Northedge *et al.* 1990; Northedge and Falkner 1987; Walmsley 1995b; Walmsley 1992b: 257; and Watson 1992: 244). The residence of the caliph moved to Baghdad, and the emergence of new forms and wares, at least in the northern areas, can be associated with the time when the 'Abbasid dynasty was strong in terms of economy and politics, and the ceramic record can be seen reflecting these influences (Walmsley 1995b: 660–668; Walmsley 1992b: 246). Regardless of the new influences, many utilitarian forms show long persistence with little change, as demonstrated by pottery forms recovered in 11th century contexts, clearly related to ceramics present in 'Abbasid period layers (see discussion in Northedge 1984; Walmsley 2001a: 544–553; Walmsley 1991; and Whitcomb 1988a).

Provenance studies of ceramics of this period in the southern areas are also affected by the lack of identified early Islamic period ceramic workshops in southern Transjordan and the Negev, excluding the 'Aqaba kilns (Melkawi *et al.* 1994; Whitcomb 2001a). Hence, at the moment, there is no direct evidence of early Islamic ceramic production in southern Transjordan or the Negev, and accordingly, there are no available reference data from southern production centres. The az-Zurraba kilns in Wadi Musa, near Petra, were used until the mid-6th century ('Amr and al-Momani 1999), as is the case with the Elusa kilns (Goldfus and Fabian 2000: 94). More evidence for early Islamic ceramic industries is available farther north, particularly from Bet Shean and Jerash (see Bar-Nathan and Atrash 2011; Bar-Nathan and Mazor 1993, Gawlikowski 1986: 117; and Schaefer 1986). Later evidence includes the 10th–11th century kilns at Tiberias (Stern 1995), al-Raqqa (Heidemann 2006; Tonghini and Henderson 1998) and Akko (Stern 1998; for an early Byzantine kiln from northern Israel, see Vitto 1986; Vitto 1981; Vitto 1980; see also Baumgarten 2001).

The majority of the published archaeometric ceramic studies deals with materials chronologically or regionally unrelated to the ceramic materials analysed in this book. One example is Watson's PIXE analysis of 6th century Jerash bowls and kiln materials (Duerden and Watson 1988; Watson 1989), a vessel type not encountered at the southern sites examined here. Watson's study, however, illustrated that the same materials were used in ceramic manufacture at Jerash from the 6th to the 7th and 8th centuries. Thus, the ceramic traditions were largely unaffected by the socio-political change. 'Amr's (1987) neutron activation analysis (NAA) of Nabataean–early Roman ceramics and the results by Tite *et al.* (2018) for Nabataean fine ware and *terra sigillata* (not sampled for this work) from Petra have a much earlier chronological focus, and their data are not directly compatible with the results of this study due to different methods and analytical approaches (see further discussion in Chapter 6).

Thematically, the NAA and XRF analyses of Roman pottery from Galilee (Adan-Bayewitz *et al.* 2009; Adan-Bayewitz 1993) provided an intriguing example of inter-communal cooking vessel exchange, although concentrated on earlier material in a different region. Other examples include a study on Late Roman 1 amphorae (Williams 2005) and a study of different jar types, locally manufactured and imported, found at Elusa (Fabian and Goren 2002).

Freestone *et al.* have carried out petrographic analyses of ceramics from the monastery of St. Lot (Deir 'Ain 'Abata), providing interesting results of ceramic supply and foreign imported amphorae and glazed ceramic types (Freestone *et al.* 2001; Joyner and Politis 2000, see Chapter 3 for discussion with regard to Jabal Harûn). Glazed wares and other fine wares have also more frequently been the subject of technical studies (see, for example, Baklouti *et al.* 2014; Frierman *et al.* 1979; Frierman 1970; Hill *et al.* 2004; Mason 1998; Mason 1997; Mason and Tite 1997; Mason and Keall 1990; Molera *et al.* 2018; Tite *et al.* 2018; see also Carreras Monfort and Williams 2002; and Meyza and Mlynarczyk 1995). An analytical study including materials from both southern Jordan and the Negev was published by Gunneweg *et al.*, but this work concentrates on 6th century BCE ceramics (Gunneweg and Balla 2002; Gunneweg *et al.* 1991).

In terms of ceramic chronology, Byzantine–early Islamic ceramics from secure stratigraphic contexts have been published from Pella (see, for example, Walmsley 1995b; Walmsley *et al.* 1993; Walmsley 1992b; McNicoll *et al.* 1982), the Amman Citadel (Bennett and Northedge 1977–78; Northedge 2001; Northedge 1991; Northedge 1984) and Jerash (see ceramic related reports in Zayadine 1989 and Zayadine 1986). Other useful contributions also include Whitcomb's chronological reassignment of the Khirbet el-Mefjer ceramic record (originally published by Baramki in the 1940s; see Baramki 1944; Whitcomb 1988b; see also Baramki 1937) and his work on Islamic 'Aqaba/Ayla (Whitcomb 1989a; Whitcomb 1989c). Relevant publications also include those of Jerusalem (Magness 1993; Magness 1992), Umm al-Rasas (Alliata 1994; Alliata 1991; Bujard and Joguin 2001; Pappalardo 2002), Khirbet Nakhil (Kareem 2001; Kareem 1999), Humeima ('Amr 2001b; Holmqvist 2013) and Gharandal (Walmsley and Grey 2001). These studies are used as the main chronological references in this study. Other works are cited as typological parallels, but not used for chronological assignments.

Typologically comparable materials have been published, among others, from Bet Shean (Bar-Nathan 2011b; Fitzgerald 1931), Mount Nebo (Schneider 1950, see also Alliata 1990 and Bagatti 1985), Ramath Rahel (Aharoni 1956), Bethany (Saller 1957), Nessana (Baly 1962), Hesbon (Sauer 1973, see also Sauer 1986; Sauer 1982), Tell Keisan (Briend and Humbert 1980), Umm el-Jimal (Parker 1998a; Parker 1987b; see also Parker 2006b), Khirbet ed-Deir (Calderon 1999), Tiberias (Stacey 2004; see also Stacey 1988–9), Khirbet edh-Dharih (Waliszewski 2001) and Khirbet es-Samra (Humbert 2001). Stylistically relevant materials have also been found at Capernaum (Peleg 1989; see also Berman 1989), Caesarea (Brosh 1986; see also Arnon 2008), Kursi (Tzaferis 1983), and Khirbet al-Karak (Delougaz 1960), all criticised for chronological inaccuracy, mainly for suggesting too early dates (see Schick 1998: 90; Stacey 2004: 15–20; Walmsley 2001b: 311).

From the Negev, late Byzantine–early Islamic ceramic finds closely comparable to those of this study have been published from various sites, including Rehovot (Rosenthal-Heginbottom 1988), Tel 'Ira (Fischer and Tal 1999) and Horvat Karkur 'Illit (Nikolsky and Figueras 2004; for the Negev, see also Calderon 2000; Nevo 1985;

and chronological revision by Magness 2003). The maps of Archaeological Survey of Israel, and particularly the reports of the Negev Emergency Survey, have provided important archaeological evidence for the region, but fairly limited ceramic finds, especially of the Byzantine and Islamic periods, are included in the reports (see, for instance, Baumgarten 2004; Gazit 1996; Govrin 1991; Haiman 1999; Haiman 1993; Lender 1990; see also Avni 1996; Rosen and Avni 1997; Rosen 1987a–b; for the Negev; see also Finkelstein and Magen 1993; Gophna and Ayalon 1998; Patrich 1994).

Ceramics from Petra have attracted scholarly interest for decades (see Hammond 1973; Parr 1970), but ceramic sequences from many sites await publication. Very limited quantities of early Islamic ceramics have been identified in excavations in Petra. The ez-Zantur excavations in central Petra provided ceramics from earlier phases (Gerber 2014; Schmid 1997; Fellmann Brogli 1996), as did the ceramic finds from a survey in the Wadi Musa area near Petra (ʻAmr and al-Momani 1999; ʻAmr *et al.* 1998; ʻAmr 1987). The ceramic finds from the Petra church included Nabataean and 5th–6th century ceramics, but sherds dated to the 7th– 8th centuries were sparse and none later than that were identified (Fiema *et al.* 1995: 301). Crusader and Ayyubid (12th century) ceramics have been published from the outskirts of Petra (e.g., Sinibaldi 2016; Sinibaldi 2013a–b; Brown 1987). The Jabal Harûn excavations have yielded a rich collection of early Islamic period ceramics and ceramic lamps, although the chronology of this ceramic corpus is affected by the lack of securely datable finds and undisturbed stratigraphic contexts (see Gerber 2016; Gerber 2008; Gerber and Holmqvist 2008; Holmqvist 2016a–b).

Cooking vessels

Open-form cooking pots or 'casseroles' are one of the most typical vessel forms in late Byzantine and early Islamic contexts in the study region (Figures 5.1 and 5.2, see samples from Jabal Harûn JH001–004; Khirbet edh-Dharih DH001–003; Elusa E001–003; Abu Matar AM001–005; and illustrations in Appendix I). The principal characteristics of these wheel-made pots are relatively thin and slightly inverted walls, flattened or angular rims (see Hendrix *et al.* 1996: 13 for terminology). The vessel exterior is often grooved, but the intensity of this treatment varies. Not all of the sampled examples have preserved handles, but this form is characterised by two horizontal loop handles attached below the rim as seen in the better-preserved examples. The mouth diameter of the pots sampled for this study is between *c.* 15–30cm. The samples have a greyish–reddish brown colour (7.5YR 4/2–4/4; the colour terminology refers to Munsell 2000). This form typically has a flat base, although not preserved in the sampled pots. Many excavations have provided cooking pot lids with a knob and often with grooved exterior design that fit with these pots (Figures 5.1, 5.2; see Franken and Kalsbeek 1975: 91, Fig. 19; and Franken 1991: 83 for the manufacturing technique).

These open-form cooking-pots are found at different locations with minor variation in the details, such as rim form, exterior pattern and handle placement (Figure 5.3). Some of these differences might be of a chronological nature, although they might also be linked to technological variation in separate workshops. The wide distribution area of this form, as illustrated by the parallels given below, suggests the pots were produced in numerous local workshops, although the possibility of cooking pot trade and transportation cannot be ruled out. The general morphological similarities favoured in a wide area probably reflect similar food preparation practices, dishes and heating methods in these regions. The apparent typological similarities between pots found at separate locations might also indicate shared sources and centralised regional production, possibly linked to the performance requirements of cooking vessels. Curiously, the open-form cooking pots sampled from Jabal Harûn appear larger compared

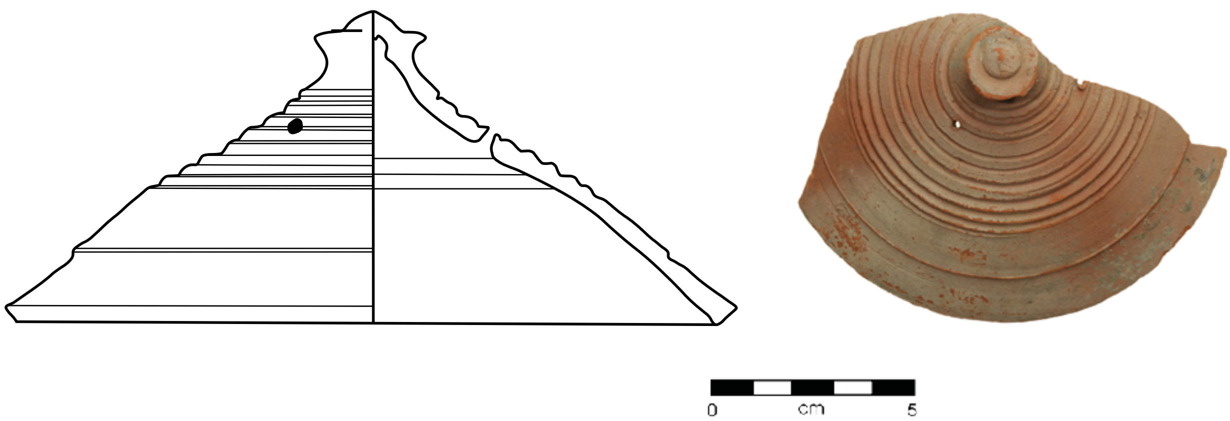

Figure 5.1: Cooking pot lid (sample JH004) recovered at Jabal Harûn.

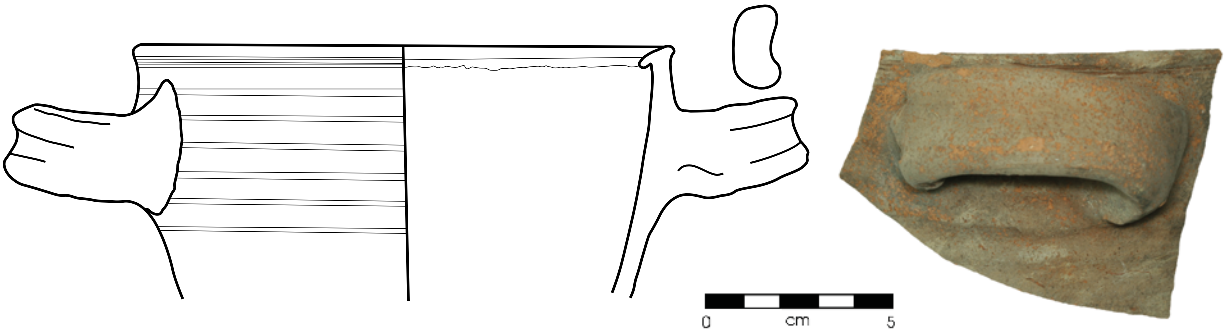

Figure 5.2: Open-form cooking pot (sample DH001) recovered at Khirbet edh-Dharih.

to pots sampled from the other sites, and while this feature might be indicative of the catering practices of the monastery, further study is required to examine the volume of cooking pots from sites representing different socio-economic contexts.

Open-form cooking pots and their lids have been associated with Umayyad and 'Abbasid levels from Pella (Walmsley 1991: 154–155, Figs. 4:4, 5:1–4, 'later 'Abbasid'; Walmsley *et al.* 1993: 216, Fig. 23:7, ' 'Abbasid' (the handles of these cooking vessels are attached higher than in the samples of this study), Jerash (Clark *et al.* 1986: 250, Fig. 21:15, 'eighth century Umayyad', see also Fig. 21:16 for a cooking pot lid fairly similar to JH004; and Parapetti *et al.* 1986: 190, Fig. 10: 5, 'Byzantine and Umayyad levels', although these Jerash cooking pots do not have exterior ribbing; see also pots and lids with white paint in Walmsley *et al.* 2008: 133, Fig. 26), and the Amman citadel (Bennett and Northedge 1977–78: Pl. CI, 1, no.3, 'Umayyad'; Northedge 1984: 402–403, Fig. 73:3–4, 'Umayyad earthquake destruction' and Fig. 74:5, 12, ' 'Abbasid', note the miniature size of no. 12). They are also present at Humeima ('Amr 2001b: 124, Fig. 9:23–26, 'mid-7th c.'; Holmqvist 2013: 20–21), and at the kiln site of 'Aqaba (also wasters, Whitcomb 1989b: 181, Fig. 3: o–p; see also Melkawi *et al.* 1994: 456, 458, Fig. 9a-e, 'mid-7th–mid-8th c.'), Umm al-Rasas (Bujard and Joguin 2001: 143, Fig. 1:8–9; see also Pappalardo 2002: 413, Fig. 20:8–17) and Jerusalem (Magness 1993: 211–215, forms 1, 3 and lids, form 1 'late 3rd cent./early 4th cent. to 8th cent./9th cent.', form 3 'late 7th cent./early 8th cent. to 9th cent./10th cent.', the latter of hemispherical form).

According to the chronology of the parallels cited above, and the stratigraphic contexts of the samples, most of the open-form cooking pots included in this study are likely to date to the 8th–9th centuries, with possible earlier and later examples. The Elusa cooking pots (nos. E001–003) may represent an earlier variant from the 6th–7th or early 8th centuries indicated by their contexts, although practically identical to pots encountered in Islamic period levels at Abu Matar (AM002–003 and AM005, loci 3090, 3156 and 3179, respectively, AM001 was found in a Byzantine context). The Abu Matar pots can be dated to the 8th century, with a possible extension to the 9th century. An early 'Abbasid period date, second half of the 8th–early 9th century or later can be associated with the open-form cooking pots from Jabal Harûn (JH001–004), found in loci that can be associated with the last phases of the site (Trench J, loci 21 and 44; Trench Z, locus 58; see Lahelma *et al.* 2016; and Juntunen 2016, respectively) with rich representation of other similarly datable ceramic forms, such as basins and jars (see below, see also Holmqvist 2016b for the early Islamic ceramic lamps from these contexts) and a similar situation applies to the Khirbet edh-Dharih open-form pots (DH001–003, loci S10C023, SD10108, S10C024). Proposing a terminal date for this form is problematic, and a later 'Abbasid, later 9th–10th century date, remains a possibility for these vessels. 'Aqaba samples A006 and A007 represent different vessel type and have been dated to the 1st–2nd centuries and the 4th–5th centuries, respectively, according to their stratigraphic contexts.

To illustrate the geographical distribution of this form, typologically parallel open-form cooking pots have been published, for instance, from Bethany (Saller 1957: 243, 246, Fig. 48, no 3338, 'Byzantine–early Arabic'), Umm el-Walid (Haldimann 1992: Fig. 5, '8th c.'; see also Bujard and Joguin 2001: 145, Fig. 3:20), the Madaba area (Harrison 1994: 434, Fig. 3:1–8, '7th–8th c.'), Sinai (Calderon: 2000, 190, Fig. 4, 'Byzantine'), el-Muwaqqar near Amman (Najjar 1989: 315, Fig. 6: 19–20), Bet Shean (Fitzgerald 1931: Pl.XXXI: 12, 'Byzantine'), Khirbet edh-Dharih (Waliszewski 2001: 104, Fig. 5:1–4, 9, '*VIIe–VIIIe s.*'), Caesarea (Arnon 2008: 151–154), Kursi (see Tzaferis 1983: 37, Fig. 6:9-16), Capernaum (Peleg 1989: 65, Fig. 52: 20–21, 67, 69), Khirbet al-Karak (Delougaz 1960: Pl. 54: 10, 13, 16–17), Ramla (Tal and Taxel 2008: 136) and Khirbet el-Lauz (Finkelstein and Magen 1993: 41, Fig. 17, no. 10, 'Byzantine'). Published examples from the Negev include the monastery of Khirbet ed-Deir (Calderon 1999: 138, 'Byzantine to early Islamic with only minor variation'), Horvat Karkur 'Illit (Nikolsky and Figueras 2004: 197-198, Figs. 45, 46: 1–6, '6th–8th c.'), Nahal Mitnan (Haiman 1995b: 7-9, '6th–8th c.'; see also Magness 2003: 152–154), Nessana (Baly 1962: Plate

Figure 5.3: Locations of sites discussed in relation to open-form cooking pots.

LII, form 74, 'Hellenistic to Arab'; see Magness 2003: 177–182), Sde Boqer (Nevo 1985: 39, nos. 4–9, '7th–8th c.'; see Magness 2003: 138–141), Tel 'Ira (Fischer and Tal 1999: 332, Fig. 6.137: nos 10–13, 'Byzantine–Early Islamic'; see also Magness 2003: 53–57, 68).

Compared to the open-form pots, the closed-form cooking pots represent a very different vessel form, typical of the Nabataean and Roman periods (Figure 5.4; see samples JH005 from Jabal Harûn; DH004–007 from Khirbet edh-Dharih, A001–004 from 'Aqaba; and E004–005 from Elusa). Only a few examples of this earlier cooking pot form were included in this study, mainly to view chronological variation in the production compared to the open-form pots. These 'jar-like' cooking pots often have an angular rim profile, and the rim is slightly everted with a carinated inner surface. For example, similar vessels from Petra are present in the layers dating from the 1st century CE through the 4th and the 5th centuries ('Amr *et al.* 1998: 509, Fig. 4:12; Fellmann Brogli 1996: 245, Fig. 736; Gerber and Fellmann Brogli 1995: 650, Fig. 2; Gerber 2001: 9; Hammond 1973: 39, Fig. 1; Lindner *et al.* 2007: 248, Fig. 18; Parr 1970: Fig. 3.33). Relatively similar vessels were also found during the excavation of pottery kilns at az-Zurraba in Wadi Musa near Petra, and from Humeima ('Amr and al-Momani 1999: 184, Fig. 11:23–24, 189, Fig. 14: 14–17; Oleson *et al.* 2008: 336, Fig. 22:8–10; see also Parker 2016b: 314, Fig. 6.1.).

The closed-form cooking pot samples from 'Aqaba have been dated according to their context as follows (all dates from S. Thomas Parker): A001 (2nd–4th century context M.1:14.31), A002 (1st–2nd century, unstratified), A003 (early Byzantine, unstratified), A004 (early Roman/Nabataean context B.1:18.31), A005 (late Roman, unstratified). No absolute date can be associated with the context of the Jabal Harûn closed-form cooking pot, JH005 (Trench C, locus 9) or the Elusa examples (E004–005, loci 2046 and 3119), although they are likely to date to the 4th–5th centuries (or earlier). The samples from Khirbet edh-Dharih (DH004–007) come from a context with a homogeneous earlier ceramic corpus labelled 'late Roman' by the excavators (locus S1H12).

Basins and bowls

The coarse ware basins and bowls sampled for this work represent both late Byzantine and early Islamic forms (Figure 5.5). The basins are especially an early Islamic feature in ceramic assemblages, appearing in Umayyad period contexts and continuing in 'Abbasid and later strata. The category of undecorated coarse ware bowls is rather generic and more ambiguous in terms of typo-chronology. Possible parallels can be found in the literature, but without distinct diagnostic features, it is difficult to associate the sampled sherds with a certain stylistic tradition. Islamic period basins are often described as hand-made in the literature (see, for example, Franken and Kalsbeek 1975: 157, Fig. 46; Schick 1998: 94), and it is therefore noteworthy that the sampled basin sherds showed characteristics typical of wheel-made vessels in both macroscopic and SEM analysis (in next chapter). This technological difference can be of chronological nature, but it might also be due to different manufacturing techniques applied in different workshops.

Like the open-form cooking pots discussed above, the Islamic period basins also provide an example of a form present in numerous locations with some variation. In addition to the manufacturing technique, variation appears in handles (vertical/horizontal), vessel size, rim forms and decorative patterns. It cannot

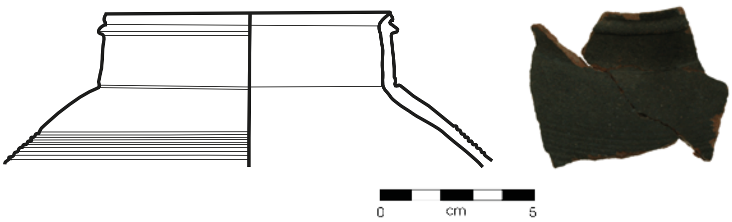

Figure 5.4: Closed-form cooking pot (sample A0001) recovered at Aila/'Aqaba.

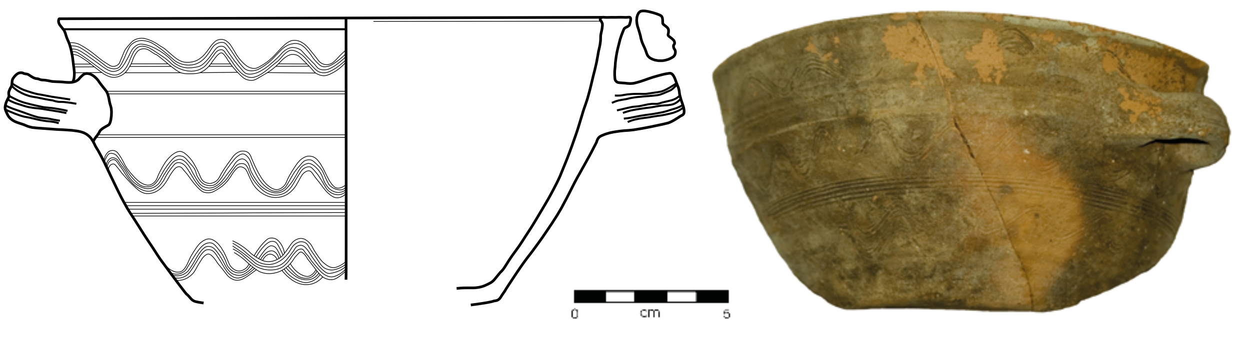

Figure 5.5: Basin with incised decoration sample (DH008) recovered at Khirbet edh-Dharih.

be established with certainty to what extent some of these features, such as the handle attachment or the vessel size, might be representative of different uses of the vessels. These differences notwithstanding, these kinds of basins that are relatively similar in terms of shape and decorative style, have been found in a wide region, ranging from the north to the southern sites. Hence, the basins might be linked to a certain food preparation practices introduced in the early Islamic period. The rim profile forms of the sampled basins are varied, although they all follow the same general form of a protruding or outward-folded rim. The colour range of these sherds is light grey–dark reddish-grey (YR7.5 7/1–4/1). For the basins and bowls, see samples from Jabal Harûn JH006–010; Khirbet edh-Dharih DH008–010; Elusa E006–009; and Abu Matar samples AM006–011.

Basins closely comparable to those sampled for this study have been published from secure contexts (see Figure 5.6), for instance, from Pella (Walmsley 1982: Pl. 145: 6, 'Umayyad pottery of A.D. 746/7' and Pl. 148: 3–4, 'Umayyad pottery, first half of the eighth century A.D.' see also Pl. 149; Walmsley *et al.* 1993: 216, Fig. 23:5, ' 'Abbasid'), Jerash (from the kiln area, Pierebon 1983–1984: 104; see also Walmsley *et al.* 2008: 132, Fig. 25:22), the Amman citadel (Bennett and Northedge 1977-78: Pl. CI, 1, no. 6., 'Umayyad'; Northedge 1984: 401, Fig. 72:5 'Umayyad earthquake destruction'; see also Rasson and Seigne 1989: Figs. 5:7 and 6:8, '8th c.'), Bet Shean (Bar-Nathan 2011b: 241–246, 'Umayyad'), 'Aqaba/Aila (the cream ware, comb decorated 'Mahesh ware' may provide a parallel, see Whitcomb 1988a: 218, Fig. l; Whitcomb 1989c: 279–280, Figs. 2–3, see in particular 2:e, '750–800 A.D. or later'), Khirbet al-Mafjar (Baramki 1944: Fig. 10:1–3, 6, ' 'Abbasid'; and Whitcomb 1988b: 55–56, 64–65, '800–850'; see also Whitcomb *et al.* 2016), Khirbet Nakhil (Kareem 1999: 198–199, '2nd half of the 8th–9th c.', Fig. 9:8 particularly parallels JH006), ar-Risha in eastern Jordan (Lenzen 1990: 138, Fig. 75: 18, 'mid-8th c.', especially JH009) and Umm al-Rasas (Alliata 1991: 394, Fig. 16:1), Gharandal (Walmsley and Grey 2001: 154, Fig. 9:1) and Jerusalem (Magness 1993: 206-209, forms 2–3, Pl.3, '6th–early 8th c.'; see also Rapuano 1999).

This vessel type is present in the mid-8th century destruction levels at Amman and Pella, and its use appears to expand into the 9th century, and relatively similar vessels seem also have been in use in later periods (see Northedge 1984: 406–407, Fig. 79:7, 'Ayyubid', Fig. 77:4, 'destruction probably of the 5th/11th [AH/AD] century'; see also Schaefer 1989: 39, Fig. 4:6 for Tel Jemmeh example). Accordingly, the sampled basins are likely to date from the mid-8th century to the 9th century. At Jabal Harûn, this form occurs in the latest occupational layers of the site (JH006 and JH008 from Trench J, loci 44 and 45, and JH007 and JH010 from Trench Z, locus 58; see Lahelma *et al.* 2016; Juntunen 2016, respectively for contexts), as is the case with the Khirbet edh-Dharih examples (DH008–DH009, S2DD19.1 and S6C2). The examples found at Abu Matar (AM006, AM010–AM011, loci 1085, unstratified, 3377, an Islamic context, and 3532, a Byzantine–Islamic context) have a thick rim profile, for which a close parallel from an 11th century context from the Amman citadel has been published (Northedge 1984: 406, Fig. 77:4; although with finger impressions on rim, similar to AM006). Basins of this kind were not encountered at Elusa, or included in the samples from 'Aqaba for this study.

Regarding the geographical distribution of these types of basins (Figure 5.6), various site reports provide additional typological parallels, for example, Khirbet ed-Deir (Calderon 1999: 141–142, '5th/6th c.', although smaller in size, JH008 and JH006 have a similar rim to pl. 3:9, '7th/mid-8th c.'), Umm al-Walid (Bujard and Joguin 2001: 146, Fig. 4:27), Khirbet edh-Dharih (Waliszewski 2001: 105, Fig. 6:7, 9, for the latter: '*partir du VIIe s. et au moins jusqu'à la fin du VIIIe*'), Abu Suwwana (Finkelstein 1997: 21, Fig. 1, 'mid-7th–mid-8th'; see also Magness 2004, 14–15), Mevo Modi'im (Eisenberg and Ovadiah 1998: 11, Fig. 4–8), Mount Nebo (Schneider 1950: 75, 80–81, Fig. 7:1, Pl. 152, 'from about the close of the sixth century to about the latter half of the seventh century'; Bethany (Saller 1957: 268, 272, Fig. 52, no. 3831, Fig. 54, nos. 3794, 3799), near Jericho (Netzer and Birger 1990: 199, nos. 10–12), Khirbet es-Samra (Humbert 2001: 161, Figs. 10–13), Capernaum (Peleg 1989: 57, nos. 1-2, 8, 'following Muslim Conquest'), Tiberias (Stacey 2004: 101–103, Fig. 5.15:2, 4–5, 7, 10–11), Caesarea (Arnon 2008: 363, see also 201, wheel-made types), el-Muwaqqar (Najjar 1989: 313, Fig. 5:11), Rehovot (Rosenthal-Heginbottom 1988: 92–93, nos. 200–201, '6th–7th c.'), Tel 'Ira (Fischer and Tal 1999: 341, Fig. 6.145: nos. 4–9, 'Byzantine'; see also Magness 2003: 53–57, 68), Horvat Karkur 'Illit in the northern Negev (Nikolsky and Figueras 2004: 169, Fig. 33; see Fig. 33:5 for a close parallel to AM010), and Nessana (Baly 1962: Pl. LII, Shape 72 'Byzantine–Arab', see especially nos. 1 and 3, closely parallel to AM010–011; see also the parallel from Khirbet el-Latatin in Finkelstein and Magen 1993: 69, Fig. 60, no. 2, 'Byzantine'; and Magness 2003, 177–182); Sinai (Calderon 2000: 195, Fig. 7:98, 'Byzantine', a close parallel to JH008). Possible parallels also include those from Kh. es Sualimiyeh (Gophna and Ayalon 1998: 43, Fig. 95.1; nos. 3, 5; 'Early Arab'), Bir el Qattar (Patrich 1994: 70, Fig. 63.6, no. 2, 'Byzantine'), Deir Maqtal el Ghuweir (Patrich 1994: 104, Fig. 97:2, no. 2, 5–6, 'Byzantine, Early Arab') and Khirbet ed-Daliya (Finkelstein and Magen 1993: 34, Fig. 6, no. 3, 'Byzantine', nos. 7–8, 'Early Islamic'), Khirbet Kafr Lut (Finkelstein and Magen 1993: 36, Fig. 10, no 3, 'Byzantine'), Khirbet Hallaba (Finkelstein and Magen 1993: 44, Fig. 21, nos. 12–13, 'Byzantine'), and Yavneh (Fischer and Taxel 2007:

Figure 5.6: Locations of sites discussed in relation to basins.

244, Fig. 20:1; see also Sarre 1925: I:1; Taxel 2013). The wide geographical region attests to the hypothesis that this form was produced in various regional workshops located in the relative vicinity of the sites.

Some of the coarse ware bowls sampled from the Negev sites were associated with Byzantine period strata (E006–008, loci 3027, 3100, 3138; and AM007 locus 3405, close parallel to Khirbet edh-Dharih sample DH010); the other examples were from unstratified contexts (E009, AM008–009). The bowls from 'Aqaba, samples A008–009, were dated to Nabataean and Roman periods by the excavator, to the 1st–2nd century and to the late Roman periods, respectively. Close parallels for the coarse ware bowl (or even possibly a lid) JH032, were not found in the literature, making its typo-chronological assignment uncertain, although its characteristics, light surface colour and incised decoration, may suggest a later 8th–9th century (or later) date. The rim form of bowls AM006–007 has a close 11th century parallel from the Amman citadel (Northedge 1984: 406, Fig. 77:3, 'destruction probably of the late 5th/11th [AH/AD] century', see also 408, Fig. 79:7 with a similar rim form; the vessel also has a clay strip of finger impressions below the rim).

Food and liquid containers

Food and liquid containers were used to transport goods in regional and inter-regional market systems and may provide evidence of contacts and trade between different locations. In most cases, the contents of the vessels cannot by identified with certainty and the ceramic byproducts are often the only surviving link to these trade actions in the archaeological record. Different container types were supposedly used for specific purposes, to transport certain goods, for varying distances, and by different means of transportation. The different purposes may be reflected in technological variation between container categories.

The jar sherds sampled for this study include both wheel- and hand-made variants with specific characteristics. However, some suggestions have been made concerning general morphological differences between Byzantine and early Islamic jars (Figures 5.7, 5.8., 5.10, 5.11, 5.13). For instance, Byzantine jars have an open, bowl-like neck form, while early Islamic (Umayyad–2nd half of the 8th/9th c.) jars are typically closed-formed, with a simple, high rim, loop handles attached to the rim, and have incised or painted decoration patterns, ribbing being rare (Kareem 1999: 196–197; see Figure 5.9 for sites with parallels). The jars described as the 'high-necked' type sampled for this study are of greyish-reddish colour (7.5YR 6/1–6/8; see Alliata 1991: 389, Fig. 12: 4–5; Northedge 1984: 400–401, 403–404, 406, 'Umayyad earthquake destruction', 'Abbasid', 'destruction probably of the late 5th/11th [AH/AD] century'; Khalil and Kareem 2002: 131, Fig. 14; Parker 1998a: 210, nos. 30–32; Whitcomb 1989c: 282, Fig. 5, '750–800 A.D. or later'; Walmsley 1991: 158, Fig. 8: 1–2, 'Abbasid'; Walmsley and Grey 2001: 150–151, Fig. 8: 15–16; Waliszewski 2001: 102–103, Figs. 3:2, '*de la deuxiéme moitié du VIIIe s. ou du début du IXe s.*', and Fig. 4:2–4, 6, '*VIIe et VIIIe s.*'; among others). See samples from Jabal Harûn JH011–015, and Khirbet edh-Dharih DH011–012, DH014. Only a few of the sampled jar sherds have preserved handles, vertical rim-to-shoulder loop handles, although it is probable that all these vessels had handles originally. On jars that have painted decoration, the colour scheme of the decoration is reddish-brown (2.5YR 5/8–4/2, Figure 5.8).

The chronology of the red-painted wares is not entirely clear, some painted forms appear to be present in Umayyad period contexts, while at some sites they are regarded as an 'Abbasid period feature (see Sauer and Magness 1997: 476; '8th–9th'; Sauer 1986: 306–309). 'Amr dates similarly painted bowls from Rujm el-Kursi to the 7th century on the basis of numismatic evidence ('Amr 1988: 247; 'Amr 1986), however, Walmsley notes

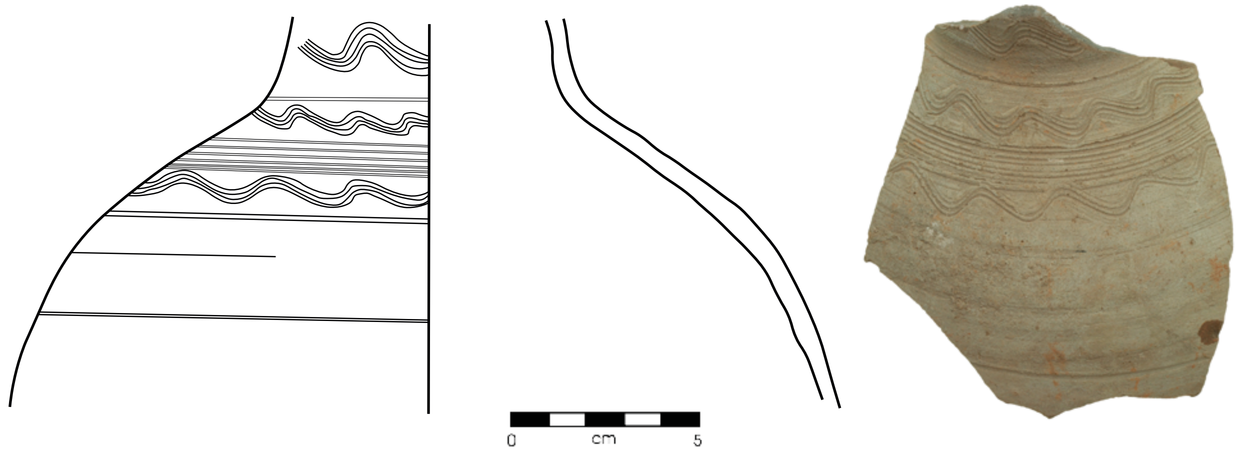

Figure 5.7: Jar with incised decoration (sample JH014) recovered at Jabal Harûn.

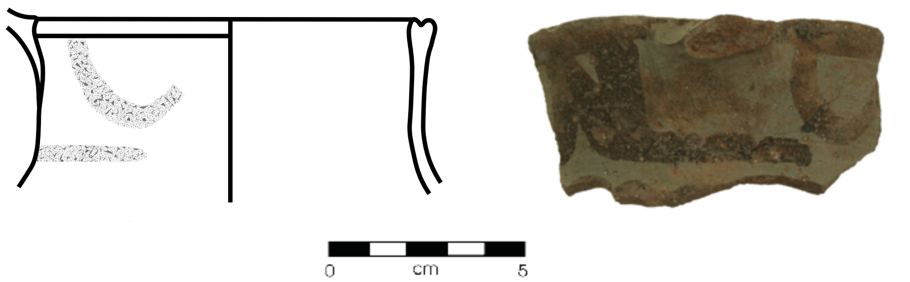

Figure 5.8: Painted jar (sample JH015) recovered at Jabal Harûn.

that painted wares are not present in the 7th century deposits at Pella, occurring only in the 'Abbasid period assemblages (Walmsley 1991: 153, Fig. 3:2, 'earlier Abbasid'; see also Walmsley *et al.* 1993: 216, Fig. 23:1–4; and Walmsley 1992b: 257). It is often suggested in the literature that the painted decoration on these vessels was applied on cream-coloured or pale reddish slip (see Schick 1998: 90), and this technological aspect will be examined in the following chapter.

The sampled painted jar sherds, almost all of them hand-made, are of great interest in terms of inter-regional influences and exchange, although painted ceramics represent only a small minority of the ceramics found at the sampled sites. According to the evidence available at the moment, it seems that this tradition was largely concentrated in the northern areas. The fact that similar vessels are present at some of the sampled sites poses questions on their origin, and whether they are imported or manufactured at the workshops in the south. See samples from Jabal Harûn JH015–016; Khirbet edh-Dharih DH019–021; Elusa E010; and Abu Matar AM014.

The painted sherds allow only tentative parallels to be given due to their state of preservation, but ceramics with similar painted patterns have been published from Pella (Walmsley 1982: Pl 143: 1, 'Umayyad pottery of A.D. 746/7'; Walmsley 1995b: 663, Fig. 6:2, 'mid-8th c.'), the Amman citadel (Bennett and Northedge 1977–78: Pl. CI, 1, nos. 7, 11, 13, 'Umayyad'; Northedge 1984: 400, Fig. 71:1–9, 'Umayyad earthquake destruction'), Umm al-Rasas (Alliata 1991: 370–413; Alliata 1994: 285, e.g., no 112, 'eighth–ninth c.'; see also Pappalardo 2002: 410, Fig. 18:3, particularly for JH015; and Bujard and Joguin 2001: 143, Fig. 1:1, '9th c.'), Khirbat Yajuz (Khalil and Kareem 2002: 131, see especially Fig. 14: 12 and 15 and Fig. 17: 8–9 and 12–25, 'Abbasid'), Khirbet es-Samra (Humbert 2001: 157, Figs. 3–5, 'until the 9th c.'), Gharandal (Walmsley and Grey 2001: 148–152, Fig. 8.3) and Khirbet Nakhil (Kareem 2001: 82–85, Figs. 1: 7 and 2: 8–9, 'Umayyad'). The published parallels and the stratigraphic contexts of the samples of painted ceramics suggest that they are most likely to date to the mid-8th–9th century. A similar date can be associated with the high-necked jars, and the jar body sherds with incised decoration (DH015–019; AM012–013). At 'Aqaba/Aila, comb incising on cream ware is typical of ceramics dating to 750–800 and later (Whitcomb 1989c: 269), and at the Amman citadel, vessels decorated in this manner date are present in mid-8th–11th century strata (Northedge 1984: 402–406). The Jabal Harûn samples JH011–016 were all recovered from contexts that provided other forms typical of early 'Abbasid period date (Trench Z, locus 58; Trench J, locus 10, 44; Trench W, locus 3; see Juntunen 2016; Lahelma *et al.* 2016). Similarly, the Khirbet edh-Dharih sherds DH011–021 were found in related contexts (S9.05, S2CC2, S7F9, S2KK1–2, S2EE16, S2DD3, S2DD5). The painted sherd from Abu Matar, AM014, was found in an Islamic period context, but no clear phasing can be given to the contexts of AM012–AM013. The painted sherd from Elusa (E010) is an unstratified find.

From a typological perspective, Umm al-Walid (Bujard and Joguin 2001: 145, Fig. 3: 15–17), Tell Jawa (Daviau and Beckman 2001: 272, no. 16, 'Umayyad?'), Khirbet edh-Dharih (Waliszewski 2001: 106, Fig. 7: 1–2, '*à la fin de la période omeyyade et au début de la période abbasside*'), Khirbet al-Karak by the Sea of Galilee (Delougaz 1960: Pls. 37, 58:4, '7th–8th c.'), Mount Nebo (Schneider 1950: 32, Fig. 2:4; Pl. 145–148; Umm el-Jimal (Parker 1998a: 212–213, nos. 51–55, 'Early Islamic') and Qasr al-Hallabat (Ghrayib 2003: 72, Fig. 10:o, q, 'Umayyad') may also offer typological comparables for the painted sherds.

Two jars from Jabal Harûn with short necks and more open forms (JH017–18) might represent an earlier variant, however, they were found in the same contexts as the forms associated with the mid-8th–9th centuries (Trench Z, locus 58 and Trench J, locus 44; Juntunen 2016; Lahelma *et al.* 2016).

Large jars or pithoi with a thickened, folded rim have been associated with late Byzantine and Umayyad and 'Abbasid contexts in publications (Figure 5.10). The mouth diameter of these jars can be narrow (*c.* 10–12cm) and finger impressions on the folded rim also occur. See samples from Jabal Harûn JH019–020; Khirbet edh-Dharih DH022–025 (DH024 with incised decoration and DH025 with finger impressions on rim).

Parallel ceramics have been found, for example, at Khirbet Nakhil (Kareem 1999: 196-197, Fig. 7: 16–17, 'Byzantine to Umayyad and 'Abbasid'; see also Kareem 2001), Khirbet edh-Dharih (Waliszewski 2001: 101, Fig. 2:1-5, '*VIIe–VIIIe* s.'), Jerusalem (Magness 1993: 232, Fig. 3, '2nd–5th c.'), Humeima ('Amr 2001b: 121, Fig. 6: 10–

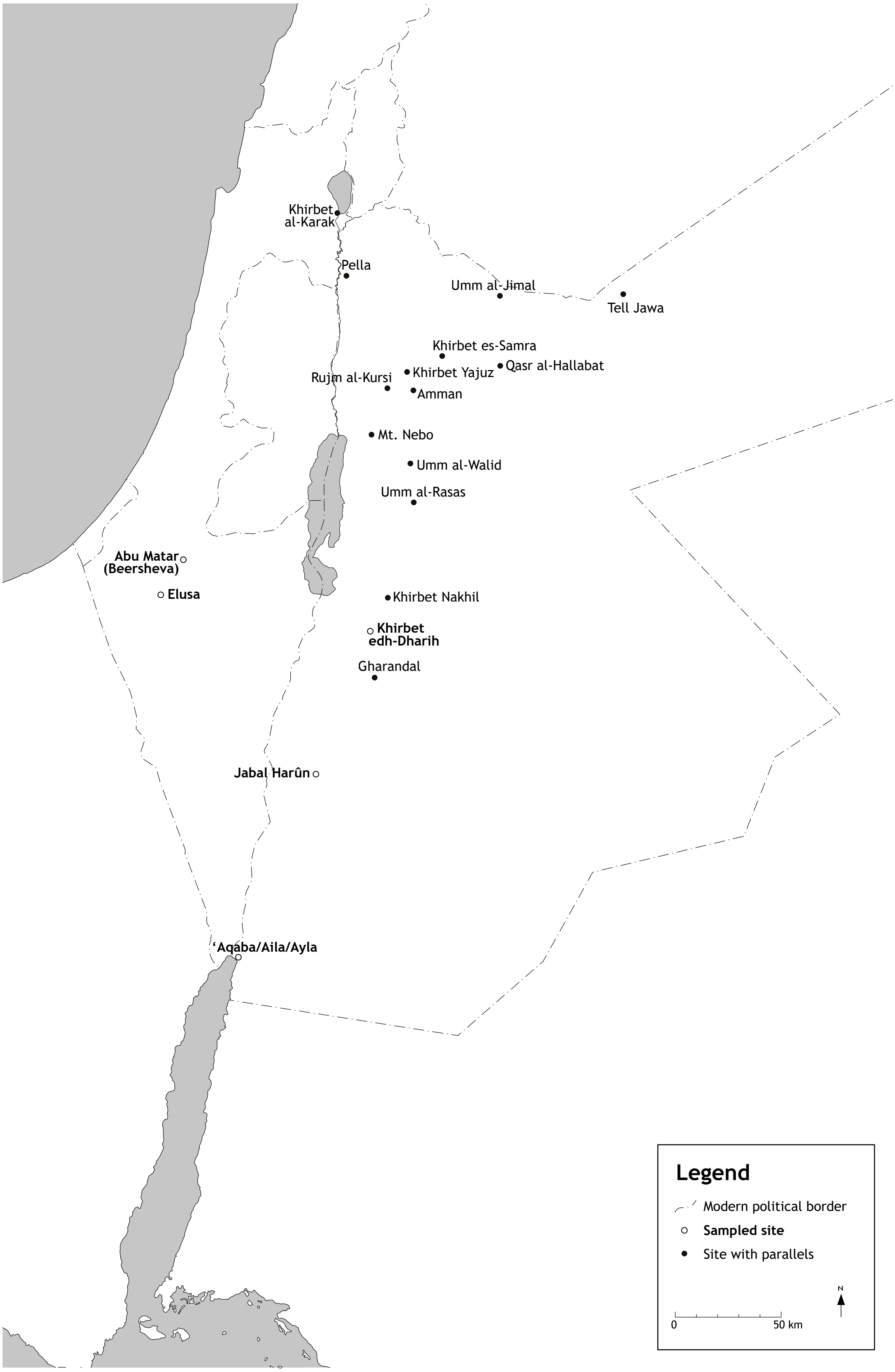

Figure 5.9: Locations of sites discussed in relation to high-necked jars with painted or incised decoration.

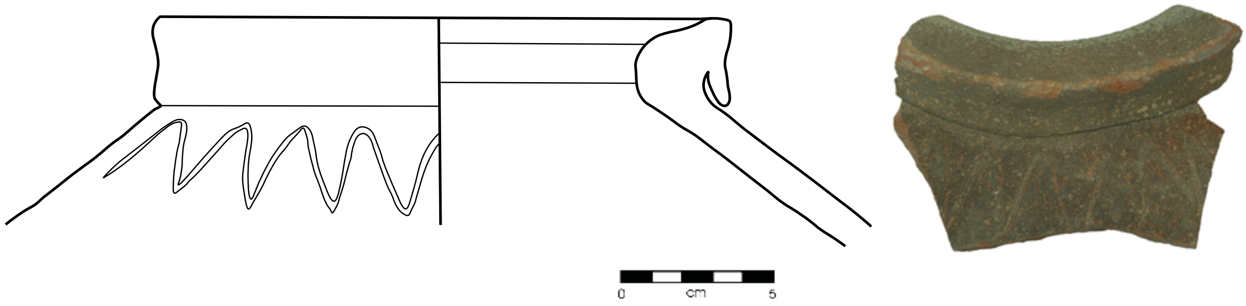

Figure 5.10: Jar with a thickened, folded rim (sample DH024) recovered at Khirbet edh-Dharih.

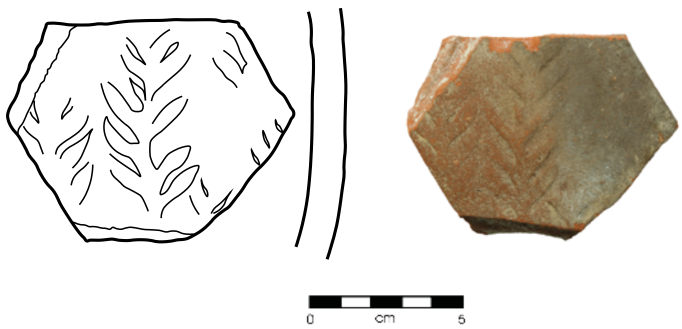

Figure 5.11: Leaf-pattern jar sherd (sample DH027) recovered at Khirbet edh-Dharih.

11, see no. 10 for a close parallel for DH025; see also Holmqvist 2013: 20–21), Mount Nebo (Alliata 1990: 457, no. 102 is similar to DH024), Umm al-Rasas (Pappalardo 2002: 427, Fig. 30:7–8), Khirbet ed-Deir (Calderon 1999: 136, Pl. 1:15), in the Madaba area (Harrison 1994: 436, Fig. 4: 14), in the Kerak plateau (Brown 1991: 277, no. 399, 'Late Byzantine'; see also Parker 2006b: Figs. 16.53–55, nos. 270, 272, 274), Qasr al-Hallabat (Ghrayib 2003: 72, Fig. 10:t, 'Umayyad') and also from further north, from the Amman area (Sami' Abu Dayyah *et al.* 1991: 279, Fig. 7:23, 'Late Byzantine'). No secure date can be given for the contexts of these sherds at Khirbet edh-Dharih. A late Umayyad, or first half of the 8th century date might be appropriate for these jars from the two sites, but it is difficult to assign them to a chronological category with certainty. One of the Jabal Harûn samples, JH020 was found with the possibly early 'Abbasid assemblage (Trench J, locus 44), but it can be an earlier residual or later intrusive material as no close parallels were found in the literature and it has a different neck and rim form compared to JH019 and the Khirbet edh-Dharih samples.

Jars decorated with leaf-patterns appear to be a phenomenon of southern Transjordan (Figures 5.11, 5.12), the published parallels being restricted to this region. Leaf-decorated sherds were sampled from Jabal Harûn and Khirbet edh-Dharih, but they were not found in the sampled Negev sites nor have they been recorded from 'Aqaba/Aila. Samples JH021–022 and DH026–027 appear very similar in the macroscopic examination, but their decoration patterns show some variation. The aspect of their possible shared source from a regional centralised production is one of the questions that will be looked into in the analytical section of this work. The jars are hand-made, which brings an aspect worth considering in future provenance studies of jars of this kind: analysis of fingerprints left on the inner vessel surfaces by the potter when applying the exterior decoration might indicate how many potters were involved in their production when examined in a large series of vessels.

From Petra, well-preserved vessels have been found with the entire body covered with the 'leaf'-pattern, four handles positioned in pairs, a body built of 'wide, flat coils', the overall height being *c.* 76–78cm. 'Amr associates these jars with 'a general form that started in the Late Byzantine and continued into the Early Islamic era', but differentiates the Petra church jars as an earlier variant, more likely dating to the second half of the 6th century ('Amr 2001a). However, in light of the contexts of the jars with similar decoration found at Khirbet edh-Dharih and Jabal Harûn, this date appears too early for these samples and they are more likely to date to the 8th century, and possibly its later half. Leaf-decorated jar sherds have been published, in addition to the Petra church examples ('Amr 2001a: 367, Fig. 2, 'second half of the 6th century'), from Khirbet edh-Dharih (Waliszewski 2001: 101, Fig. 2:6, '*VIIe–VIIIe s.*'), and Gharandal (Walmsley and Grey 2001: 148, 150, Fig. 8:5; the excavators report similar sherds from nearby Khirbat Khairan, Rashadiya and Khirbat Nusraniyah).

The term 'bag-shaped' jar is broadly used in the literature for vessels with varying characteristics, the chronological range continuing from the 1st century BCE to the Islamic periods with only minor stylistic variation (often cited as LR 5/6 in the literature, see Kingsley 1994–1995: 39; and also Calderon 1999: 135–136, Pl. 1 for discussion). Bag-shaped jars were presumably produced in various locations and used in the regional trade of agricultural products, but have also been linked with wine export and long-distance

Figure 5.12: Locations of sites discussed in relation to leaf-pattern jars.

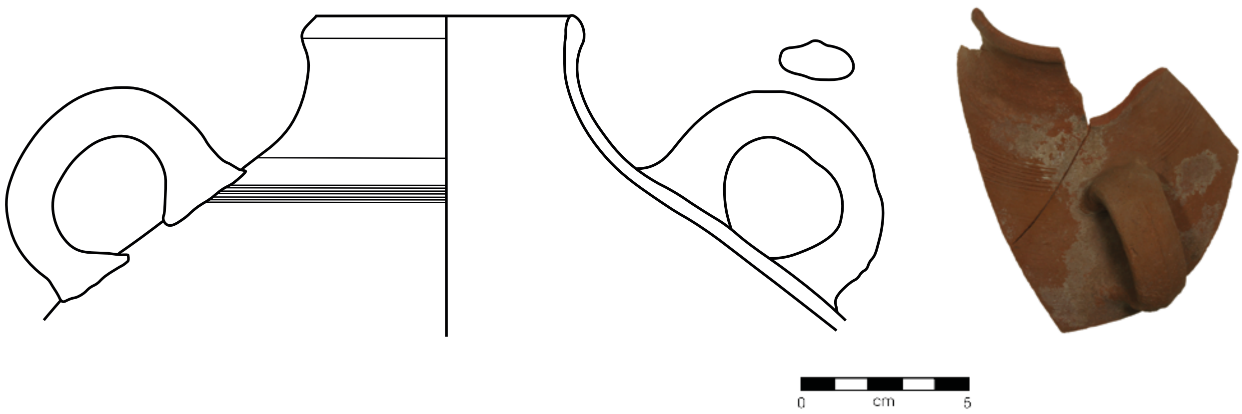

Figure 5.13: Bag-shaped jar (sample JH023) recovered at Jabal Harûn.

trade, being the most common jar type in the 6th–7th century shipwrecks in the Mediterranean (see Kingsley 2001: 49–50; Kingsley 1994–1995: 45, Reynolds 2005: 573–578). See samples from Jabal Harûn JH023 (Figure 5.13); and Khirbet edh-Dharih DH028 and Abu Matar samples AM015–017.

Bag-shaped storage jars have been found at several sites, from Jerash (Clark 1986: 335, Pl. XIII:25, 26, 'Umayyad', with white painted decoration), Pella (McNicoll and Walmsley 1982: 342, Fig. 5:5, 'Early Islamic'; Walmsley 1982: Pl. 146: 3; 'Umayyad pottery of A.D. 746/7' and Pl. 148: 4, 6, 'Umayyad pottery, first half of the eight century A.D.'), the Amman citadel (Northedge 1984: 402, Fig. 73:5, 'Umayyad earthquake destruction', with incised wavy-lines on the body), they are common in the Jerusalem area (Magness 1993: 227-230, forms 5-6, 'late 6th to 8th c.'; see also Calderon 1999: 134; Rapuano 1999), Bet Shean (Bar-Nathan 2011b: 232–234, 'Umayyad'), 'Aqaba/Aila (Whitcomb 1989c: 282, Fig. 5: l, '750–800 A.D. or later'), Humeima ('Amr 2001b: 119, Fig. 4, 'mid-7th c.'), Horvat Karkur 'Illit (Nikolsky and Figueras 2004: 151, 178–185, 'early Islamic'), Rehovot (Rosenthal-Heginbottom 1988: 84; see Magness 2003: 191–194), Sde Boqer (Nevo 1985: 39, Pl. 5:1–3, 'Byzantine–Arab'; see Magness 2003: 138–141), Mount Nebo (Alliata 1990, 452, Nos. 3–6). In addition, bag-shaped jars are found at Tell Keisan (Landgraf 1980: 70, Fig. 22), Caesarea (Blakely 1987: 121, Fig. 39:150–154, Fig. 42: 186), Kursi (Tzaferis 1983: 59, Fig. 7:1), Capernaum (Peleg 1989: 81, Fig. 60) and Khirbet al-Karak (Delougaz 1960: Pls. 35:1–6, 8, 55).

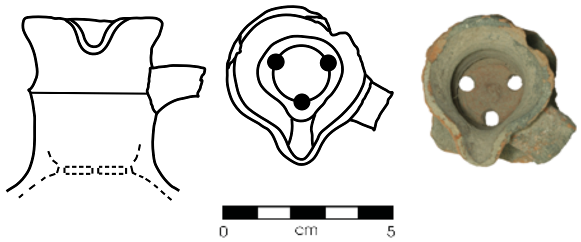

Figure 5.14: Strainer jug (sample DH029) recovered at Khirbet edh-Dharih.

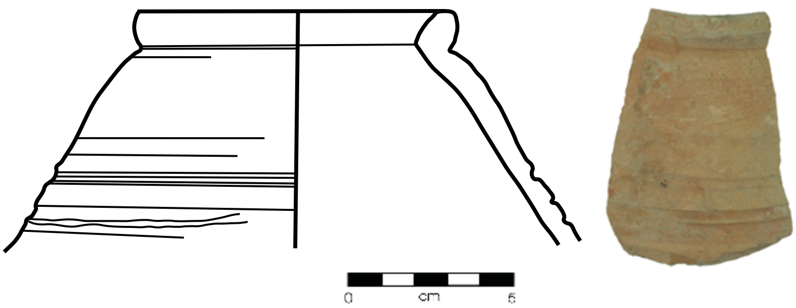

Figure 5.15: Elusa jar (sample E011) recovered at Elusa.

This jar shape is very common, and there are numerous variants in the literature. Thus, a very accurate date for the first appearance of the bag-shaped jars at the sampled sites, probably representing local versions, cannot be given with great certainty, but it could be 6th century, the possible terminal date extending to the 9th century. The contexts of JH023 and DH028 (Trench J, locus 20 and S2DD16, respectively, see also Holmqvist 2016b: 247, for an early Islamic lamp from the Jabal Harûn context) may indicate Umayyad, or 6th–7th century date, AM017 was found in an Islamic stratum, whereas AM015, AM016 and AM018 were found in mixed late Byzantine–early Islamic deposits.

Not many jug or bottle sherds (Figure 5.14) were sampled for this study, but it is worth noting that the strainer jugs from Jabal Harûn and Khirbet edh-Dharih (JH024 and DH029, respectively) are almost identical. A close parallel to these was published from Bethany (Saller 1957, 243, Fig. 48, no. 3202). A mid-8th century date can be associated with jug JH024, found in a locus with forms dated to the 8th–9th centuries (Trench Z, locus 58). A similar date is probable for DH029, while DH030 may also be a later variant.

One of the jar sherds sampled from Elusa resembles the so-called 'Gaza jar' (Figure 5.15; for Gaza jar parallels, see, for example, Meyza and Mlynarczyk 1995: 174–177; and for their production, see the survey of ceramic workshops in southern Israel and suggested other production sites of these vessels Yigael 1993; see also Majcherek 1995). It is even more likely, however, that this sherd is a so-called 'Elusa jar', a type which was produced locally at Elusa (Fabian and Goren 2002). Fabian and Goren typologically differentiate this type from the 'Gaza' and 'Ashkelon' jars by its very short, vertical and only slightly everted neck and being without the ridging typical of the other forms. The Elusa jars have been dated from the 2nd half of the 4th century into the 6th century, when they are more common (Fabian and Goren 2002: 145–146), and a 6th, possibly 7th century date can be suggested for this form. Furthermore, one of the Elusa samples, E012, with engraved (*Kerbschnitt*) decoration that appears to be a rim fragment of a closed-form, possibly a jar with a handle attached below the rim. The engraved (*Kerbschnitt*) vessels are discussed in more detail below (Figure 5.19, see JH034).

The jar fragments sampled from 'Aqaba include a late Roman form A010 (unstratified), a late 1st–2nd century garum container jar A011 (for 'Aqaba amphorae and discussion of fish product export, see below), a possible 4th century jar A012, an early Roman/Nabataean jar A013, and early Byzantine jar A014, a handle fragment A015 of late Roman–early Byzantine type (unstratified), and an early Byzantine, possibly 4th century jar sherd A016 with incised decoration (all dates from S. Thomas Parker). These earlier samples will be useful to explore diachronic trends, e.g., in exploitation of the same resources.

The majority of the amphora sherds included in this study are body sherds, thus making it difficult to associate them with known amphora types with certainty. Typical 'Aqaba/Aila amphorae (Figure 5.16) were sampled from 'Aqaba, A017 was found in a 5th century Byzantine context, and A020 from a 7th century Umayyad stratum (see also Melkawi *et al.* 1994: 459–460, Fig. 10; Whitcomb 2001a: 303, Fig. 2:a; Whitcomb 1989b: 183:a). The 'Aqaba/Aila amphorae are described by Melkawi *et al.* as 'carrot shaped with heavily rilled body...handles are heavy extending from just below the rim to the shoulder...the most distinguishing feature is the internal ledge below the rim for receiving the lid' (Melkawi *et al.* 1994: 460). These vessels were produced locally in 'Aqaba at least until the 7th century, possibly to the mid-8th century, as is attested by wasters found from the kiln site (Melkawi *et al.* 1994; Whitcomb 2001a: 298). The excavators estimate that the production capacity of the kiln complex exceeds the demands of local consumption. Thus, there appears to have been an industrial production centre of amphorae in 'Aqaba, possibly needed to repack land transported products for sea transport (Melkawi *et al.* 1994: 463–464; Whitcomb 2001a: 299).

Evidence for the transportation of these vessels in the Red Sea trade is provided by finds of this type recorded, for example, from Adulis on the northern coast of the Red Sea (the port of Axum in Ethiopia) and Qana in South Arabia (see Whitcomb 2001a: 299 and for further references; see also Tomber 2004; see Figure 2.1 in Chapter 2). The transportation of the 'Aqaba/Aila amphorae is regarded as mainly south orientated, not extending beyond Petra in the north (Parker 2006a: 228; see Holmqvist 2013 for Aila amphorae for Humeima). There is evidence for the production of high quality garum at 'Aqaba, as indicated by fish remains found in a locally produced early Roman period jar (Van Neer *et al.* 2010; Van Neer and Parker 2008). This evidence might link to the distribution of the locally produced ceramics, as it seems probable that the fish products were exported in ceramic containers.

Greenish amphora sherds with deep grooves were very frequent finds at Jabal Harûn. In addition, *scaridae* parrotfish fish scales form the majority of fish remains found at the site (see Frösén *et al.* 2001a), and Red Sea fish remains have also been identified in the Negev (Lernau 1986). Thus, it is possible that fish products of Red Sea origin, or other goods, were transported in an inland distribution network in 'Aqaba-made ceramic containers. To examine this, amphorae sherds macroscopically similar to the 'Aqaba/Aila amphorae were sampled (see samples from Jabal Harûn, JH026–031, Khirbet edh-Dharih DH031–038, and Elusa E014, sherds with similar characteristics were not present in the Abu Matar assemblage).

The contexts of the sampled amphora sherds from Jabal Harûn, Khirbet edh-Dharih and Elusa do not offer great assistance as to their date, but DH037 was found with painted wares (see above, locus S2DD5), JH028 was found in a stratum rich with ceramics that can be associated with the mid-8th–9th century (Trench Z, locus 58) and an early Islamic date is also possible for the context of JH026 (Trench J, locus 17; Juntunen 2016; Lahelma *et al.* 2016). In general, amphorae are a complex ceramic category in terms of chronology, as they probably had a long life span in secondary use after being emptied of their original contents (Callender 1965: xxii; see also examples of amphora reuse for various purposes in Peña 2007: 47–56, 61–192).

In addition to the typical 'Aqaba/Aila amphorae, amphora sherds sampled from 'Aqaba/Aila include sample A018 from a 4th century early Byzantine context, and A019 from 1st–2nd century context. These earlier

Figure 5.16: 'Aqaba/Aila amphora (sample A017) recovered at Aila/'Aqaba.

variants, in case that they prove to be of local origin, provide excellent comparative material for the study of chronological variation in ceramic manufacture in 'Aqaba.

One of the finds from Elusa, sample E013, resembles the so-called 'Late Roman 1' (LR 1) jar, a type whose chronological range has been suggested to vary from the early 5th to the mid-7th centuries (Figure 5.17; see a parallel published from a kiln site at Kato Paphos, Cyprus in Demesticha and Michaelides 2001: 296, Fig. 10; see also Calderon 1999: 139, Pl. 2:1, suggested to be from Cyprus or Antioch; Calderon 2000: 186–187, Fig. 2: 20–22; Landgraf 1980: 81, Fig. 26:3; see Figure 2.1 in Chapter 2). There has been some debate over the chronology of the LR 1 jars as they have also been found in 8th and 9th century contexts (see Armstrong 2009; see also Kingsley 2009: 35; Majcherek 2004: 235; Tomber 2004; Riley 1979) and there is also evidence that demonstrates their production at numerous locations (see Williams 2005; Reynolds 2014; Reynolds 2005: 564–567, 573–578; and Peacock and Williams 1986). No parallels for amphora JH025 were found in the literature, and it may be a form local to the Petra region.

Elusa kiln wasters

Ceramic wasters from the Elusa kilns were included in this study (Figure 5.18, see samples E015–020). The Elusa jars, for instance, probably used to store and transport wine, were produced locally at the site in the late 4th–6th centuries (Fabian and Goren 2002). One of the samples, E020, probably is a waster of this jar type. It seems that the Elusa production was specialised in the manufacture of a few particular forms. In addition to the Elusa jars, two of the Elusa kiln wasters (E015 and E016) resemble a form called a water-jug, used to 'draw water from wells -- a rope was tied around the rim' (Calderon 2000: 194, Fig. 6). Cooking pot wasters were not found at the sites (P. Fabian, personal communication, 2007). The ceramic wasters are of greenish colour (approximately 10YR 6/2, very light gray). The terminal date of the Elusa manufactured ceramics may exceed the 6th century, however, features typically associated with early Islamic ceramics were absent in the Elusa assemblage. Open-form cooking pots were found, but basins and high-necked jars were not present in the studied Elusa assemblage from the recent excavations, the red-painted (E010) and engraved (*Kerbschnitt*) (E012) sherds being unstratified finds.

Figure 5.17: Jar (LR 1) (sample E013) recovered in Elusa.

Figure 5.18: Elusa kiln wasters (samples E017 and E019).

Figure 5.19: Engraved (Kerbschnitt) sherds (samples JH034 and E012) recovered at Jabal Harûn and Elusa.

Other forms

Sample JH034 is of a greenish ware (5Y 7/4) with engraved motifs (Figure 5.19). Its decoration is relatively similar to that of E012, but the Jabal Harûn find seems to belong to an open-form vessel, and be an outward folded rim of a plate or a bowl (for a related basin from Horvat Karkur 'Illit, see Nikolsky and Figueras 2004: 171, Fig. 34:4). There is a tradition of engraved (*Kerbschnitt*, cut-ware) bowls in the early Islamic period (see published examples, for instance, in Walmsley 1991: 155; Figs. 5:8; 6:1–3, 'later Abbasid'; Walmsley *et al.* 1993: 217, Fig. 24:5–6, ''Abbasid'; Walmsley 1995b: 668; Baramki 1944: Plate XXI:5, 7, ' 'Abbasid', Whitcomb 1988b: 64–65, '750–850', Aharoni 1956: 110, Fig. 6, ' 'Abbasid', Fitzgerald 1931: Pl.XXVII, no.1, 'Arab'; Peleg 1989: 55, Fig. 46: 1–6, 'Umayyad'). This ceramic tradition, emerging in the 9th century (or *c.* 850), is of particular interest as it reflects an Islamic flow of influence from the Arabian Peninsula, imitating the 8th century stone bowls from the al-Hijaz quarries (Kisnawi *et al.* 1983; Whitcomb 1987: 262–266; Magness 1994: 203–204; Walmsley 1995b: 668). The engraved sherds sampled for this study (E012, JH034) cannot, however, be associated with this tradition with certainty as they have features such as the leaf- or zigzag-imprints on the rim that seem not to belong to the early Islamic *Kerbschnitt* ware tradition. Thus, it is possible that these sherds are of earlier, perhaps 7th century date, but their typo-chronology cannot be determined at this point (JH034 may be a late intrusion in its context, Trench O, locus 64, and E012 is a surface find).

The hand-made coarse ware bowls or cups found at Jabal Harûn and Khirbet edh-Dharih represent the coarsest wares sampled (see samples from Jabal Harûn JH033; Khirbet edh-Dharih DH039–040). The vessels have blackened, roughly formed hand-made walls, with straight, simple rims (colour 2.5Y 3/1, very dark gray). The contexts of these sherds represent the latest use phases of both sites (JH033, Trench Y, locus 28, Phase 11), but it is difficult to give very precise dating for these contexts. A 10–12th century date has been suggested for JH033 (Sinibaldi 2016: 206; see also Sinibaldi 2013a–b). These sherds may also be later intrusive materials. The context of DH039 was labelled 'Mamluk–Ottoman' by the excavators, whereas DH040 was found in a layer with early Islamic, possibly 'Abbasid period sherds (S2KK2).

These sherds have no painted decoration and for that reason cannot be associated with the 'hand-made geometrically painted ware' (HMGPW) emerging in the 12–13th centuries and continuing for centuries in a wide area (see Brown 1987; Brown 1988; Brown 1992; Brown 2006; Grey 1994: 60; Johns 1998; Walmsley 2008: 524–530 for further references; see also Franken and Kalsbeek 1975: 167–200). An unpainted possible precursor ware to the painted tradition has been identified in 11th century contexts in the southern areas (Walmsley and Grey 2001: 153, 158, Fig. 9:6–10, Fig. 10; Walmsley 2008: 524–526; see Johns 1998 for discussion of the origin and distribution of HMGPW), but the sampled sherds with relatively thick walls cannot be linked with this tradition with certainty, and the ledge-handle of DH040 is also unusual in this tradition. Forms relatively similar to the sampled sherds have been published from the Petra area, (Sinibaldi 2016: 206; see also Sinibaldi 2013a–b; Lindner 1999: 481, 485, 'Mamluk') and from Umm al-Rasas (Pappalardo 2002: 427, Fig. 30: 9–12; see also Avni 1996: 47, 51; Rosen and Avni 1997: 66–70). The date of these coarse, hand-made vessels cannot presently be determined, and their chronological assignment may vary from the mid-11th century up to the modern time (see Sinibaldi 2016; Sinibaldi 2013a; Walmsley and Grey 2001: 158–159).

The glazed sherds, probably bowl fragments, have greenish glaze applied on both surfaces (see samples JH035, DH041, AM020, Figure 5.20), and one sample (JH035) also has brownish paint on its interior. Glazed sherds represent a minority of the selected samples, but they were included in the study in order to examine their technology and origins. Glazed sherds are rare at the sampled sites. In the Islamic levels at 'Aqaba/Ayla, glazed wares, possible imports from Egypt, form only a small minority, 5–10% of the ceramic assemblage, and appear in layers dated to the 2nd half of the 8th century (Khouri and Whitcomb 1988: 29; Whitcomb 1989c: 270). The sherds sampled for this study, however, do not have characteristics that can be associated with the Coptic tradition.

In general, the state of preservation of the sampled glazed sherds makes their typo-chronological assignment uncertain. The sherds are likely to date from the late 8th–9th century or later. According to Sauer, glazed wares are very rare before the 8th century outside Iraq and Iran and still very rare in Umayyad contexts (Sauer 1986: 308; Sauer and Magness 1997: 478; see also Zarins 1989), and glazed wares emerge only in the 9th century strata at Pella (Walmsley 1992b: 257). In terms of techno-chronological differences of glazes, it has been suggested that the alkali silicate glazes were produced only until the 9th century and then re-emerge in the 11th and 12th centuries whereas lead-glazes have a long and continuous chronological span (for discussion, see, e.g., Frierman 1970: 387; Walton and Tite 2010). A close parallel to JH035, a painted ring-based bowl 'glazed slip-painted ware' fragment, dated to the 13th century, has been published from Tel Jezreel (Grey 1994: 59, Fig.9:5; see also Pringle 1985; Pringle 1984; Pringle 1981).

One of the Abu Matar samples, AM019, is a cream-ware sherd ('Khirbet al-Mafjar' ware; Figure 5.21; for discussion, see Sauer and Magness 1997: 477–478; Walmsley 2001b). Parallels for this cream-coloured (2.5YR, 8/4 pale yellow) mould-made bottle/jug/jar with floral and geometric designs have been published from many sites (see Walmsley 2001b for parallels and chronology, and Arnon 2008, 133, 135–136; Brosh 1986: 73, Fig. 1:7, Pl.III:2, 'Umayyad'; Stacey 2004: 145–146, Fig. 5.61:13, 'mid–late 10th century'; Waliszewski 2001, 106, Fig. 7:5, '*VIIIe–XIIe s.*'; Whitcomb 1988b: 55, 57, Fig. 1, period 3, type B, '900–1000' for typological parallels; see also an example from Khirbet Kafr Rasiya in Finkelstein and Magen 1993: 113, Fig. 124, no. 8, 'Early Islamic'). According to the parallel evidence, this sherd is likely to date to the 11th (or 10th) century.

Architectural ceramics can be useful in provenance studies with the hypothesis that they were produced using local resources and relatively near the location where they were used. For example, roof tiles were fired in the same kilns as domestic pottery at Jerash (Kehrberg 2009; Schaefer 1986: 427–429). The sampled roof tiles (JH036–038; DH042–043) have slightly variant details, but they are representatives of the same Byzantine tradition. All of the tiles are of brownish colour (10YR 5/1–5/3). Close parallels to the sampled tiles have been published, for example, from Khirbet ed-Deir, Mount Nebo, Tell Keisan and Deir Qal'a (see Alliata 1991: 410, Fig. 24:25; Calderon 1999: 144, Pl. 5: 7; Hirschfeld 2002: 182, Fig. 39: 13–15, 'Byzantine'; Landgraf 1980: 85-86, Schneider 1950: 132, Fig. 15; Figs. 27–28; for more Jabal Harûn tiles, see also Hamari 2008).

Jabal Harûn ceramic samples

JH001: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, grooved exterior, mouth diam. 26cm, context: J-44-68.

JH002: wheel-made open-form cooking pot, flat, inward slanting rim, grooved exterior, mouth diam. 26cm, context: J-21-36.

JH003: wheel-made open-form cooking pot, flat, inward slanting rim, grooved exterior, mouth diam. 28cm, context: Z-58-25.

JH004: wheel-made cooking pot lid with a knob, flat, slanting rim, grooved exterior, two pierced steam-holes, mouth diam. 16cm, context: J-44-68.

JH005: wheel-made closed-form cooking pot with protruding rim, carinated neck, mouth diam. 6.5cm, context: C-9-21.

JH006: wheel-made basin with protruding rim, combed wavy-line decoration on exterior, clay strip with finger impressions applied on the mid-section after wheel-throwing, mouth diam. 28cm, context: J-44-68.

Figure 5.20: Glazed sherd (sample DH041) recovered at Khirbet edh-Dharih.

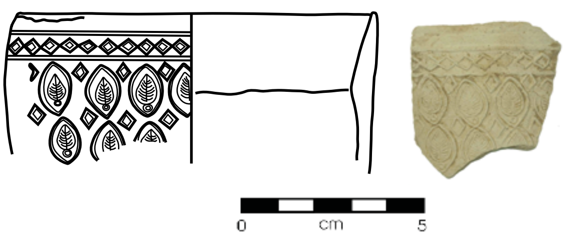

Figure 5.21: 'Khirbet al-Mafjar' cream ware (sample AM019) recovered at Abu Matar.

JH007: wheel-made basin with protruding rim, combed horizontal and wavy-lined decoration on exterior, mouth diam. 34cm, context: Z-58-25.

JH008: wheel-made basin with protruding rim, carved double lines on rim, combed horizontal and wavy-line decoration on exterior, mouth diam. *c.* 27cm, context: J-45-72.

JH009: basin (production technique unclear) with protruding rim, incised single wavy-lines on rim and exterior, clay strip with finger impressions applied on mid-section after forming, mouth diam. 25cm, context: W-3-6.

JH010: wheel-made basin with protruding rim with finger impressions, incised wavy-line decoration on exterior, mouth diam. 35cm, context: Z-58-25.

JH011: wheel-made jar with a high neck and plain, slightly rounded rim, mouth diam. 10cm, context: Z-58-25.

JH012: wheel-made jar with high neck and plain, slightly rounded rim, vertical grooved rim-to-shoulder loop handle(s), slightly carinated neck-shoulder join, mouth diam. 10cm, context: Z-58-25.

JH013: wheel-made jar with a high neck and plain, slightly rounded rim, carinated neck-shoulder join, mouth diam. 8cm, context: J-44-68.

JH014: wheel-made jar with combed horizontal and wavy-line decoration on neck and shoulder, context: J-44-68.

JH015: hand-made jar with straight neck and handle fragment on rim, painted brownish stripes on neck, mouth diam. 8cm, context: J-10-60.

JH016: hand-made jar with painted reddish stripes on body, context: W-3-5.

JH017: wheel-made jar with short neck and roundish rim, grooved exterior, mouth diam. 16cm, context: Z-58-25.

JH018: wheel-made jar with short neck and roundish rim, grooved exterior from shoulder, mouth diam. 10cm, context: J-44-68.

JH019: jar with thickened, folded rim, mouth diam. 12cm, context: C-9-21.

JH020: wheel-made jar with roundish, thickened rim, mouth diam. 10cm, context: J-44-68.

JH021: hand-made jar, stamped leaf-pattern decoration on exterior, context: A-11-13.

JH022: hand-made jar, stamped leaf-pattern decoration on exterior, context: B-5-7.

JH023: wheel-made 'bag-shaped' jar with high, slightly everted neck, roundish rim, vertical plain shoulder-to-shoulder loop handle(s), incised lines on neck-shoulder join, mouth diam. 8cm, context: J-20-82.

JH024: wheel-made strainer jug, carinated neck, vertical neck-to-shoulder handle, incised wavy-line decoration on shoulder, pinched spout at 45° angle from handle, marks of strainer on inner neck-shoulder join, mouth diam. *c.* 4.5cm, context: Z-58-25.

JH025: wheel-made amphora, strongly carinated neck, combed lines on neck-shoulder join, mouth diam. 9cm, context: B1-6-22.

JH026: wheel-made amphora with roundish rim, carinated neck inner surface, mouth diam. 8cm, context: J-17-43.

JH027: wheel-made amphora with deeply grooved exterior, context: W-3-4.

JH028: wheel-made amphora with deeply grooved exterior, context: Z-58-25.

JH029: wheel-made amphora with deeply grooved exterior, context: W-3-6.

JH030: wheel-made amphora with deeply grooved exterior, context: W-3-5.

JH031: wheel-made amphora with deeply grooved exterior, context: D-1-1.

JH032: wheel-made bowl (or lid), combed wavy-line decoration on exterior, mouth diam. *c.* 30cm, context: A-18-22.

JH033: hand-made coarse ware cup/bowl with straight walls and thinned rim, mouth diam. *c.* 16cm, context: Y-28-39.

JH034: plate? with engraved angular motifs (*Kerbschnitt*), and stamped leaf-like patterns, context: O-64-99.

JH035: glazed bowl, greenish glaze applied on both surfaces, painted brownish lines on interior, flat base, context: J-20-48.

JH036: roof-tile with rectangular edge, context: V-14-29.

JH037: roof-tile with rectangular edge, context: V-07-21.

JH038: roof-tile with angular edge, context: V-10-19.

Khirbet edh-Dharih ceramic samples

DH001: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, grooved exterior, mouth diam. 15cm, context: S10C023.

DH002: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, grooved exterior, mouth diam. 15cm, context: SD10108.

DH003: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, two grooves visible on exterior, mouth diam. 15cm, context: S10C024.

DH004: wheel-made closed-form cooking pot with rim-to-shoulder vertical grooved loop handle(s), angular rim, grooved exterior from shoulder, mouth diam. 12cm, context: S1H12.

DH005: wheel-made closed-form cooking pot with rim-to-shoulder vertical grooved loop handle(s), angular rim, grooved exterior from shoulder, mouth diam. 10cm, context: S1H12.

DH006: wheel-made closed-form cooking pot, angular rim, carinated neck interior, mouth diam. 10cm, context: S1H12.

DH007: wheel-made closed form cooking pot, angular rim, grooved exterior from shoulder, mouth diam. 7cm, context: S1H12.

DH008: wheel-made basin with flat, slightly protruding rim, horizontal grooved loop handle(s) on body, combed horizontal and wavy-line decoration on exterior, flat base, mouth diam. 26cm, context: S2DD19.1.

DH009: wheel-made basin with rounded, protruding rim, incised single wavy-line decoration on exterior, mouth diam. 22cm, context: S6C2.

DH010: wheel-made bowl with angular rim, mouth diam. 24cm, context: S10D.

DH011: wheel-made jar with high neck, grooved rim, combed wavy-line decoration on neck, carinated neck-shoulder join, mouth diam. 8cm, context: S9.05.

DH012: wheel-made jar with high neck and thinned slightly everted rim, grooved exterior from shoulder, mouth diam. 10cm, context: S2CC2.

DH013: wheel-made jar with everted neck and rounded rim, carinated mid-neck, mouth diam. 10cm, context: S2DD3.

DH014: wheel-made jar with straight, high neck and simple rim, vertical grooved rim-to-shoulder loop handle(s), grooved exterior from shoulder, mouth diam. 8cm, context: S7F9.

DH015: wheel-made jar with combed horizontal and wavy-line decoration on shoulder, context: S2KK2.

DH016: wheel-made jar with combed horizontal and wavy-line decoration on shoulder, context: S2KK1.

DH017: wheel-made jar with combed horizontal and wavy-line decoration, context: S2KK1.

DH018: wheel-made jar with combed horizontal and wavy-line decoration on shoulder, context: S2KK1.

DH019: jar with painted red stripes on exterior, context: S2EE16.

DH020: hand-made jar with painted reddish stripes on exterior, context: S2DD3.

DH021: hand-made jar with painted brownish stripes on exterior, context: S2DD5.

DH022: jar with thickened, folded rim, mouth diam. 12cm, context: S1.G306.

DH023: jar with thickened, folded rim, mouth diam. 12cm, context: S905.

DH024: jar (hand-made?) with a thickened, folded rim, single wavy-line incised below rim, mouth diam. 12cm, context: S7C04.

DH025: jar with thickened, folded rim with finger impressions on rim exterior, mouth diam. 24cm, context: S2FF.

DH026: hand-made jar with stamped leaf-pattern on exterior, context: S2003.

DH027: hand-made jar with stamped leaf-pattern decoration on exterior, context: S3M11.

DH028: wheel-made 'bag-shaped' jar with vertical grooved shoulder-to-shoulder loop handle(s), combed horizontal lines on neck-shoulder join, context: S2DD16.

DH029: wheel-made strainer jug, carinated neck, vertical neck-to-shoulder handle, pinched spout at a slight angle to handle, three-holed strainer on neck-shoulder join, mouth diam. *c.* 4.5cm, context: S10E-1.

DH030: wheel-made bottle (or jug with spout on shoulder) with high, carinated neck, vertical handle fragment attached below rim, mouth diam. 4.5cm, context: S903.

DH031: wheel-made amphora with deeply grooved exterior, context: S21128.1.

DH032: wheel-made amphora with deeply grooved exterior, context: S2W2A.

DH033: wheel-made amphora with deeply grooved exterior, context: S3408.

DH034: wheel-made amphora with deeply grooved exterior, context: S2JJ37.3.

DH035: wheel-made amphora with deeply grooved exterior, context: S113.

DH036: wheel-made amphora with deeply grooved exterior, context: S7A006.7.

DH037: wheel-made amphora with deeply grooved exterior, context: S2DD5.

DH038: wheel-made amphora with deeply grooved exterior, context: S2DD1.

DH039: hand-made coarse ware cup/bowl with straight walls and thinned rim, mouth diam. *c.* 20cm, context: S11B006.

DH040: plain ledge-handle of hand-made coarse ware, context: S2KK2.

DH041: glazed vessel with handle, green glaze applied on both surfaces, context: S9.05.

DH042: roof-tile, context: V10N70.

DH043: roof-tile with rectangular edge, context: S903.

Elusa ceramic samples

E001: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat rim, grooved exterior, mouth diam. 16cm, context: 3043.

E002: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, grooved exterior, context: 3111.

E003: wheel-made open-form cooking pot, flat, inward slanting rim, grooved exterior, mouth diam. *c.* 20cm, context: 2046.

E004: wheel-made closed-form cooking pot with vertical grooved (rim-to-shoulder) loop handle(s), angular rim, mouth diam. 12cm, context: 2046.

E005: wheel-made closed-form cooking pot with vertical grooved rim-to-shoulder loop handle(s), inward slanting rim, exterior grooved from shoulder, mouth diam. *c.* 15cm, context: 3119.

E006: wheel-made basin with rectangular, protruding rim, incised line on rim, finger impressions on mouth, mouth diam. *c.* 24cm, context: 3027.

E007: wheel-made basin with rounded, protruding rim, incised line on rim, incised lines on exterior, mouth diam. *c.* 24cm, context: 3100.

E008: wheel-made basin with rectangular, protruding rim, mouth diam. *c.* 20cm, context: 3138.

E009: wheel-made bowl with rounded, protruding rim, incised lines on exterior, mouth diam. 20cm, context: surface find.

E010: jar with painted red stripe on exterior, context: surface find.

E011: wheel-made jar with rounded, folded rim, grooved exterior from shoulder, mouth diam. 8cm (possibly a so-called Elusa jar or a Gaza jar), context: 3021.

E012: hand-made jar? with engraved angular motifs (*Kerbschnitt*), straight neck, stamped decoration on rim, handle fragment below rim, mouth diam. 12cm, context: surface find.

E013: wheel-made amphora with rounded, everted rim, vertical (neck-to-shoulder?) grooved (neck-to-shoulder) loop handle(s) below rim, carinated upper neck, mouth diam. 7cm, context: 2007.

E014: wheel-made amphora with deeply grooved exterior, context: 3531.

E015: wheel-made jug/bottle with grooved exterior, flat base, signs of over-firing, context: unstratified.

E016: wheel-made jug/bottle grooved exterior, flat base, signs of over-firing, context: 3017.

E017: wheel-made jar? with vertical grooved rim-to-shoulder loop handle(s), grooved exterior, signs of over-firing, context: unstratified.

E018: wheel-made jar? with horizontal loop handle(s), grooved exterior, signs of over-firing, context: unstratified.

E019: wheel-made vessel fragments melted together, grooved exteriors, signs of over-firing, context: 3055.

E020: wheel-made jar (possibly a so-called 'Elusa jar' type) with rounded everted rim, grooved exterior from shoulder, mouth diam. 8cm, context: 3091.

Abu Matar ceramic samples

AM001: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, grooved exterior, mouth diam. 20cm, context: 3065.

AM002: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, plain exterior, mouth diam. 20cm, context: 3090.

AM003: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat rim, grooved exterior, mouth diam. 20cm, context: 3156.

AM004: wheel-made cooking pot lid with a knob, grooved exterior, context: Area A, 217 (unstratified).

AM005: wheel-made open-form cooking pot with horizontal grooved loop handle(s) below rim, flat, inward slanting rim, grooved exterior, mouth diam. 22cm, context: 3179.

AM006: wheel-made basin with rounded rim, finger impressions on rim exterior, mouth diam. 25cm, context: 1085 (surface find).

AM007: wheel-made bowl with angular rim, mouth diam. 15cm, context: 3405.

AM008: wheel-made bowl with angular rim, mouth diam. 24cm, context: 3453.

AM009: wheel-made bowl with rounded, slightly protruding rim and carinated exterior (rim and carination show production flaw of slipped potter's finger or tool before firing), grooved upper exterior, mouth diam. *c.* 20cm, context: 1138 (surface find).

AM010: wheel-made basin with thickened, rounded rim, combed horizontal and wavy-line decoration on exterior, mouth diam. *c.* 30cm, context: 3377.

AM011: wheel-made basin, combed horizontal and wavy-line decoration on exterior, mouth diam. *c.* 30cm, context: 3532.

AM012: wheel-made jar with combed horizontal and wavy-line decoration on shoulder, context: 1065 (surface find).

AM013: wheel-made jar with combed horizontal and wavy-line decoration on shoulder, context: Area A, 217 (unstratified).

AM014: jar with brownish painted lines on exterior, context: 3350.

AM015: wheel-made cream ware jar with straight neck and simple roundish rim, carinated neck-shoulder join, exterior grooved from shoulder, mouth diam. 9cm, context: Area A, 217 (unstratified).

AM016: wheel-made cream ware jar with thinned, slightly everted rim, carinated neck-shoulder join, mouth diam. 9cm, context: 3494.

AM017: cream ware jar with straight neck and slightly thinned rim, mouth diam. 9cm, context: 3407.

AM018: cream ware jar with flat, ridged and hole-mouth-like rim, mouth diam. 14cm, context: 3453.

AM019: cream ware, mould-made so-called ‘Khirbet al-Mafjar’ type bottle/jug/jar/ with mould-made floral and geometric decoration patterns, context: 3078.

AM020: glazed vessel, greenish glaze applied on both surfaces, context: Area A, 217 (unstratified).

‘Aqaba/Aila ceramic samples

A001: wheel-made closed-form cooking pot with protruding rim, grooved exterior from shoulder, mouth diam. 10cm, context: M.1:14.31.

A002: wheel-made closed-form cooking pot with vertical grooved (rim-to-shoulder) loop handle(s), angular rim, double carinated neck interior, mouth diam. 10cm, context: Area B.

A003: wheel-made closed-form cooking pot, rounded rim, slightly everted neck, exterior grooved from shoulder, mouth dim. 8cm, context: Area B.

A004: wheel-made closed-form cooking pot with handle fragment, grooved exterior, context: B.1:18.31.

A005: wheel-made open-form cooking pot (early form) with vertical grooved rim-to-shoulder loop handle(s), rounded outward rim, plain exterior, mouth diam. *c.* 15cm, context: Area B.

A006: wheel-made open-form cooking pot/casserole, straight rim, upper exterior grooved, mouth diam. 20cm; context: O.1:8.21.

A007: wheel-made thin-walled cooking pot/casserole, context: J.3:106.256.

A008: wheel-made bowl with simple, straight rim, mouth diam. 10cm, context: B.1:0.74.

A009: wheel-made bowl, context: B.1:5.12.

A010: wheel-made jar with roundish rim, mouth diam. 10cm, context: B.1:0.69.

A011: wheel-made jar (garum container) with grooved exterior, context: M.4:45.80.

A012: wheel-made jar with grooved exterior, context: A.10:21.93.

A013: jar with incised lines on exterior, context: M.1:14.31.

A014: wheel-made jar with grooved exterior, context: J.1:50.119.

A015: grooved pithos loop handle, context: Area B.

A016: pithos with incised single wavy-lines on exterior, context: B.2:56.59.

A017: wheel-made typical Aila-type amphora with rounded rim, carinated inner and outer neck surfaces, vertical grooved rim-to-shoulder loop handle(s), mouth diam. 9cm, context: J.8:2.7.

A018: wheel-made amphora, grooved exterior, context: J.21:9.38.

A019: wheel-made amphora with slightly inverted rim, mouth diam. 8cm, context: M.1:15.27.

A020: wheel-made amphora with deeply grooved exterior, context: J.23:117.169.

Chapter 6

Geochemical and microstructural ED-XRF and SEM-EDS data

There are numerous analytical methods available for chemical analysis of archaeological artefacts, and there are certain criteria that can be followed when selecting the method used for ceramic provenance analysis (see, e.g., discussion in Tite 2017). The main criteria, following the availability of equipment, are 'the range of elements that can be analysed; the concentration range covered (i.e., from major through minor to trace element concentration); the accuracy and, perhaps more important, the precision of the analyses; the ease of sample preparation and the speed of analysis; and finally, the cost per sample analyzed' (Tite 2001: 444; Tite 1999: 197).

In this study, bulk chemical analysis by energy dispersive X-ray fluorescence spectrometry (ED-XRF) was used to determine chemical compositions of the ceramics (see, e.g., Angeli *et al*. 2019; Beltrame *et al.* 2019; Frahm 2018; Holmqvist 2017; Santacreu and Cau Ontiveros 2017; for recent applications of ED-XRF in ceramic analysis). ED-XRF is the main analytical method employed in this work, 136 of the total 141 sherds were analysed by ED-XRF (see Appendix II for analytical methods used to analyse individual samples). The resultant chemical compositions were used to form compositional groups in the ceramic assemblages, based on the major, minor and trace elemental patterns of the ceramics.

The compositional group assignments of certain samples were further examined by scanning electron microscopy analysis (SEM-EDS) in which the chemical composition of the ceramic paste and mineralogical inclusions in the ceramic fabric were examined. Furthermore, scanning electron microscopy was used to examine other technological aspects of the ceramics, such as production techniques, microstructures, surface treatments and firing temperature (see, e.g., Bland *et al.* 2017; Beltrame et al. 2019; Holmqvist *et al.* 2018; Van Valkenburgh *et al.* 2017, for recent applications of SEM-EDS in ceramic analysis).

The analytical work for this study was carried out in the Wolfson Archaeological Science Laboratory at the UCL Institute of Archaeology. In the following, the employed analytical methods, their general principles and their application in this particular research project are discussed.

Selecting samples

The sample selection for this work aimed to facilitate the requirements of the selected methods, stylistic and functional categorisation, bulk chemical analysis by X-ray fluorescence spectrometry (ED-XRF) and microstructural analysis by scanning electron microscopy (SEM-EDS). Thus, an ideal sample would contain as much archaeological (stylistic, chronological and stratigraphic) data as possible, and be accessible for the invasive sampling needed for sample preparation for the selected methods. In other words, an incomplete vessel, preserved well enough to provide the required typological evidence and enough material to produce samples for the analytical study without compromising the find in the sampling process.

The analytical methods employed in this study (ED-XRF and SEM-EDS) require invasive sampling, and although invasive sampling of archaeological artefacts should always be carefully considered and justified, scientific analysis can offer valuable information on the artefacts, and thus increase their value in archaeological terms, compared to a situation where the finds are preserved in their current form (see discussion in Tite 2002). The artefacts were fully documented and photographed before the samples were taken. Destructive sampling should also be done in a manner where areas containing special or cultural information, such as decoration, are not entirely destroyed (Bishop *et al.* 1982: 280; see Tite 2002: 2–3).

Naturally, complete vessels should not be compromised in invasive sampling, hence a favourable sample would be 'comparable but damaged' (Tite 2002: 3; see also Merriman 2002). The restrictions are more relevant when dealing with artefacts belonging to museum collections, which were not included in this study. The samples in this study did not include any 'registered objects', objects that were considered particularly rare or important finds by the excavators, possibly to be submitted to museum collections at a later stage.

In ceramic studies in general, it is not always possible to store, record, process, and publish the entire ceramic assemblage found, but instead the ceramic evidence available from each site strongly depends on the decisions made while processing the finds. Even more so, in analytical ceramic studies, it is not possible to analyse every artefact that has the characteristics desired of a sample, and sampling strategy plays an important role when selecting a representative sample from each site (see Drennan 1996: 85–86; Hein and Kilikoglou 2017). In the sampling procedure, the starting point was to examine the entire ceramic collection of each site in order to form a general idea of the nature of the assemblages and typical forms present in each category (this applies to the Jabal Harûn, Khirbet edh-Dharih, Elusa and Abu Matar ceramic assemblages, stored in the University of Helsinki, Yarmouk University and Ben Gurion University premises, respectively; the 'Aqaba samples were selected by the excavator).

The excavators' suggestions of chronologically relevant and well-deposited stratigraphic contexts were used as a basis in the selection of the sampled loci. It should be noted here, however, that the chronological and stratigraphic evaluation of the contexts and the stratigraphic processing of the sites was not in all cases completed at the time of the sampling. For these reasons, lists of other datable objects in the contexts were not always available, and the interpretations of the stratigraphic sequences were still in progress. Datable materials in general, such as coins, are extremely rare at the sites, seriously affecting the possibilities of forming absolute chronologies for the sites or the sample ceramics. For these reasons, comparative data published from other sites also plays an important role in the chronological assignments of the finds (see the ceramic catalogue, Chapter 5).

In the overall assessment of the ceramic assemblages of the sites, a general picture of the typical forms present was established, and the sampling proceeded in selected form categories, which were sampled separately using a stratified sampling frame. In stratified sampling, the population is divided into subgroups, *strata*. For example, in the case of ceramic assemblages, the assemblage from each site can be divided into subgroups according to vessel function assignments or other characteristics, and each subgroup or stratum is then sampled separately. The subgroup assignments should follow the principle that there should be minimised variability within the groups and maximised variability between groups or strata (Bishop 2017: 68; Orton 2000: 30). These sherds were drawn, photographed and examined macroscopically, after which the samples considered to be the most informative and suitable for the analysis were selected in each category (see Appendix I for illustrations of samples from each site). The aim was to gather as representative a sample as possible, bearing in mind the research questions, timetable and resources of this research project.

There are some additional principles that can be followed when sampling ceramic sherds for destructive analysis, particularly for provenancing purposes. Extended sample size is required when examining a broader research question, such as exchange and trade, when the aim of the analysis is not only to determine 'local' and 'non-local' manufacture. Sherds selected for analyses should hold as much archaeological (contextual and chronological) and typological data as possible; therefore, small, weathered sherds should not be analysed. Furthermore, the sampling should be biased toward the most 'typical' specimens, but less common examples should also be included for compositional comparison (Bishop *et al.* 1982: 278–279; Hein and Kilikoglou 2017; Rands and Bargielski-Weimer 1992: 34).

Provenance studies based on bulk chemical analysis of ceramic compositions allow compositional 'fingerprinting', grouping or differentiating ceramics on the basis of their major, minor and trace elemental patterns, indicating the same or different recipes used in their manufacture. Chemical compositions may vary within a clay or temper source, and in turn, compositions of different sources may be similar. For this reason, provenance studies based on chemical composition should involve analysis of a large number of samples, and data processing and group formation by statistical analysis. In order to gain meaningful results, it is recommended that in sample selection, each group (sherds sampled from a single site, pottery type, form or chronological category) would ideally include 15–20 samples (Tite 1999: 197). The analysis of about as half as many samples mineralogically is also recommended (Bishop *et al.* 1982: 279).

Based on all the aforementioned parameters, a total of 141 ceramic sherds were selected from the five sites, 38 from Jabal Harûn (sample code JH), 20 from 'Aqaba (A), 43 from Khirbet edh-Dharih (DH), 20 from Elusa (E) and 20 from Abu Matar (AM). Of these samples, 136 were prepared for ED-XRF bulk chemical analysis (34 from JH, 20 from A, 43 from DH, 20 from E and 19 from AM) and 54 for SEM-EDS analysis (34 from JH, 6 from A, 10 from DH, 9 from E, and 8 from AM), making sure that there was sufficient overlap between methods, i.e., that the same sherd was analysed by the two independent methods (for analytical methods used to analyse individual samples, see the table of prepared samples in Appendix II). The sample of this book is restricted for 141 due to resource-based issues. A larger sample and additional archaeological sites would, naturally, aid in building a more comprehensive picture of the production, exchange and influence networks examined here. The sample for this inter-site analytical study is, nevertheless, larger than those of previous studies in this region and chronological frame; thus, it provides a reference model to be tested, clarified and built upon with future work.

To follow the guidelines suggested in the literature, and to accommodate the research questions of this study, focusing on local ceramic production and distribution systems on regional and inter-regional levels, vessels representing different ceramic morphological and functional categories were sampled. The main focus of this study lies on coarse wares, domestic and utilitarian wares; thus, the bulk of the samples are household ceramic forms, including kitchen and cooking vessels and food and liquid containers. In addition, a few examples of more exotic wares, such as glazed sherds, were included to examine their presumed status as imported objects. Different jar and amphora forms were of special interest in the sampling as they might have been used to transport other goods between the sites.

Energy dispersive X-ray fluorescence spectrometry (ED-XRF)

There are two main types of detectors employed in XRF, energy dispersive X-ray fluorescence spectrometers (ED-XRF) and wavelength dispersive spectrometers (WD-XRF). Both are based on the same principles, the surface of the sample is radiated by primary X-rays, creating inner shell (K, L, and M) vacancies in the atoms. As a result, the vacancies de-excite by producing secondary, fluorescent, X-rays, whose energy is characteristic of the different elements in the sample. The energies absorbed from the sample can be counted, measured and recorded as a spectrum, and comparisons of these values with known values of elements enable identification and quantification of the elements of the sample (Hall 2017; Kempe and Templeman 1983: 43–44; Moens *et al.* 2000: 57; Pollard *et al.* 2007: 101–109; Pollard and Heron 1996: 41–49).

The two detectors, WD-XRF and ED-XRF, are different in terms of characterisation of the secondary radiation. In X-ray fluorescence, the spectrometer needs to distinguish and identify different peaks, and measure and quantify the position and the intensity of the peaks. In WD-XRF, this is done by measuring the wavelengths and in ED-XRF, by measuring the energy of the secondary X-rays. In ED-XRF, employed in this study, the secondary X-rays released by the excited atom are regarded as a particle, an X-ray photon, the energy of which is characteristic of the atom emitting it. Both ED-XRF and WD-XRF can measure elements with $Z > 8$. The main performance differences between ED-XRF and WD-XRF are that the resolution and sensitivity of WD-XRF are better compared to those of ED-XRF, but ED-XRF instruments are more affordable and thus more accessible (see Hall 2017: 351–352).

A few notes should be made here concerning the advantages and disadvantages of the XRF methodology in general, and one way to view the different aspects is to discuss them briefly in comparison with those of instrumental neutron activation analysis (INAA), employed in ceramic compositional studies since the 1960s. In the most recent decades, however, there has been a tendency, at least in European laboratories, towards a decreased accessibility of reactors for archaeological research purposes, which has increased the use of alternative methods, such as XRF and ICP-MS in ceramic compositional analysis (for recent applications of NAA in ceramic studies, see, e.g., Barber and Pierce 2019; Cohen *et al.* 2019; Minc and Sterba 2017; Müller *et al.* 2018; see also Glascock *et al.* 2004: 96; Tite 1999: 198; and Yellin 2018).

The principal advantages of XRF methodology compared to INAA are that the results can be obtained fast (after sample preparation, data of several samples can be acquired in a few hours in a simultaneous analysis for the batch of samples) and relatively cost-efficiently. In XRF analysis, the sample is left uncontaminated and re-usable for further analysis (in INAA, the sample material becomes radioactive waste). Most importantly, it is a much more accessible method, as no nuclear facility is needed (Bishop *et al.* 1982: 292; Bishop *et al.* 1990: 539; García-Heras *et al.* 2001; Minc and Sterba 2017: 425; Neff 2000: 104–106; Pollard *et al.* 2007: 132–136; Yellin 2018). ED-XRF can be used to analyse elements from sodium (NA) to uranium (U). The detection limits of ED-XRF are relatively low, allowing determination of elements in major, minor and trace quantities, although INAA does allow analysis of elements in even smaller concentrations and thus provides more trace elemental data crucial for provenance analysis (INAA is able to analyse 35–40 elements, and detects many trace elements in the low ppm and ppb range, see Minc and Sterba 2017: 425). The sample size required for INAA is considerably smaller, 50–200 mg (Adan-Bayewitz *et al.* 2009; Adan-Bayewitz *et al.* 1999; Glascock *et al.* 2004: 96), whereas a minimum of 4 grams is required to prepare a powdered pellet for ED-XRF analysis. However, it is often recommended to powder *c.* 10 grams of each sample to produce a representative sample of the ceramic fabric, particularly when dealing with coarse ware ceramics. The requirement of extracting a larger sample from coarser ceramics to ensure a representative sample applies to INAA as much as to XRF. Another possible problem of the XRF technique is overlapping of spectral peaks, particularly in ED-XRF (Pollard *et al.* 2007: 107–108).

Although XRF is often described as a non-destructive technique, quantitative compositional analysis of ceramics usually require destructive sampling in order to gain a homogeneous sample; thus, the sample is usually powdered (Bishop *et al.* 1982: 292; see Frahm 2018; Holmqvist 2017 for non-invasive applications). Due to the fact that XRF is a relatively surface sensitive technique, carefully prepared samples, preferably powder pellets or glass beads, are necessary to produce quantitative data, although the sample preparation is time-consuming. A non-homogeneous sample surface may result in poor quality data.

The instrument employed at the Institute of Archaeology was a Spetro XLab 2000 polarising ED-

XRF spectrometer. The use of secondary targets to polarise the X-ray beam results in an enhanced peak in background resolution in the spectra, with a subsequent improvement in the sensitivity and detection limits whilst keeping the advantages of conventional ED-XRF, such as analytical speed and quantification of all elements heavier than Na. The analytical set-up used in this project was based on the 'Turboquant' method developed by Spectro, which employs three secondary targets and is optimised for the analysis of soils.

Sample preparation

In the sample preparation for ED-XRF analysis, the analytical specimens were prepared by cutting *c.* 10g from each sherd. Due to the relatively coarse nature of the ceramics, this was considered to be an adequate sample size in order to produce a representative sample. The specimen was ground into a fine powder in a planetary mill with counterweight, down to a particle size of approximately 50μm. This powder was dried in an oven overnight, after which *c.* 4 grams of the powder were thoroughly mixed with a small amount of industrial wax, and pressed into a pellet in a 32mm diameter mould under 15 T of pressure. All the compositional values presented in this study are averages of three XRF runs, with oxygen added by stoichiometry and results normalised to 100% by weight.

Precision and accuracy

The analysis of standard reference materials of known composition is necessary for evaluating the quality of data produced in the analysis of archaeological samples of unknown compositions. Analytical precision tests illustrate how repeatable the analysis is and how comparable are the results obtained, for example, from different sample batches. Analytical accuracy tests allow calculations of how close the measured values are to the actual concentrations, by comparing the analytical values of the standards obtained during the analysis to their certified compositions (Bishop *et al.* 1990: 539–542).

In order to monitor the precision and accuracy of the ED-XRF analysis, each analysis was run three times and every batch included three standards of known composition. The standards analysed with each batch of samples were ECRM 776 1, NIST 76a and SARM 69. In addition, USGS BHVO-2 was analysed separately to examine the accuracy of the equipment in the analysis of materials with high CaO content. The full results of the precision and accuracy tests are given in Appendix III and Appendix IV, respectively.

For the precision tests, data from three runs of the standards on nine separate days are used, and coefficients of variation are calculated for the total of 27 runs. The tests showed good precision values, with relative variation coefficients being below 3% for all of the major oxides, and below 5% for most other oxides. The lighter oxides, Na_2O and MgO, showed less consistent results when present in concentrations lower than 1% (ECRM 776 1 and NIST 76a). Coefficients of variation were also slightly higher in the cases of SO_3, Cl, MnO and Co_3O_4 with concentrations below 0.1%.

To examine the accuracy of the analyses, the average results of the 27 runs were compared to the certified values of the standards. In the case of ECRM 776 1, the relative errors of Na_2O, Al_2O_3, P_2O_5, Cr_2O_3, Fe_2O_3 and BaO are lower than 10%, MgO and SiO_2 less than 15% and K_2O, CaO and TiO_2 20–25%. For NIST 76a, relative errors of MgO, Al_2O_3, Fe_2O_3 and SrO were lower than 10%, and the rest of the errors were lower than 30% with the exception of the lightest oxide, Na_2O, for which high error values are to be expected with this type of equipment. Accuracy decreases for some oxides in concentration below 3%. An exception to this is SiO_2, which appears underestimated in the accuracy tests of all of the standards. In the accuracy test of NIST 76a, the measured SiO_2 values show a relative error of 17.4%.

In the test of SARM 69, relative accuracy errors are lower than 15% for most concentrations, excluding the lightest oxides Na_2O and MgO, and K_2O, CaO, TiO_2, and NiO, in which cases the reference concentrations are always less than 2.5%. USGS BHVO-2 was only analysed on one day with three consecutive runs in order to test the accuracy of the analysis of materials with relatively high CaO values, as some of the samples analysed showed high concentrations of CaO. A relative error lower than 15% was measured for Na_2O, Al_2O_3, SiO_2, Fe_2O_3, Co_3O_4, NiO and SrO. The highest relative errors typically appear when the concentrations of the oxides are low, such as P_2O_3, K_2O, V_2O_5, Cr_2O_3, MnO (concentrations less than 1%), and BaO (concentration approximately 150ppm). The measured relative error of CaO was 18 %. On a different note, the light oxide MgO, with a high concentration in the standard (7.23%), yielded a high relative error (40.2%). However, such high concentrations of MgO are extremely rare in ceramics and thus this error has little bearing here.

As a result of the precision and accuracy tests, it can be concluded that the precision of the ED-XRF equipment was good over the period when the analysis was carried out. The accuracy tests show that the values of the lightest oxide, Na_2O, in general, show high relative error, and for this reason, the concentrations of this oxide measured in the sampled ceramics will not be considered or included in statistical data analysis. The precision tests allow adequate comparisons between the samples analysed on different days and in different sample batches. The accuracy tests, however, show that the concentrations of SiO_2, CaO and TiO_2 were consistently underestimated in the analyses. This should be taken into consideration when these data are compared to that produced in another laboratory.

Statistical processing of data

The data acquired in ED-XRF analysis were processed by multivariate statistical methods, cluster analysis (CA) and principal component analysis (PCA), and by bivariate plots to compare two variables and to examine and illustrate their correlation. These methods are commonly used in processing analytical compositional data in materials science studies and to examine the patterns in multivariate data (see Baxter and Freestone 2006; Baxter and Buck 2000; see also Hancock *et al.* 2008). Cluster analysis was chosen as the most appropriate for identifying groups in the data set, whereas principal component analysis was used to confirm the group attributions and also to show which variables are determining the group structure.

Multivariate analysis and data reduction and grouping are needed when there are multiple variables for each analysed sample. By using methods such as CA and PCA, it is possible to reduce the number of the variables, but maintain the information in the raw data. Groups or clusters of the data can be formed on the basis of the original or the reduced set of variables, in a way where samples belonging to each group share similarities but differences can be interpreted between each group (Fletcher and Lock 2005: 139). The mathematical and statistical theory and principles behind the selected statistical methods and their applications in archaeological data processing are described in detail in the literature (see Baxter 2003; Baxter 1994; Drennan 1996; Fletcher and Lock 2005; Shennan 1988).

In hierarchical cluster analysis, each sample is assigned to its own cluster, so there are as many clusters as there are samples. The similarity between the samples is measured according to given rules of combining clusters, such as Euclidean distance and average linkage, and the individual clusters are merged into larger clusters hierarchically, stage by stage, so that eventually there is only one main cluster. The output of the analysis, the dendrogram, indicates the similarity between the members of each cluster (Baxter 2003: 90–95; Fletcher and Lock 2005: 140–147). In the dendrogram, samples of similar characteristics appear on close branches that gradually merge into larger clusters of less similar samples (Orton 1980: 47–56).

There has been some debate over the problems relating to interpreting dendrograms and the difficulty in discerning distinct clusters in the cluster chains, and one of the responses to this problem is the Ward linkage method, also utilised in the hierarchical cluster analysis carried out in this study. In the Ward linkage method, compared to the single linkage method, for example, the clusters are linked on the basis of the similarity between groups of samples, rather than individual samples, making the dendrogram easier to interpret. The disadvantage of the Ward method can be oversimplification of data by suggesting a clear structure for a random data set. For these reasons, the cluster analysis solutions should be carefully interpreted (Baxter 2003: 93; Baxter 1994: 146; Glascock 1992: 17).

PCA was used in this study because it is regarded as a useful tool in processing multivariate data and investigating the relationships between variables. In PCA, the number of original variables is reduced to facilitate the data interpretation, the results indicating how many new, reduced variables are required in order to explain the data in a satisfactory way (Fletcher and Lock 2005: 148). As Orton notes (1980: 56–57), the idea in PCA is to 'find which variable (or combination of variables) contributes most to the variability' of the samples, and this variable is known as the first principal component. The combination of variables that contain the second highest variation in the data set is called the second principal component and so on. The number of principal components is the same as the number of variables but usually the first few principal components contribute mostly to the variability (Orton 1980: 56–57).

The advantages of PCA include the ability of the method to indicate major trends in the raw data, and the variables involved in these trends. Furthermore, it compresses the variation in a large number of variables into a smaller number of variables, which are uncorrelated (see Shennan 1988: 246–262). To quote Shennan, 'if a set of variables possesses some underlying common factor the implication is that their values are correlated with one another – they are closely related to one another. The common factor can be seen as in some sense the average of the group variables; the more closely related they are the stronger the common factor will be and the more meaningful on its own as a substitute for the original variables' (Shennan 1988: 246).

PCA can be used to reduce rows of chemical data per sample into a two-dimensional picture of the first two principal components, which are most informative when presented together with a variable plot based on the correlation matrix and coefficients of the same components (Baxter 2003: 79). In the plot, the groups are differentiated according to their chemical compositions, also allowing examination of the variation of archaeological variables associated with the data, such as archaeological sites from which the analysed samples are retrieved. The picture also shows how the variables of the data matrix are related, which elements are associated, and which elements affect the data structure the most and in which ways (Baxter 2003: 73–89; Baxter 1994: 48–62).

PCA is particularly useful when there are apparent groups in the data set as the method does not require the data to have a multivariate normal distribution (Baxter 2003: 74, 123). When dealing with ceramic compositional data, it is usually possible to describe 70% or more of the total variance in the data set by the first three principal components (Glascock 1992: 17–18). In addition to multivariate methods, bivariate plots, or two-dimensional scattergrams are used in this study to examine and graph the correlation between two variables. Bivariate plots are considered as a practical method of displaying and examining multivariate data, as plotting two variables against each other in a bivariate plot may highlight trends and patterns in the data set. Bivariate plots are commonly used to examine the relation, association and correlation between the variables. Viewing bivariate plots can also reveal perturbations of natural correlations, caused, for example, by added tempers (Baxter 1994: 32–33, 154–170; Fletcher and Lock 2005: 115–127; Glascock 1992: 17).

Scanning electron microscopy with energy dispersive spectrometry (SEM-EDS)

As discussed earlier, this study employs an integrated analytical approach, where bulk chemical data, in this case attained by ED-XRF analysis, are combined with microscopic data. The selected method for microscopic analysis is scanning electron microscopy with energy dispersive spectrometry (SEM-EDS), which is employed to confirm the bulk compositional groups determined by the ED-XRF analysis and to examine the ceramic microstructure and technology. The integrated approach of bulk chemical and microscopic analysis is generally favoured in provenance analysis of archaeological ceramics over an only one-sided approach (Arnold 1981: 33–34; Beltrame *et al.* 2019; Day *et al.* 1999; Froh 2004: 159; Holmqvist *et al.* 2018; Montana 2017: 89–90; Tite *et al.* 2018; Tite 1999: 201; Stoltman *et al.* 1992; Tschegg *et al.* 2009). In this study, a scanning electron microscope with an energy dispersive detector was employed to achieve simultaneous multi-element analysis in addition to imaging allowing observation of the analysed area. The electron beam can be focused on a spot down a few μm in diameter; hence, the chemical composition of very small areas, such as individual mineral inclusions in the ceramic matrix, can be analysed (Pollard *et al.* 2007: 111–112; see also Potts 1987: 326–348).

In microscopic studies such as petrography and scanning electron microscopy, a ceramic sherd can be considered as a metamorphosed sedimentary rock, enabling identification of minerals and rock fragments and their various properties, such as abundance, sorting, size, shape, particle orientation and interrelations in the clay fabric (Quinn 2013; Quinn 2009). The identification is based on different properties of minerals in microscopic examination. In addition, different surface treatments, such as slips, glazes and paints, void sizes, shapes and locations, manufacturing faults, such as cracking due to firing, and post-depositional features can be examined (Matin 2018; Molera *et al.* 2018; Quinn 2013; Rice 1987: 379–382; Riederer 2004; Van Valkenburgh *et al.* 2017; Williams 1983: 302–303).

The orientation and position of particles in ceramic fabric might also be indicators of the production technique of the vessel (see Courty and Roux 1995). Angular grains typically indicate intentionally added tempers, whereas rounded grains suggest natural erosion (Rye 1981). Bimodal distribution of grain size indicates the addition of well-sorted tempers whereas normally distributed grain size implies poorly sorted, naturally graded clay (Rye 1981: 52–53). Particle size and shape in microscopic analysis can be used to identify the environmental origin of the sediment (e.g., coastal areas, rivers) and causes of weathering (such as sea or wind) (Shackley 1975: 87). The orientation of voids, pores and elongated inclusions can also show evidence of wheel manufacturing[1], as these tend to become 'drawn out in a spiral pattern up and around the walls of the vessel...conversely, coiling techniques tend to produce a horizontal alignment of pores' (Tite 1999: 186; see also Franken 2005: 13, 69, 201; and Franken and Kalsbeek 1969: 93).

In scanning electron microscopy with energy dispersive spectrometry (SEM-EDS), two methods are combined by using the high image resolution of the electron microscope, and analysis of the characteristic X-rays resulting from the sample being bombarded with electrons. The principles are very similar to those of XRF (see above), with the difference that in scanning electron microscopy, electrons, not X-rays, are used to create initial vacancies in the inner electron shells. Optical microscopy is limited by the wavelength of light whereas, in scanning electron microscopy, imaging of smaller objects is possible by employing a shorter wavelength, which can be produced by using a beam of high energy electrons (Pollard *et al.* 2007: 109).

[1] In this book, the wheel-manufacturing technique refers to the so-called fast-wheel, and the term 'wheel-made' pottery is used in the sense as determined by Franken and Kalsbeek: 'pottery made on a wheel which creates a centrifugal force in the clay and from a clay that responds to this force' (Franken and Kalsbeek 1969: 93; and Franken 2005: 13, 69, 201 for terminological critique; see also Tite 1999: 186).

Images on the SEM can be obtained using two detectors: a backscattered electron detector (BSE) and a secondary electron detector (SE). Secondary electrons (SE) of a very low energy and bounce from the outer electronic orbitals of the surface atoms. The intensity of the secondary electrons of the sample surface reflects the topography of the sample surface and forms the basis of the imaging process in electron microscopy. With ceramics, SE images are particularly useful to investigate the sintering of clay minerals, porosity and vitrification. Back-scatter electrons are of high energy, thus they can be emitted from deeper within the sample. In BSE images, the brightness (from black to white) of the grey-scale image reflects the average atomic number of the phase being analysed, black corresponding with low and white with high atomic numbers, and thus, chemically different crystalline phases, such as minerals, can be recognised. The energy dispersive X-ray spectrometer (EDS) can then be used for elemental analysis in order to determine the chemical compositions of the different phases. Hence, unlike the XRF, SEM-EDS allows the analyses of ceramic matrix and inclusions separately. The SEM-EDS can also be used as an additional tool for provenance analyses; the elemental analysis of mineral inclusions in the fired clay matrix can be used to determine the type and source of the rock from which they originate (Tite 1992: 113).

Voids surrounding inclusions are probably due to the different shrinkage of the matrix and inclusions during firing. The forms of the voids may also be indicative of the dissolution of the original constituents, e.g., calcite dissolution leaves tabular and shell fragments curved, parallel-sided, voids, while rhombic voids may indicate dissolution of crushed calcite, and long and arching voids typically originate from organic materials combusted during firing (Quinn 2013: 99, Fig. 4.27; Williams and Jenkins 1997: 94). The outlines of these voids will become less angular with increasing firing temperatures. Grog fragments, crushed sherds of discarded pottery, are often also used to produce ceramic fabrics (Williams and Jenkins 1997: 96). The presence of grog and the source areas of the previous generation pots used as temper need to be considered in provenance analysis of grog-tempered pottery (for methodology, see, Holmqvist *et al.* 2018).

The success of provenancing artefacts on the basis of mineralogic data relies on the geology of both the archaeological site and the possible source areas, and provenancing is often most successful when working with relatively coarse ceramic materials from distinctive geological environments, such as islands, where identification of local rock types is possible. Rock inclusions are often the most informative components in the ceramics, either being included in the natural clay matrix or added as tempers (Williams and Jenkins 1997: 92–93; Williams 1979). This kind of sourcing is the least successful when analysing sherds with very common inclusions, such as ceramics containing mainly quartz grains. In these cases, textural analysis of the sherds can nevertheless provide information on the size, shape and frequency of the quartz grains, and the sherds can be categorised accordingly, based on the idea that ceramics manufactured in a certain geological area should contain approximately similarly sized, sorted and weathered grains (Tite 1999: 201–202; Williams 1983: 93, 303–304). In addition, in such cases, chemical analysis of ceramic matrices by SEM-EDS may be useful for further groupings.

SEM of ceramic sections allows analysis of both the vessel surface and the body; hence, it can be used to study various technological properties of unglazed common ware ceramics, such as the clay preparation and chemical composition of the clay matrix, surface treatments like slip and paint, and firing temperatures. The extent of vitrification, as represented by the level of mineral particle interconnection, can be used to estimate the firing temperature, as the grain-to-grain interconnection increases together with the firing temperature, resulting in interconnecting glass/relict clay phases between non-plastic inclusions (such as quartz, feldspars and micas) (Bland *et al.* 2017; Chatfield 2010; Quinn 2013: 191; Tite 1992: 111). The firing temperature can be estimated, but there is no '1:1 correspondence' between the temperature and certain properties in the ceramic material (Heimann 1982: 89; see also Kaiser and Lucius 1989: 90; Quinn 2013: 190–198; and José-Yacamán and Ascencio 2000; firing temperatures exceeding 1000 °C can cause alteration in certain minerals, see Williams 1983: 302). It should also be noted here that the firing temperature can also vary significantly in different parts of the kiln (Tite *et al.* 1982: 113), and thus differences in estimated firing temperatures do not necessarily indicate different manufacture or technology.

In this study, 54 out of the total of 141 sherds were selected for the SEM analysis (see Appendix II for analytical methods applied to individual samples). The main purpose was to test the assignment of samples into compositional groups on the basis of the ED-XRF data. This was done in order to study whether samples with similar bulk chemical composition also share similar mineralogical inclusions and chemical composition of the clay matrix, attesting that they were produced from the same raw materials and technologies. For this reason, most of the samples analysed by SEM were selected on the basis of the bulk chemical compositions of the sherds. In addition, some sherds of particular interest, or sherds too small to provide material for pellet preparation required for ED-XRF analysis, were analysed using SEM-EDS as the principal analytical method. This applied particularly to some glazed ware sherds, which were analysed in order to compare the composition and technology of the glaze, but which were relatively small in size.

The instrument used for the SEM analyses was a Philips XL30 Environmental SEM (ESEM), with an INCA Oxford spectrometer package, based at the Institute of Archaeology laboratory. This instrument has both secondary electron (SE) and backscattered electron (BSE) detectors, allowing topographical and compositional examination, respectively, enabling detailed imaging-based examination of the ceramics. Furthermore, this instrument was equipped with an energy-dispersive (EDS) X-ray microanalyser which can be used to measure scanned areas or spot analysis. To accommodate comparative analysis, the images of the samples were principally taken at 50x, 200x, and 1000x magnification, and 500x and 800x magnifications were used on some particular occasions due to the characteristics of the examined features. In the analysis, the working distance from the sample surface was 10mm, accelerating voltage 20 kV, spot size 5–6.8 with detector deadtime being 30–40%, and livetime around 50 seconds.

In the SEM analysis, the microstructure of the ceramics was examined, and the chemical compositions of the ceramic matrices and the inclusions were analysed to assess their possible alteration of the bulk chemical results. In addition, the ceramic matrix vitrification was studied in order to estimate the relative differences in firing temperatures in the assemblage. Initially, a general BSE image of the sample was taken with 50x magnification (*c.* 2.3 x 2.3mm in size), in order to illustrate the general nature of the sample, including different mineral inclusions, voids and other characteristics. All the images were taken in a sample position in which the vessel surfaces were parallel to the long axes of the images. In the matrix analysis, the analysed areas were selected trying to avoid large mineral inclusions, which were probed separately. The chemical composition of the ceramic matrix of the sample was determined by analysing four areas of 250μm by 200μm. The composition of the clay matrix of each sample was gained from averages of the four analyses, combined with oxygen stoichiometry and normalised to 100 percent by weight (wt %).

Sample preparation

SEM-EDS analyses were conducted on polished cross-sections. In sample preparation, a *c.* 1x0.5cm piece of the ceramic sherds was cut vertically parallel to the vessel profile in order to provide a cross-section. The ceramic piece was mounted in epoxy resin in order to produce resin blocks. The blocks were then ground and polished with sandpapers and diamond pastes of different grades down to diamond paste of a 0.25μm grain size following established procedures. Finally, the samples were washed with IMS in an ultrasonic bath, and carbon-coated in a standard vacuum carbon sputter before the analysis to ensure electrical conductivity.

Compositional groups

Next, the results of the ED-XRF and SEM-EDS analysis will be presented. Altogether, 141 ceramic samples were selected for analysis from five archaeological sites: 38 from the monastery of Jabal Harûn near Petra, 20 from the port city of ʻAqaba, 43 from the village site of Khirbet edh-Dharih, 20 from the city of Elusa, and 20 from the farm house site of Abu Matar in Beersheva. Bulk chemical compositions were obtained for 136 samples by ED-XRF analysis. ED-XRF was applied to 34 Jabal Harûn sherds, 20 ʻAqaba sherds, 43 Khirbet edh-Dharih sherds, 20 Elusa sherds and 19 Abu Matar sherds. Microanalysis by SEM-EDS was conducted on 54 sherds, 21 of which were from the Jabal Harûn excavations, 6 from ʻAqaba, 10 from Khirbet edh-Dharih, 9 from Elusa and 8 from Abu Matar (see Appendix II for analytical methods employed to individual samples).

ED-XRF was used to form compositional groups of the ceramics based on major, minor and trace elemental contents of the samples. SEM-EDS analysis was employed to examine the ceramic microstructure, mineralogical inclusions, chemical composition of the ceramic matrix and other technological aspects. These microanalytical data were also employed to test the group allocation of some sherds made on the basis of the XRF data and generally to develop fabric characterisation.

The average ED-XRF results for the 136 analysed samples are presented in Table 1. The ED-XRF data were processed with hierarchical cluster analysis (CA) and principal component analysis (PCA). According to the cluster analysis, the samples for which ED-XRF results were obtained can be assigned to 13 main compositional groups. From each of these main groups, samples were selected for SEM-EDS analysis. This was done in order to ascertain that samples assigned to a bulk compositional group on the basis of the ED-XRF analysis also share microstructural characteristics, similar mineralogical inclusions and chemical composition of the ceramic matrix, further attesting to their compositional similarity and probable production using similar raw materials and technologies. Similarly, microscopic analysis by SEM-EDS was used to examine whether samples assigned to different compositional groups can be differentiated on the basis of their microstructural characteristics. In addition to the group assignment based on a combination of the ED-XRF and SEM-EDS

Table 1: ED-XRF compositional data obtained from the ceramic samples. Results have been normalised to 100% and taken from the average of three XRF runs.

Only trace elements above 20 ppm are shown. Analytical total before normalisation is given.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As	Br	Rb	SrO	Y	ZrO	Nb	BaO	La_2O_3	CeO	PbO	Analytical
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (%)
Jabal Harûn																															
JH001	0.63	2.37	23.65	61.05	0.11	0.06	0.26	1.98	1.50	0.87	0.02	0.02	0.04	7.33	78	44	45	85	44			65	110	40	242		122	23	49	32	95.29
JH002	0.23	2.17	21.41	63.33	0.15	0.07	0.24	1.88	2.60	0.83	0.02	0.02	0.04	6.91	92	41	85	63	41			62	136	38	226		137	20	48	22	93.63
JH003	0.26	2.43	19.70	62.12	0.24	0.18	0.16	2.13	4.80	0.76	0.02	0.02	0.04	7.03	89	41	41	67	35			61	169	39	238		140	22	41		91.07
JH004	0.46	3.46	19.59	60.61	0.24	0.06	0.28	2.48	4.76	0.81	0.02	0.02	0.05	7.03	84	36	72	88	36			79	172	45	278		149	22	48	28	93.29
JH006	0.66	2.78	20.75	58.68	0.32	0.11	0.25	2.15	6.20	0.78	0.02	0.02	0.06	7.11	91	43	42	88	37			66	207	45	255		170	24	54	22	90.06
JH007	0.71	2.38	22.00	61.41	0.16	0.20	0.28	2.11	3.28	0.79	0.02	0.02	0.04	6.51	72	37	55	67	38	33		56	147	35	274		124	21	38	23	91.57
JH008	0.79	1.80	24.81	60.69	0.08	0.39	0.38	2.01	0.93	0.92	0.02	0.02	0.04	7.03	87	41	50	66	45			58	92	36	264		121	22	35	22	94.64
JH009	0.14	1.99	23.50	60.74	0.10	0.05	0.21	2.14	2.29	0.74	0.02	0.03	0.03	7.91	88	55	45	88	45			72	128	28	128		105	21	39		93.60
JH010	0.29	2.24	23.55	63.04	0.11	0.32	0.22	2.08	1.26	0.90	0.02	0.02	0.03	5.80	68	37	46	54	41			58	91	42	320		156	26	53	26	93.34
JH011	0.66	3.13	21.55	60.82	0.14	0.19	0.12	2.25	3.12	0.87	0.02	0.02	0.04	6.93	79	43	53	69	41			64	331	37	242		129	21	49	23	92.40
JH012	0.89	3.47	22.03	60.08	0.15	0.34	0.28	2.32	2.65	0.79	0.02	0.02	0.04	6.84	93	45	67	67	39			55	130	36	255		127	21	42		90.54
JH013	0.28	1.79	22.55	65.62	0.11	0.05	0.15	1.76	1.15	0.84	0.02	0.02	0.02	5.52	71	43	62	67	39			58	109	33	245		143		38	23	92.70
JH014	0.72	3.61	19.38	56.41	0.35	0.02	0.30	2.87	7.90	0.73	0.02	0.02	0.06	7.49	86	45	64	106	39			92	215	45	193		137	23	48	22	92.95
JH015	0.49	1.37	20.69	55.82	1.00	0.01	0.12	1.47	12.39	0.83	0.03	0.02	0.04	5.58	71	65	48	171	38			60	351	44	272		215	24	53	29	96.66
JH016	0.04	1.37	24.14	63.51	0.12	0.04	0.13	1.68	0.98	0.92	0.02	0.02	0.03	6.89	95	44	58	98	48			65	109	44	229		120	23	60	41	95.01
JH017	0.72	2.33	22.32	61.87	0.20	0.20	0.13	1.90	2.37	0.85	0.02	0.02	0.04	6.93	87	40	49	65	39			59	127	43	298		135	22	45		92.39
JH018	0.54	2.09	25.50	60.13	0.10	0.11	0.42	2.04	1.11	0.94	0.02	0.02	0.04	6.83	78	39	33	70	41			52	83	59	273		108	23	54	23	92.82
JH019	0.29	1.60	24.34	63.90	0.10	0.25	0.26	1.60	0.48	0.93	0.02	0.02	0.02	6.08	62	49	56	72	49			61	92	51	275		153	26	56	29	94.37
JH020	0.98	1.64	24.59	62.29	0.15	0.10	0.30	2.21	0.38	0.83	0.02	0.02	0.01	6.39	66	49	66	75	43			57	76	30	190		104		33	31	93.82
JH021	0.55	1.42	23.60	64.87	0.10	0.07	0.22	1.58	0.49	0.92	0.02	0.02	0.02	6.01	99	43	45	73	44			60	91	56	302		138	25	53	39	93.05
JH022	0.24	1.54	22.97	64.49	0.09	0.07	0.11	1.70	0.66	0.82	0.02	0.02	0.03	7.13	102	47	41	75	47			68	95	35	185		116	26	54	24	92.57
JH023	0.49	2.77	22.85	60.82	0.13	0.13	0.38	1.93	1.71	0.89	0.02	0.02	0.06	7.69	78	44	98	64	44			66	127	39	230		127	23	35	23	93.99
JH026	1.66	2.67	19.49	54.14	0.39	0.01	0.19	2.03	12.29	0.66	0.02	0.01	0.09	6.17	85	41	52	119	39			70	554	36	151		431	30	72	22	95.96
JH027	1.84	3.44	17.64	56.41	0.52		0.21	2.37	9.68	0.66	0.01	0.01	0.13	6.86	77	38	48	139	41			93	637	41	189		565	33	76	41	89.89
JH028	1.75	4.24	17.51	54.47	0.35	0.12	0.16	2.30	11.72	0.64	0.02	0.01	0.12	6.39	85	49	51	122	37			78	572	39	188		558	25	62	24	91.85
JH029	1.77	3.22	13.27	50.48	0.40	0.01	0.35	1.68	21.34	0.76	0.02	0.02	0.12	6.34	82	57	82	109	25			46	788	44	335		543	22	41	28	84.42
JH030	1.82	3.66	18.45	54.45	0.35	0.01	0.23	2.08	11.28	0.66	0.02	0.01	0.12	6.68	83	44	50	130	40			88	575	40	198		556	28	62	30	93.98
JH031	1.06	4.80	17.22	56.57	0.35	0.02	0.03	2.22	10.18	0.67	0.03	0.01	0.12	6.49	85	50	54	130	38			87	559	40	183		1021	20	58	36	88.60
JH032	0.44	2.15	20.23	60.07	0.24	0.03	0.22	2.02	6.34	0.79	0.02	0.01	0.06	7.27	98	46	52	87	38			66	208	45	241		173	24	58	21	92.05
JH033	0.77	4.00	22.66	50.12	0.13	1.54	0.26	3.03	8.47	0.70	0.02	0.02	0.04	8.13	80	54	25	114	42			66	267	24	112		147		35	26	87.83
JH035	0.59	0.76	31.02	58.07	0.06	0.11	0.16	1.13	0.48	1.48	0.03	0.02	0.03	5.73	77	51	114	71	40			54	259	54	220	21	213	36	85	1722	98.31

Table 1 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As	Br	Rb	SrO	Y	ZrO	Nb	BaO	La_2O_3	CeO	PbO	Analytical
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (%)
JH036	0.11	2.15	19.07	66.39	0.13	0.02	0.03	1.87	1.87	0.70	0.02	0.02	0.05	7.49	95	54	42	64	41			70	115	31	139		105	23	40		93.83
JH037	0.09	2.17	22.01	63.24	0.16	0.05	0.02	2.08	1.36	0.74	0.02	0.02	0.05	7.91	101	58	43	66	45			73	112	34	146		98		33	23	91.77
JH038	0.29	4.07	16.89	59.18	0.17	0.05	0.12	1.43	12.00	0.63	0.02	0.01	0.04	4.96	61	38	36	90	31			40	381	35	223		179		45	53	88.80
Aqaba																															
A001	0.18	1.16	21.66	64.89	0.12	0.05	0.02	1.91	1.05	0.78	0.03	0.02	0.06	7.98	91	48	42	104	47			61	208	33	134		128	21	48		91.07
A002	0.61	1.42	18.38	68.64	0.20	0.25	0.32	1.70	1.93	0.66	0.02	0.02	0.03	5.71	76	40	46	136	35			66	182	35	219		123		42		89.97
A003	2.86	2.07	17.79	50.10	0.27	3.53	0.61	1.94	14.03	0.64	0.01	0.01	0.07	5.85	67	40	57	130	34			62	1009	32	158		352	25	58	29	91.68
A004	0.67	1.88	20.31	64.14	0.19	0.20	0.27	1.59	2.80	0.77	0.02	0.02	0.04	6.99	89	51	50	101	40			53	143	34	200		126		43		93.17
A005	1.56	1.94	20.19	56.40	0.28	0.71	0.33	3.01	9.79	0.50	0.02	0.01	0.07	5.00	61	28	36	91	51		21	117	404	30	221		597	29	63	24	91.56
A006	2.75	4.66	17.77	55.73	0.22	0.28	1.01	2.11	9.39	0.62	0.01	0.02	0.05	5.20	77	33	57	114	37		46	67	647	31	162		410	21	49	35	91.01
A007	0.69	0.96	28.59	57.58	0.12	0.05	0.03	5.41	0.99	0.29	0.02		0.03	5.06	62		81	68	84			196	192	23	269		644	25	69	34	94.10
A008	2.66	2.11	18.83	50.54	0.35		0.55	2.09	16.06	0.63	0.01	0.01	0.10	5.86	81	47	57	120	38		21	72	573	36	124		422	27	62	52	93.69
A009	4.74	3.49	17.02	50.25	0.59		2.07	1.56	13.62	0.59	0.02	0.01	0.11	5.75	70	47	28	120	34		56	46	592	35	135		420	22	57		95.42
A010	2.39	2.24	18.57	52.20	0.41		0.25	1.57	16.21	0.56	0.02	0.02	0.09	5.32	66	44	37	140	35			52	506	31	144		465	23	52		95.31
A011	2.19	3.18	19.05	51.67	0.31	0.19	0.51	2.04	13.54	0.67	0.02	0.01	0.08	6.33	85	40	48	134	39			68	648	38	166		495	29	72	22	91.05
A012	1.96	3.20	18.56	53.49	0.33	0.56	0.13	1.83	12.29	0.67	0.02	0.01	0.11	6.65	86	47	33	124	39			59	622	40	158		513	26	62		93.95
A013	1.21	2.48	16.86	58.40	0.26	0.06	0.09	1.98	12.56	0.63	0.01	0.01	0.09	5.18	65	34	65	120	33			65	680	33	197		388	22	55	25	91.35
A014	1.25	3.31	19.31	53.49	0.32	0.16	0.08	2.32	12.12	0.68	0.02	0.01	0.10	6.61	92	46	48	132	38			89	793	41	173		502	32	65	41	92.23
A015	2.57	4.75	15.71	56.74	0.30	0.27	0.28	1.58	12.19	0.49	0.01	0.02	0.08	4.82	55	47	64	118	37		21	43	575	29	144		463	20	51		90.78
A016	2.35	2.89	18.30	56.48	0.37		0.27	1.96	10.72	0.59	0.02	0.02	0.11	5.74	71	32	39	106	38			77	493	35	171		503	34	68	27	94.94
A017	2.03	4.71	17.65	53.60	0.30	0.05	0.18	1.59	12.23	0.66	0.02	0.02	0.12	6.65	82	51	55	140	39			56	576	39	178		506	29	69	36	95.94
A018	0.80	15.32	10.04	50.45	0.34	0.34	0.13	1.59	11.18	0.41	0.02	0.15	0.13	8.85	145	1059	97	161	22		34	56	596	21	78		208		24	24	85.34
A019	1.45	1.85	20.14	55.03	0.38	0.02	0.19	2.86	11.12	0.64	0.02	0.01	0.09	5.98	68	47	58	126	40			90	953	36	128		413	25	57	71	87.93
A020	1.49	3.57	18.21	52.03	0.39	0.32	0.12	2.70	13.52	0.67	0.02	0.01	0.12	6.60	78	46	45	135	36			81	792	40	182		515	25	60	44	85.21
Khirbet edh-Dharih																															
DH001	0.50	1.67	22.56	63.53	0.14	0.13	0.17	2.13	1.21	0.83	0.02	0.02	0.03	6.95	95	45	43	63	43			73	158	38	253		137	23	52	23	93.25
DH002	0.25	2.16	22.77	61.30	0.14	0.03	0.09	2.28	2.75	0.80	0.02	0.02	0.04	7.24	97	61	47	65	47			82	178	43	210		111	26	46		92.38
DH003	0.77	3.07	18.55	61.82	0.45	0.07	0.10	2.36	5.12	0.67	0.02	0.02	0.08	6.78	80	58	45	114	37			79	283	59	207		158	21	49		94.18
DH004	0.25	2.41	24.55	58.72	0.13	0.03	0.01	2.54	1.90	0.77	0.03	0.02	0.04	8.48	109	67	53	76	51			93	151	34	116		157	22	42		92.21
DH005	0.37	2.12	22.74	59.16	0.18	0.01		2.68	2.17	0.75	0.03	0.02	0.05	9.59	112	67	49	207	45			95	280	31	124		198		35		93.86
DH006	0.81	2.82	21.71	56.96	0.19		0.01	2.33	5.98	0.74	0.03	0.02	0.06	8.19	82	59	38	107	44			78	322	34	149		516		40		92.12
DH007	0.27	1.66	22.97	60.52	0.15	0.08		2.14	1.78	0.90	0.03	0.02	0.05	9.28	119	39	39	77	48			60	453	29	176		434		47	30	92.24
DH008	0.25	1.74	22.33	63.81	0.12	0.03	0.05	1.96	1.09	0.86	0.02	0.01	0.04	7.59	78	49	42	68	42			72	117	36	229		123	22	44	22	91.53

Table 1 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As	Br	Rb	SrO	Y	ZrO	Nb	BaO	La_2O_3	CeO	PbO	Analytical
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (%)
DH009	0.85	8.34	12.03	51.56	0.40	1.52	0.26	3.20	14.33	0.57	0.02	0.01	0.10	6.67	75	39	49	67	26			75	487	23	129		238		42	27	84.33
DH010	0.19	3.68	19.99	55.51	0.36	0.01	0.16	2.06	10.49	0.79	0.02	0.02	0.08	6.49	74	42	52	68	39			73	451	43	225		177	22	45		89.12
DH011	0.74	2.37	18.55	55.03	0.34	0.01	0.17	3.16	11.14	0.83	0.02	0.01	0.09	7.42	95	48	59	86	40			85	320	30	160	23	116	24	49	30	94.60
DH012	0.71	1.00	20.86	65.64	0.15	0.02	0.01	2.84	0.58	1.41	0.03	0.01	0.06	6.53	72	39	46	73	52			84	151	77	474	62	215	36	76		93.18
DH013		1.38	20.15	67.42	0.09	0.03	0.01	1.72	1.48	0.79	0.02	0.02	0.03	6.75	65	42	32	61	39			64	125	33	233		116	21	44	22	92.78
DH014	0.38	4.84	15.11	57.99	0.29	0.02	0.15	3.16	9.43	0.74	0.02	0.01	0.07	7.61	100	47	46	67	33			98	587	27	165		324		43		90.69
DH015	0.33	3.93	20.86	54.88	0.24	0.08	0.16	2.20	8.85	0.67	0.02	0.02	0.07	7.57	85	46	43	81	44			74	334	30	176		130	22	45	22	90.12
DH016	0.47	3.72	20.93	54.99	0.20	0.01	0.09	2.37	8.69	0.69	0.02	0.02	0.07	7.62	82	50	44	84	44			75	351	31	171		124	20	30		91.48
DH017	0.03	2.15	20.97	62.92	0.40		0.02	2.19	3.85	0.86	0.03	0.02	0.08	6.36	80	51	38	70	44			81	229	60	211		162	28	58	21	93.33
DH018	0.38	2.19	16.69	59.26	0.42	0.05	0.07	3.35	8.99	0.90	0.02	0.01	0.04	7.47	90	30	27	66	37			81	633	44	302	23	237	24	49		89.48
DH019	0.03	2.10	20.45	51.96	0.30		0.08	2.14	15.45	0.79	0.02	0.02	0.05	6.37	65	51	36	133	37	702		68	529	34	174		449		42		89.71
DH020	0.18	2.40	22.69	60.08	0.20	0.02	0.08	2.69	3.04	0.80	0.02	0.02	0.05	7.63	82	63	59	67	47			90	173	36	153		109	22	38		93.14
DH021	0.11	2.31	22.36	61.10	0.20		0.05	2.58	2.88	0.78	0.02	0.02	0.05	7.43	74	60	50	67	47			88	172	37	151		102	22	44		94.03
DH022	0.24	3.29	21.78	57.00	0.13			2.49	7.11	0.65	0.02	0.02	0.05	7.10	91	59	53	78	46			87	273	28	117		199		38		92.39
DH023	0.24	2.87	20.47	58.85	0.22	0.05	0.21	2.54	7.11	0.62	0.02	0.02	0.05	6.62	68	50	49	94	39			77	287	31	111		114		37		92.30
DH024	0.44	3.28	22.68	59.15	0.13		0.06	2.37	3.73	0.71	0.03	0.02	0.04	7.26	101	59	59	72	49			93	149	31	119		107		35		92.79
DH025	0.48	3.04	17.20	54.18	0.40	0.01	0.25	2.65	13.94	0.71	0.02	0.02	0.06	6.94	95	51	62	66	37			73	414	26	109		79	21	31		93.57
DH026		1.83	20.85	63.45	0.32	0.10	0.02	2.44	2.62	0.75	0.02	0.02	0.05	7.41	77	60	49	142	44			89	300	35	152		118	23	45		89.96
DH027	0.72	2.69	22.61	58.65	0.30	0.22	0.14	2.66	2.98	0.76	0.03	0.02	0.08	8.01	99	66	54	147	45			93	324	44	136		123	23	49	21	93.03
DH028	0.31	1.93	23.93	61.26	0.11		0.04	1.95	2.51	0.88	0.02	0.02	0.05	6.88	90	56	40	79	51			75	185	40	196		128	23	51	24	93.24
DH029	0.27	1.29	19.95	68.37	0.12	0.03	0.01	2.30	1.19	0.81	0.02	0.02	0.01	5.48	63	28	49	50	42			76	211	37	290		161	23	55	21	92.82
DH030	0.83	1.19	21.38	66.46	0.15	0.08	0.07	1.86	3.54	1.23	0.03	0.02	0.02	2.97	44	21	45	54	37			63	470	53	532	27	269	24	53	29	91.42
DH031	1.55	3.64	16.82	57.54	0.38	0.01	0.04	2.01	10.51	0.67	0.02	0.01	0.11	6.46	78	45	48	141	39			80	597	41	219		583	28	67	29	95.00
DH032	1.56	3.82	17.06	56.87	0.34	0.01	0.02	2.06	10.78	0.68	0.02	0.01	0.11	6.46	75	48	53	128	37			80	611	40	220		534	29	68	24	93.67
DH033	2.02	2.92	16.41	59.86	0.33	0.01	0.03	2.38	8.81	0.68	0.02	0.01	0.12	6.21	67	43	63	117	36			88	578	40	237		536	28	62	22	93.88
DH034	1.15	3.30	16.72	58.10	0.33		0.03	2.07	10.96	0.67	0.01	0.01	0.11	6.33	79	44	45	120	38			79	635	39	214		519	24	58	20	93.57
DH035	0.29	1.16	19.93	63.15	0.17	0.01		1.93	5.52	0.66	0.03	0.02	0.03	6.97	73	48	38	86	36			56	415	22	126		399		32		91.93
DH036	0.28	5.67	14.72	51.28	0.40	0.19	0.03	2.95	15.53	0.72	0.02	0.01	0.10	7.91	91	41	48	62	34			86	696	27	132		456		36		84.22
DH037	1.58	2.80	17.52	56.54	0.33	0.01	0.07	2.53	10.98	0.65	0.02	0.01	0.11	6.63	67	51	72	131	37			89	655	41	184		537	27	69	32	92.96
DH038	1.36	3.17	17.62	56.35	0.37		0.08	2.53	10.82	0.66	0.02	0.01	0.12	6.68	87	50	69	141	38			91	587	39	184		532	24	57	72	90.87
DH039	0.76	1.97	21.02	57.82	0.46	2.51	0.15	3.84	1.95	1.16	0.03	0.02	0.02	8.15	83	30	62	76	50			85	359	23	230	29	190	21	49	20	90.69
DH040	0.49	2.26	25.74	56.69	0.16	0.02	0.04	2.76	1.25	0.82	0.03	0.02	0.03	9.57	136	72	47	83	54			100	158	38	116		118	25	49		91.98
DH041	2.35	5.18	14.73	53.52	0.16		0.16	1.73	13.17	0.59	0.02	0.04	0.13	7.97	117	263	356	100	29			52	612	29	115		372		35	33	92.82

Table 1 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As	Br	Rb	SrO	Y	ZrO	Nb	BaO	La_2O_3	CeO	PbO	Analytical
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (%)
DH042	0.63	3.62	14.58	62.71	0.57	0.08	0.13	3.47	5.59	0.85	0.02	0.01	0.06	7.51	97	51	86	85	34			94	376	36	218		330	23	49		94.39
DH043	0.14	2.48	22.22	61.88	0.20	0.03	0.19	2.34	2.89	0.73	0.02	0.02	0.04	6.72	83	51	44	71	46			83	182	36	185		187	21	48		91.09
Elusa																															
E001	1.42	1.51	17.70	65.91	0.08	0.05	0.37	1.39	0.95	1.06	0.03	0.02	0.14	9.21	149	74	67	135	39			67	203	56	261	23	378	22	57		91.76
E002	0.80	1.26	14.58	71.84	0.09	0.09	0.13	1.22	0.88	0.95	0.03	0.02	0.13	7.84	111	60	57	117	35			58	179	47	256		347	22	51		93.16
E003	0.97	2.16	14.51	66.65	0.13		0.09	1.38	4.50	1.02	0.03	0.02	0.13	8.24	100	61	61	112	33			59	309	47	298	21	439		45		93.41
E004	0.68	1.56	17.60	66.47	0.11	0.13	0.09	1.45	0.71	1.13	0.03	0.02	0.14	9.73	164	70	69	144	42			70	227	56	246	25	418	23	60		94.07
E005	0.69	1.44	17.46	66.24	0.10	0.04	0.21	1.43	0.98	1.16	0.03	0.02	0.16	9.86	137	80	64	151	43			74	252	61	275	23	570	24	64		91.70
E006	1.31	3.15	13.09	55.78	0.30	0.01	0.29	2.00	16.55	0.78	0.02	0.02	0.11	6.37	87	51	67	107	28			56	687	40	307		634	20	47		84.31
E007	1.95	2.85	12.07	56.45	0.26	0.36	0.33	1.99	17.10	0.69	0.02	0.02	0.10	5.58	54	52	104	93	26			52	757	35	324		560		36		81.90
E008	3.91	3.79	11.73	49.05	0.47	0.37	1.12	3.35	19.64	0.63	0.01	0.01	0.10	5.57	64	45	59	95	24			41	1027	32	291		545		33	23	75.49
E009	2.46	3.39	12.59	50.50	0.24	0.25	0.64	2.09	20.86	0.67	0.02	0.02	0.10	5.93	78	52	47	108	25			55	886	35	259		685		37	24	82.20
E010	1.57	2.90	15.62	60.95	0.17	0.12	0.11	1.61	6.41	1.16	0.03	0.02	0.14	8.94	98	76	98	114	36			57	598	44	328	20	880		46		92.13
E011	2.54	3.42	12.30	50.89	0.31	0.09	0.50	1.73	21.19	0.70	0.02	0.02	0.11	5.97	69	56	54	105	26			51	779	36	283		519		47		81.15
E012	0.52	3.17	12.64	62.98	0.48	0.08	0.05	1.68	10.45	0.86	0.03	0.02	0.13	6.67	97	52	71	107	28			55	789	39	340		814		40	40	91.03
E013	2.11	3.70	13.03	48.70	0.14	0.01	0.26	2.38	22.27	0.51	0.02	0.08	0.09	6.47	83	234	62	109	27	22		89	881	27	123		305		42	29	78.82
E014	1.92	3.00	17.45	56.73	0.34		0.41	2.18	10.13	0.69	0.02	0.01	0.12	6.77	72	43	53	129	36			86	677	42	195		514	28	60	37	93.21
E015	1.17	3.17	11.53	62.61	0.19		0.10	1.53	12.83	0.75	0.02	0.02	0.10	5.80	69	51	46	109	25			48	539	36	333		486		38		94.34
E016	1.30	2.76	11.90	60.73	0.19	0.01	0.01	1.54	14.25	0.80	0.02	0.02	0.11	6.15	78	54	65	102	28			53	535	38	315		601		40		92.57
E017	1.60	2.64	11.37	56.83	0.22	0.28	0.10	1.44	18.37	0.77	0.02	0.02	0.11	6.04	83	56	63	106	28			45	789	38	306		499		40		89.37
E018	1.39	3.05	14.18	57.93	0.16	0.01	0.17	1.61	12.96	0.93	0.03	0.02	0.12	7.23	98	60	63	109	31			53	638	42	361		580		42		90.61
E019	1.76	3.55	11.85	58.80	0.19		0.20	1.56	14.74	0.75	0.02	0.02	0.10	6.26	72	55	49	109	29			49	684	36	262		515		37		94.64
E020	1.30	2.46	11.65	60.30	0.21	0.01	0.03	1.47	15.29	0.73	0.02	0.02	0.11	6.19	70	53	57	109	28			45	627	37	276		539		39		92.37
Abu Matar																															
AM001	0.50	1.48	18.17	66.05	0.17	0.05	0.01	1.44	0.88	1.14	0.03	0.02	0.17	9.71	165	71	65	151	40			76	202	60	239	28	445	29	65		92.22
AM002	0.62	1.38	15.84	70.95	0.08	0.04	0.10	1.15	0.80	0.93	0.02	0.02	0.08	7.84	95	59	47	107	33			52	178	46	256	21	329		47		93.35
AM003	0.85	1.40	16.01	69.31	0.09	0.05	0.03	1.28	0.83	1.03	0.03	0.02	0.14	8.78	134	67	66	126	37			66	166	53	248		414	24	57		93.36
AM004	1.00	1.45	17.57	67.31	0.13	0.06	0.12	1.49	0.82	1.04	0.03	0.02	0.14	8.66	140	63	61	134	34			59	216	53	255	22	388	22	52		90.67
AM005	0.63	1.23	16.16	69.22	0.16	0.05	0.05	1.42	1.02	1.05	0.03	0.02	0.15	8.63	103	68	81	131	33			66	229	52	281	25	522	21	60		91.56
AM006	0.49	1.44	17.42	67.23	0.10	0.06	0.03	1.36	0.94	1.13	0.03	0.02	0.16	9.38	156	68	75	139	38			70	202	58	273	21	707	22	58		89.16
AM007	0.83	1.45	12.93	48.44	1.51	0.01	0.14	1.19	26.93	0.65	0.03	0.04	0.09	5.41	64	117	126	202	26	20		34	1120	59	417		1121		36	21	80.73
AM008	1.41	2.91	13.16	53.61	0.37	0.03	0.04	1.91	19.04	0.75	0.03	0.02	0.14	6.26	83	77	70	119	28			53	861	51	286		1470		34		84.63
AM009	0.69	2.57	13.58	67.09	0.13		0.01	1.27	5.88	0.97	0.03	0.02	0.13	7.46	101	58	64	99	32			56	431	43	324	21	434		38		94.34
AM010	1.08	2.92	12.55	61.90	0.18	0.01	0.05	1.73	11.96	0.84	0.02	0.02	0.12	6.42	67	53	51	91	28			49	602	38	376		444	21	45		88.21

Table 1 (continued)

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
AM011	1.31	3.08	13.88	58.84	0.20	0.01	0.11	1.49	12.73	0.92	0.02	0.02	0.11	7.06
AM012	0.44	2.58	17.87	60.18	0.58	0.02	0.03	2.55	6.53	0.92	0.03	0.02	0.11	7.94
AM013	1.53	2.84	14.65	53.99	0.47	0.24	0.20	1.96	16.01	0.70	0.01	0.03	0.11	6.71
AM014	0.66	1.06	28.59	49.19	0.55		0.03	1.56	6.63	1.53	0.04	0.03	0.06	9.87
AM015	1.78	3.05	11.71	54.20	0.28	0.16	0.19	1.32	20.36	0.70	0.02	0.02	0.09	5.79
AM016	1.14	2.71	12.44	47.07	0.60	0.01	0.05	1.79	27.05	0.74	0.03	0.03	0.09	6.02
AM017	0.42	1.70	18.94	54.66	0.20		0.06	3.98	12.23	0.82	0.02	0.02	0.09	6.70
AM018	1.37	2.92	12.49	47.70	0.46	0.08	0.02	1.94	25.76	0.67	0.01	0.02	0.10	5.95
AM019	0.90	1.62	13.16	56.37	1.26		0.09	1.00	18.53	0.73	0.03	0.04	0.09	5.87

	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As	Br	Rb	SrO	Y	ZrO	Nb	BaO	La_2O_3	CeO	PbO	Analytical
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	total (%)
AM011	89	60	75	95	31			51	621	39	374		592		48		89.84
AM012	95	56	72	156	36			83	286	48	379	22	476	23	52	36	88.06
AM013	103	92	71	133	31			59	1143	65	261		3223		28	50	87.44
AM014	107	116	58	211	63			78	468	66	299	38	301	45	85	31	94.09
AM015	85	48	51	99	24			46	1551	37	274		827		36		83.30
AM016	81	96	92	168	25			42	935	43	308		473		34		78.65
AM017	67	45	47	95	36			76	471	38	257		229	22	42		87.35
AM018	67	83	77	122	28			45	1119	68	274		3045		27		80.04
AM019	79	101	93	204	25			24	893	57	375		1038		36		91.09

data, some samples analysed solely by SEM-EDS were associated with certain compositional groups on the basis of apparent microstructural similarities, most importantly mineralogical inclusions and chemical composition of the ceramic matrix. Each of these assignments will be discussed with the relevant groups. In addition, samples analysed solely by SEM-EDS that did not show similar characteristics with the other main groups were assigned to additional compositional groups, groups 14–15. Some of the 15 groups are represented by only a single sample and thus these cases can be seen as outliers of the larger groups.

In the CA, Ward Linkage method based on the squared Euclidian distances was used to process the ED-XRF data set. The concentrations of the following compounds were included in the cluster analysis in major, minor and trace quantities: MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, V_2O_5, Cr_2O_3, MnO, Fe_2O_3, Co_3O_4, NiO, CuO, ZnO, Rb_2O, SrO, ZrO_2 and BaO. The ED-XRF results were also processed by principal component analysis, in which selected oxides, concentrations of which appeared to dominate the structure in group forming, were included. The PCA was based on the covariance matrix with no rotation of the axes, and the compounds used as variables were MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, MnO, ZnO, SrO, ZrO_2 and BaO. Of the major elements, Na_2O was excluded from the statistical analysis, since its values appeared inconsistent in the precision and accuracy test, as is typical for the equipment in question (see Appendices III and IV for precision and accuracy tests, respectively). In addition, P_2O_5 and SO_3 were excluded from the statistical analysis since post-depositional conditions may cause alteration in their concentrations. PbO was also excluded from the statistical analysis as the ceramic bodies of the glazed sherds showed systematic PbO enrichment. The enrichment is likely to be contamination from the glaze although the glazing was removed before sample preparation. In Table 1, full ED-XRF data for each sample are presented. In Table 2, the ED-XRF data of groups 1–13 indicated by the cluster analysis are given as group mean values and maximum and minimum concentrations of each measured oxide with concentrations over 20ppm (see also Appendix V for complete ED-XRF results of all samples organised according to the order indicated by the cluster analysis).

The dendrogram of the hierarchical cluster analysis of the ED-XRF data is presented in Figure 6.1, and sections of the dendrogram will be presented in further detail when each compositional group is discussed (see below). Figure 6.2 shows the principal component plot including the first two principal components (the first three components representing 71.72% of the total variance of the data set). In Figure 6.2, the first plot shows the ED-XRF samples marked by the groups determined on the basis of the cluster analysis. When viewed with the second, compositional plot in Figure 6.2, showing the significance of the different oxides in the PCA, the elemental concentrations affecting the cluster analysis groupings can be seen. This PCA plot shows that the first principal component discriminates mainly calcareous and non-calcareous samples, whereas the second principal component allows further discrimination based on minor and trace elements. In the third plot of Figure 6.2, the same analysis is shown with samples marked according to the site where they were recovered. Compared to the first plot, the third gives a general indication of the distribution of samples from the different sites into the main compositional groups. The last plot also shows that the samples divide into two broad areas according to their chemical compositions reflecting the geologically distinct regions of the Negev and southern Transjordan.

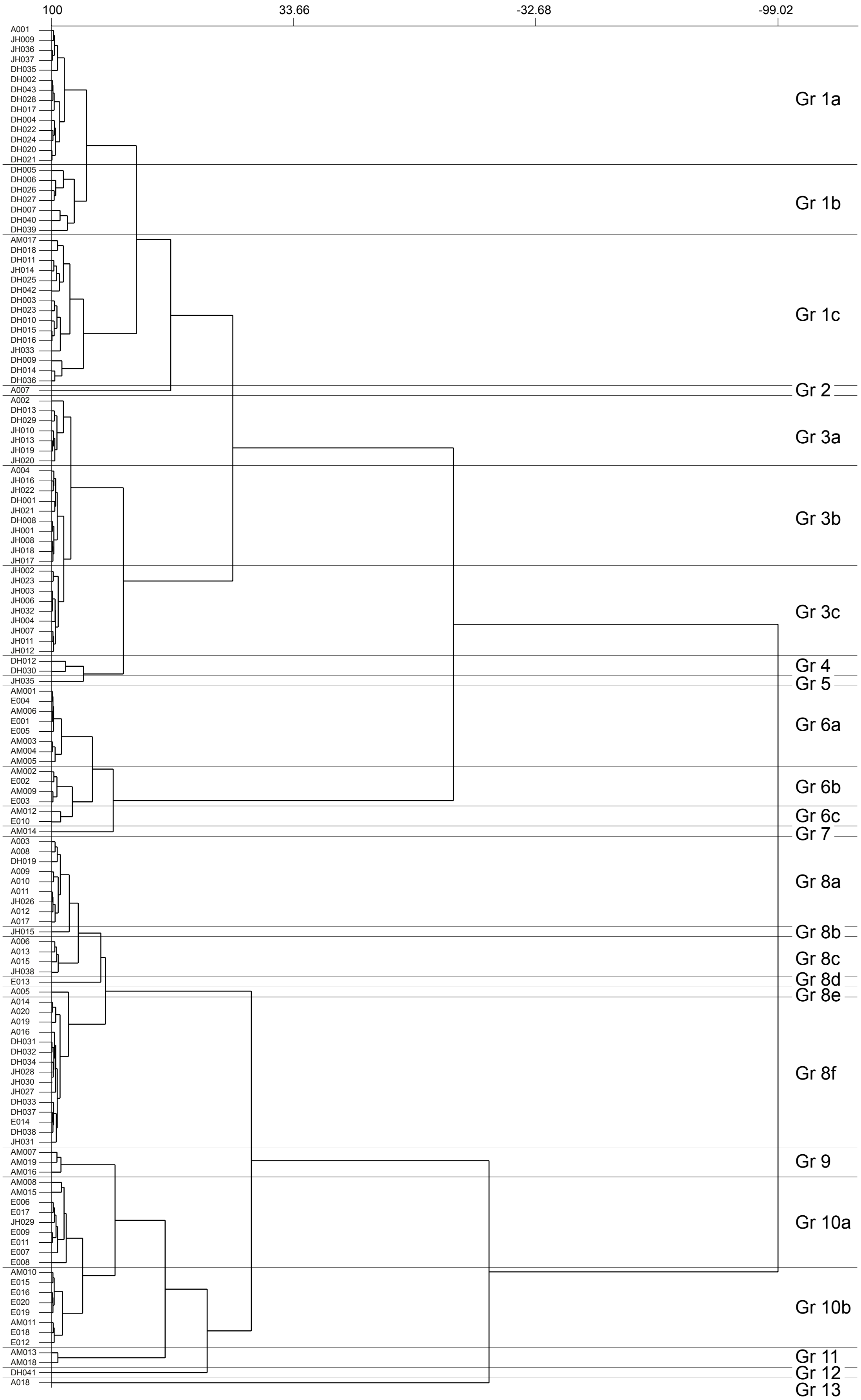

Figure 6.1: Dendrogram of the hierarchical cluster analysis of the ED-XRF data and indicated compositional groups.

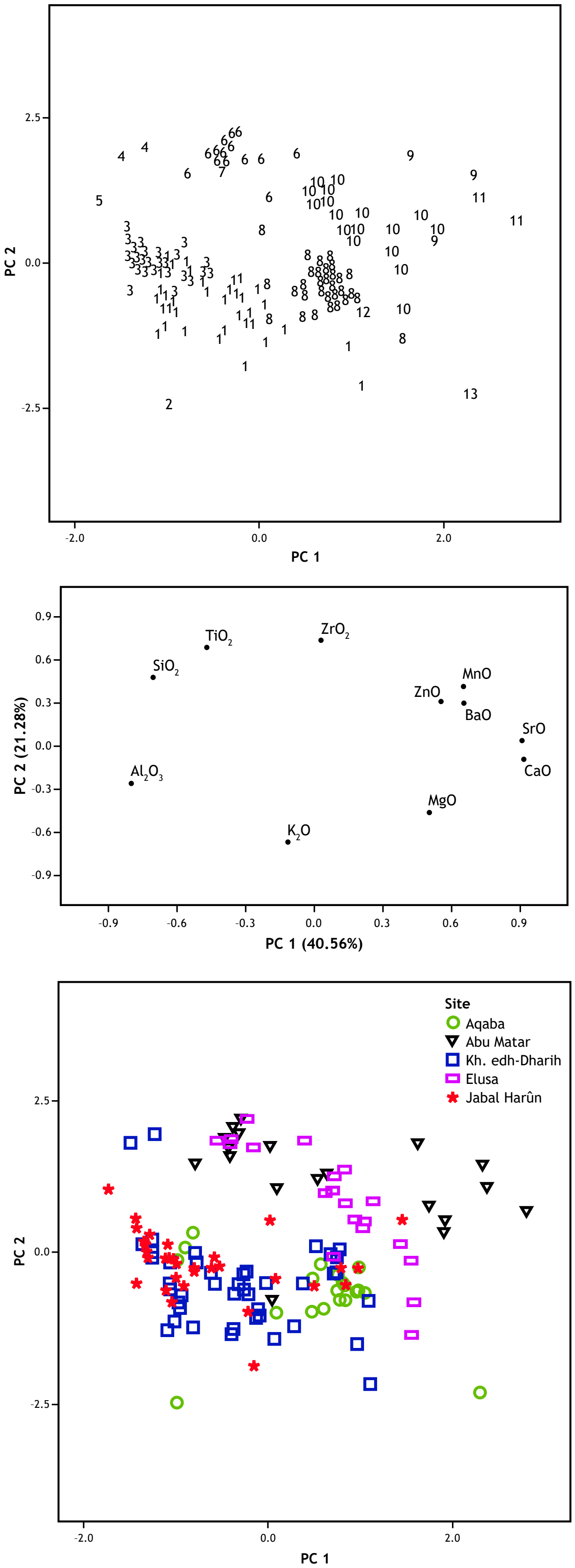

Figure 6.2: ED-XRF data: PCA plots of the first two PCs, from top: samples marked by main cluster analysis groups; component plot of elements; samples marked by site.

Group 1 (a–c)

Group 1 is dominated by Khirbet edh-Dharih samples, and the majority of samples from the site (29 of 43) analysed by ED-XRF are associated with this group in the cluster analysis. In addition, a few samples from other sites, namely ʻAqaba, Jabal Harûn and Abu Matar cluster with these Khirbet edh-Dharih samples in main group 1. Compositional group 1 can be divided into three subgroups (1a–c, see Figure 6.3) according to the cluster analysis and the compositional patterns of the samples in the ED-XRF data (see Tables 1 and 2 and Figures 6.1 and 6.2 and Appendix V).

The following samples form the first subgroup, 1a: an open-form cooking pot (DH002), a closed-form cooking pot (DH004), a jar with combed decoration (DH017), two hand-made jars with painted decoration (DH020, DH021), two jars with thickened, overlapping rims (DH022, DH024), a bag-shaped jar (DH028), an amphora (DH035), and a roof tile (DH043) from Khirbet edh-Dharih. In addition, three Jabal Harûn samples, a basin with finger-pressed decoration (JH009) and two roof tiles (JH036, JH037), and one ʻAqaba sample, a closed-form cooking pot (A001), cluster in group 1a.

The morphological diversity of group 1a continues in the second subgroup of this main group, 1b. The second subgroup includes closed-form cooking pots (DH005, DH006 and DH007), hand-made leaf-pattern jars (DH026, DH027) and coarse hand-made vessels (DH039 and DH040) found at Khirbet edh-Dharih. The third subgroup, 1c, includes an open-form cooking pot (DH003), a basin (DH009), a coarse ware bowl (DH010), jars with high necks and/or combed decoration (DH011, DH014, DH015, DH016, DH018), jars with thickened, overlapping rims (DH023, DH025), an amphora (DH036) and a tile (DH042) from Khirbet edh-Dharih, as well as a jar with combed decoration (JH014) and a coarse, hand-made vessel (JH033) from Jabal Harûn, and a jar from Abu Matar (AM017). Based on the criterion of abundance, the identification of a jar from Abu Matar clustering in this group might indicate that the jar originates from southern Transjordan and is therefore an import to Abu Matar. The typological similarity of this sherd compared to other Abu Matar samples interpreted as local to the Negev area (see below) forces one to be cautious with its provenance (see Appendix I for Abu Matar jars). However, this appears to be a very common jar type produced in different regional workshops and the bulk chemical composition of the sherd strongly indicates that it belongs to this compositional group (see Chapter 5 for bag-shaped jars).

Table 2: Compositional groups based on the cluster analysis of the ED-XRF data.

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 1a	μ (n=14)	0.20	2.22	22.15	61.56	0.17	0.02	0.06	2.24	3.05	0.76	0.02	0.02	0.05	7.38	90	57	47	75	46			79	191	35	152		150	16	42	5
	σ	0.11	0.61	1.47	2.47	0.08	0.02	0.07	0.27	1.62	0.07			0.01	0.57	11	6	7	11	4			12	78	9	34		79	11	7	10
	min	0.03	1.16	19.07	57.00	0.10			1.87	1.05	0.65	0.02	0.02	0.03	6.36	73	48	38	64	36			56	112	22	116		98		32	
	max	0.44	3.29	24.55	66.39	0.40	0.05	0.21	2.69	7.11	0.88	0.03	0.03	0.08	8.48	109	67	59	104	51			93	415	60	211		399	28	58	24
Gr 1b	μ (n=7)	0.49	2.19	22.52	59.04	0.25	0.42	0.05	2.69	2.67	0.84	0.03	0.02	0.05	8.60	101	56	48	120	47			86	314	33	155	4	243	13	45	10
	σ	0.30	0.43	1.65	2.35	0.11	0.92	0.07	0.55	1.56	0.15			0.02	0.87	22	16	8	49	4			13	89	7	39	11	164	12	6	13
	min		1.66	20.85	56.69	0.15			2.14	1.25	0.74	0.02	0.02	0.02	7.41	77	30	38	76	44			60	158	23	116		118		35	
	max	0.81	2.82	25.74	63.45	0.46	2.51	0.15	3.84	5.98	1.16	0.03	0.02	0.08	9.59	136	72	62	207	54			100	453	44	230	29	516	25	49	30
Gr 1c	μ (n=15)	0.51	3.78	18.04	55.95	0.33	0.24	0.16	2.89	9.85	0.73	0.02	0.02	0.07	7.26	84	46	50	84	37			80	411	34	178	3	200	15	42	8
	σ	0.22	1.61	2.94	3.65	0.12	0.52	0.08	0.53	3.09	0.09			0.02	0.51	10	7	15	18	5			9	142	10	57	8	104	11	7	13
	min	0.19	1.70	12.03	50.12	0.13		0.03	2.06	5.12	0.57	0.02	0.01	0.04	6.49	67	30	25	62	26			66	215	23	109		79		30	
	max	0.85	8.34	22.66	62.71	0.57	1.54	0.30	3.98	15.53	0.90	0.02	0.02	0.10	8.13	100	58	86	114	44			98	696	59	302	23	456	24	49	30
Gr 2	μ (n=1)	0.69	0.96	28.59	57.58	0.12	0.05	0.03	5.41	0.99	0.29	0.02		0.03	5.06	62		81	68	84			196	192	23	269		644	25	69	34
Gr 3a	μ (n=7)	0.39	1.62	21.93	65.61	0.13	0.15	0.18	1.91	1.12	0.82	0.02	0.02	0.02	5.96	67	41	51	74	41			63	127	37	253		137	14	46	22
	σ	0.31	0.32	2.44	2.60	0.04	0.12	0.13	0.28	0.54	0.09			0.01	0.47	5	7	11	29	4			7	51	7	44		22	13	9	10
	min		1.29	18.38	62.29	0.09	0.03	0.01	1.60	0.38	0.66	0.02	0.02	0.01	5.48	62	28	32	50	35			57	76	30	190		104		33	
	max	0.98	2.24	24.59	68.64	0.20	0.32	0.32	2.30	1.93	0.93	0.02	0.02	0.03	6.75	76	49	66	136	49			76	211	51	320		161	26	56	31
Gr 3b	μ (n=10)	0.49	1.82	23.22	62.81	0.12	0.13	0.21	1.86	1.31	0.87	0.02	0.02	0.03	6.97	89	44	46	76	43			62	112	42	247		124	21	49	23
	σ	0.24	0.35	1.47	1.72	0.04	0.11	0.12	0.20	0.73	0.06			0.01	0.41	9	4	7	14	3			7	24	9	38		10	8	7	14
	min	0.04	1.37	20.31	60.13	0.08	0.03	0.05	1.58	0.49	0.77	0.02	0.01	0.02	6.01	78	39	33	63	39			52	83	34	185		108		35	
	max	0.79	2.37	25.50	64.87	0.20	0.39	0.42	2.13	2.80	0.94	0.02	0.02	0.04	7.59	102	51	58	101	48			73	158	59	302		138	26	60	41
Gr 3c	μ (n=9)	0.53	2.75	21.12	60.88	0.20	0.15	0.25	2.14	3.94	0.81	0.02	0.02	0.05	7.04	86	42	63	73	39	4		64	181	40	249		142	22	46	18
	σ	0.21	0.51	1.13	1.33	0.06	0.09	0.07	0.19	1.65	0.04			0.01	0.32	9	3	19	11	3	11		7	64	4	18		18	2	7	10
	min	0.23	2.15	19.59	58.68	0.13	0.03	0.12	1.88	1.71	0.76	0.02	0.01	0.04	6.51	72	36	41	63	35			55	127	35	226		124	20	35	
	max	0.89	3.47	22.85	63.33	0.32	0.34	0.38	2.48	6.34	0.89	0.02	0.02	0.06	7.69	98	46	98	88	44	33		79	331	45	278		173	24	58	28

Table 2 (continued)

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 4	μ (n=2)	0.77	1.10	21.12	66.05	0.15	0.05	0.04	2.35	2.06	1.32	0.03	0.02	0.04	4.75	58	30	46	64	45			74	310	65	503	45	242	30	64	15
	σ	0.08	0.13	0.36	0.58		0.04	0.05	0.69	2.10	0.13			0.02	2.51	20	13		13	11			15	226	17	41	25	38	8	17	21
	min	0.71	1.00	20.86	65.64	0.15	0.02	0.01	1.86	0.58	1.23	0.03	0.01	0.02	2.97	44	21	45	54	37			63	151	53	474	27	215	24	53	
	max	0.83	1.19	21.38	66.46	0.15	0.08	0.07	2.84	3.54	1.41	0.03	0.02	0.06	6.53	72	39	46	73	52			84	470	77	532	62	269	36	76	29
Gr 5	μ (n=1)	0.59	0.76	31.02	58.07	0.06	0.11	0.16	1.13	0.48	1.48	0.03	0.02	0.03	5.73	77	51	114	71	40			54	259	54	220	21	213	36	85	1722
Gr 6a	μ (n=8)	0.78	1.44	17.26	67.22	0.12	0.06	0.11	1.41	0.89	1.09	0.03	0.02	0.15	9.24	144	70	69	139	38			68	212	56	260	21	480	23	59	
	σ	0.31	0.10	0.76	1.36	0.03	0.03	0.12	0.06	0.10	0.05			0.01	0.50	20	5	7	9	3			5	25	3	15	9	113	3	4	
	min	0.49	1.23	16.01	65.91	0.08	0.04	0.01	1.28	0.71	1.03	0.03	0.02	0.14	8.63	103	63	61	126	33			59	166	52	239		378	21	52	
	max	1.42	1.56	18.17	69.31	0.17	0.13	0.37	1.49	1.02	1.16	0.03	0.02	0.17	9.86	165	80	81	151	43			76	252	61	281	28	707	29	65	
Gr 6b	μ (n=4)	0.77	1.84	14.63	69.13	0.11	0.03	0.08	1.26	3.01	0.97	0.03	0.02	0.12	7.84	102	59	57	109	33			56	274	46	284	16	387	5	45	
	σ	0.15	0.63	0.93	2.64	0.03	0.04	0.05	0.10	2.57	0.04			0.03	0.32	7	1	7	7	1			3	121	2	33	10	57	11	5	
	min	0.62	1.26	13.58	66.65	0.08		0.01	1.15	0.80	0.93	0.02	0.02	0.08	7.46	95	58	47	99	32			52	178	43	256		329		38	
	max	0.97	2.57	15.84	71.84	0.13	0.09	0.13	1.38	5.88	1.02	0.03	0.02	0.13	8.24	111	61	64	117	35			59	431	47	324	21	439	22	51	
Gr 6c	μ (n=2)	1.01	2.74	16.75	60.56	0.38	0.07	0.07	2.08	6.47	1.04	0.03	0.02	0.12	8.44	96	66	85	135	36			70	442	46	353	21	678	12	49	18
	σ	0.80	0.22	1.59	0.55	0.29	0.07	0.05	0.66	0.09	0.18			0.02	0.70	2	14	18	30				18	221	3	36	1	285	16	4	26
	min	0.44	2.58	15.62	60.18	0.17	0.02	0.03	1.61	6.41	0.92	0.03	0.02	0.11	7.94	95	56	72	114	36			57	286	44	328	20	476		46	
	max	1.57	2.90	17.87	60.95	0.58	0.12	0.11	2.55	6.53	1.16	0.03	0.02	0.14	8.94	98	76	98	156	36			83	598	48	379	22	880	23	52	36
Gr 7	μ (n=1)	0.66	1.06	28.59	49.19	0.55		0.03	1.56	6.63	1.53	0.04	0.03	0.06	9.87	107	116	58	211	63			78	468	66	299	38	301	45	85	31
Gr 8a	μ (n=9)	2.28	2.86	18.60	51.99	0.36	0.48	0.51	1.87	13.97	0.65	0.02	0.01	0.09	6.11	76	45	45	129	37	78	9	61	623	36	154		450	23	61	18
	σ	1.23	0.88	1.03	1.51	0.10	1.16	0.62	0.24	1.60	0.06			0.02	0.45	9	4	11	9	2	234	19	9	151	3	18		51	9	10	19
	min	0.03	2.07	17.02	50.10	0.27		0.08	1.56	12.23	0.56	0.01	0.01	0.05	5.32	65	40	28	119	34			46	506	31	124		352		42	
	max	4.74	4.71	20.45	54.14	0.59	3.53	2.07	2.14	16.21	0.79	0.02	0.02	0.12	6.65	86	51	57	140	39	702	56	72	1009	40	178		513	30	72	52
Gr 8b	μ (n=1)	0.49	1.37	20.69	55.82	1.00	0.01	0.12	1.47	12.39	0.83	0.03	0.02	0.04	5.58	71	65	48	171	38			60	351	44	272		215	24	53	29
Gr 8c	μ (n=4)	1.71	3.99	16.81	57.51	0.24	0.16	0.37	1.78	11.54	0.59	0.01	0.02	0.06	5.04	64	38	55	111	34		17	54	571	32	182		360	16	50	28
	σ	1.17	1.05	0.84	1.56	0.05	0.13	0.43	0.32	1.45	0.07		0.01	0.02	0.18	9	6	13	14	3		22	14	134	2	35		125	11	4	22
	min	0.29	2.48	15.71	55.73	0.17	0.05	0.09	1.43	9.39	0.49	0.01	0.01	0.04	4.82	55	33	36	90	31			40	381	29	144		179		45	
	max	2.75	4.75	17.77	59.18	0.30	0.28	1.01	2.11	12.56	0.63	0.02	0.02	0.09	5.20	77	47	65	120	37		46	67	680	35	223		463	22	55	53

Table 2 (continued)

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 8d	μ (n=1)	2.11	3.70	13.03	48.70	0.14	0.01	0.26	2.38	22.27	0.51	0.02	0.08	0.09	6.47	83	234	62	109	27	22		89	881	27	123		305		42	29
Gr 8e	μ (n=1)	1.56	1.94	20.19	56.40	0.28	0.71	0.33	3.01	9.79	0.50	0.02	0.01	0.07	5.00	61	28	36	91	51		21	117	404	30	221		597	29	63	24
Gr 8f	μ (n=15)	1.61	3.36	17.76	56.06	0.36	0.05	0.13	2.30	10.89	0.66	0.02	0.01	0.11	6.46	78	45	53	129	38			85	648	40	191		559	27	63	37
	σ	0.35	0.68	0.99	1.92	0.05	0.09	0.11	0.26	1.08	0.02			0.01	0.30	8	5	9	9	2			5	117	2	26		134	4	6	16
	min	1.06	1.85	16.41	52.03	0.32		0.02	1.96	8.81	0.59	0.01	0.01	0.09	5.74	67	32	39	106	36			77	493	35	128		413	20	57	20
	max	2.35	4.80	20.14	59.86	0.52	0.32	0.41	2.86	13.52	0.69	0.03	0.02	0.13	6.86	92	51	72	141	41			93	953	42	237		1021	34	76	72
Gr 9	μ (n=3)	0.96	1.93	12.84	50.63	1.12	0.01	0.10	1.33	24.17	0.71	0.03	0.03	0.09	5.77	75	105	103	191	25	7		33	983	53	367		877		35	7
	σ	0.16	0.68	0.37	5.02	0.47	0.01	0.05	0.41	4.89	0.05		0.01		0.32	9	11	19	20	1	12		9	120	9	55		353		1	12
	min	0.83	1.45	12.44	47.07	0.60		0.05	1.00	18.53	0.65	0.03	0.03	0.09	5.41	64	96	92	168	25			24	893	43	308		473		34	
	max	1.14	2.71	13.16	56.37	1.51	0.01	0.14	1.79	27.05	0.74	0.03	0.04	0.09	6.02	81	117	126	204	26	20		42	1120	59	417		1121		36	21
Gr 10a	μ (n=9)	2.08	3.16	12.37	53.09	0.32	0.17	0.40	1.95	19.38	0.72	0.02	0.02	0.11	5.98	76	55	66	105	26			49	903	39	296		698	5	39	8
	σ	0.81	0.35	0.70	2.93	0.08	0.15	0.33	0.59	1.76	0.05			0.01	0.30	11	9	18	8	2			5	261	6	24		307	9	5	13
	min	1.31	2.64	11.37	49.05	0.22	0.01	0.04	1.32	16.55	0.63	0.01	0.01	0.09	5.57	54	45	47	93	24			41	687	32	259		499		33	
	max	3.91	3.79	13.27	56.83	0.47	0.37	1.12	3.35	21.34	0.78	0.03	0.02	0.14	6.37	87	77	104	119	28			56	1551	51	335		1470	22	47	28
Gr 10b	μ (n=8)	1.23	3.02	12.52	60.51	0.23	0.01	0.09	1.58	13.15	0.82	0.02	0.02	0.11	6.47	80	55	60	104	29			50	629	38	330		571	3	41	5
	σ	0.35	0.32	1.01	1.89	0.10	0.03	0.07	0.09	1.57	0.08			0.01	0.48	13	3	11	7	2			3	82	2	43		112	7	4	14
	min	0.52	2.46	11.53	57.93	0.16		0.01	1.47	10.45	0.73	0.02	0.02	0.10	5.80	67	51	46	91	25			45	535	36	262		444		37	
	max	1.76	3.55	14.18	62.98	0.48	0.08	0.20	1.73	15.29	0.93	0.03	0.02	0.13	7.23	98	60	75	109	31			55	789	42	376		814	21	48	40
Gr 11	μ (n=2)	1.45	2.88	13.57	50.84	0.47	0.16	0.11	1.95	20.88	0.68	0.01	0.02	0.10	6.33	85	87	74	127	29			52	1131	66	267		3134		27	25
	σ	0.11	0.05	1.53	4.45		0.11	0.13	0.01	6.89	0.02		0.01	0.01	0.54	25	6	4	8	2			10	17	2	9		125		1	36
	min	1.37	2.84	12.49	47.70	0.46	0.08	0.02	1.94	16.01	0.67	0.01	0.02	0.10	5.95	67	83	71	122	28			45	1119	65	261		3045		27	
	max	1.53	2.92	14.65	53.99	0.47	0.24	0.20	1.96	25.76	0.70	0.01	0.03	0.11	6.71	103	92	77	133	31			59	1143	68	274		3223		28	50
Gr 12	μ (n=1)	2.35	5.18	14.73	53.52	0.16		0.16	1.73	13.17	0.59	0.02	0.04	0.13	7.97	117	263	356	100	29			52	612	29	115		372		35	33
Gr 13	μ (n=1)	0.80	15.32	10.04	50.45	0.34	0.34	0.13	1.59	11.18	0.41	0.02	0.15	0.13	8.85	145	1059	97	161	22		34	56	596	21	78		208		24	24

The bulk chemical compositional patterns of the subgroups 1a–c show minor variation in the concentrations of certain elements. Subgroups 1a and 1b are particularly similar in terms of compositional characteristics: these ceramics are of non-calcareous clay (CaO *c.* 1–6wt %), with Al_2O_3 concentration generally above 20wt %, and with comparatively low SrO, ZrO_2 and BaO values (*c.* 110–450ppm, 115–230, and 100–500ppm, respectively). The difference between groups 1a and 1b is marked by a very minor difference in Fe_2O_3 values, which tend to appear slightly higher in group 1b (*c.* 7.5–9.6wt % compared to 6.4–8.5wt % of group 1a). Compared to subgroups 1a and 1b, subgroup 1c displays higher CaO values (5.1–15.5wt %), wider variation of MgO (1.7–8.3wt %), and slightly lower range of Al_2O_3 with values typically being below 20wt % (12–22.6wt %), but similar concentrations of other elements.

The mineralogical inclusions and chemical compositions of the ceramic matrices of the samples were examined with SEM (Table 3, Figure 6.4, and Appendices VI–VII). The SEM-EDS analysis was conducted on nine samples assigned to this compositional group selected on the basis of the ED-XRF bulk chemical data (DH011, DH028, DH020, DH025, DH026, JH033, JH036, JH037 and A001). The mineral inclusions of these samples show abundant quartz (grain size < 1mm), clay pellets (< 1mm) and iron oxides (< 50µm), frequent ilmenite (< 20µm) and apatite (0.1–0.3mm), and rare rutile (~ 10µm) and zircon (~ 20µm). In addition, the mineralogy of sample JH037 displays very rare magnetite in a clay pellet (particle size 5–10µm) and DH011 a very rare rock inclusion that appears to be melted albite (~ 10µm) (see Figure 6.4). Heterogeneous, unsorted ceramic fabrics with rounded

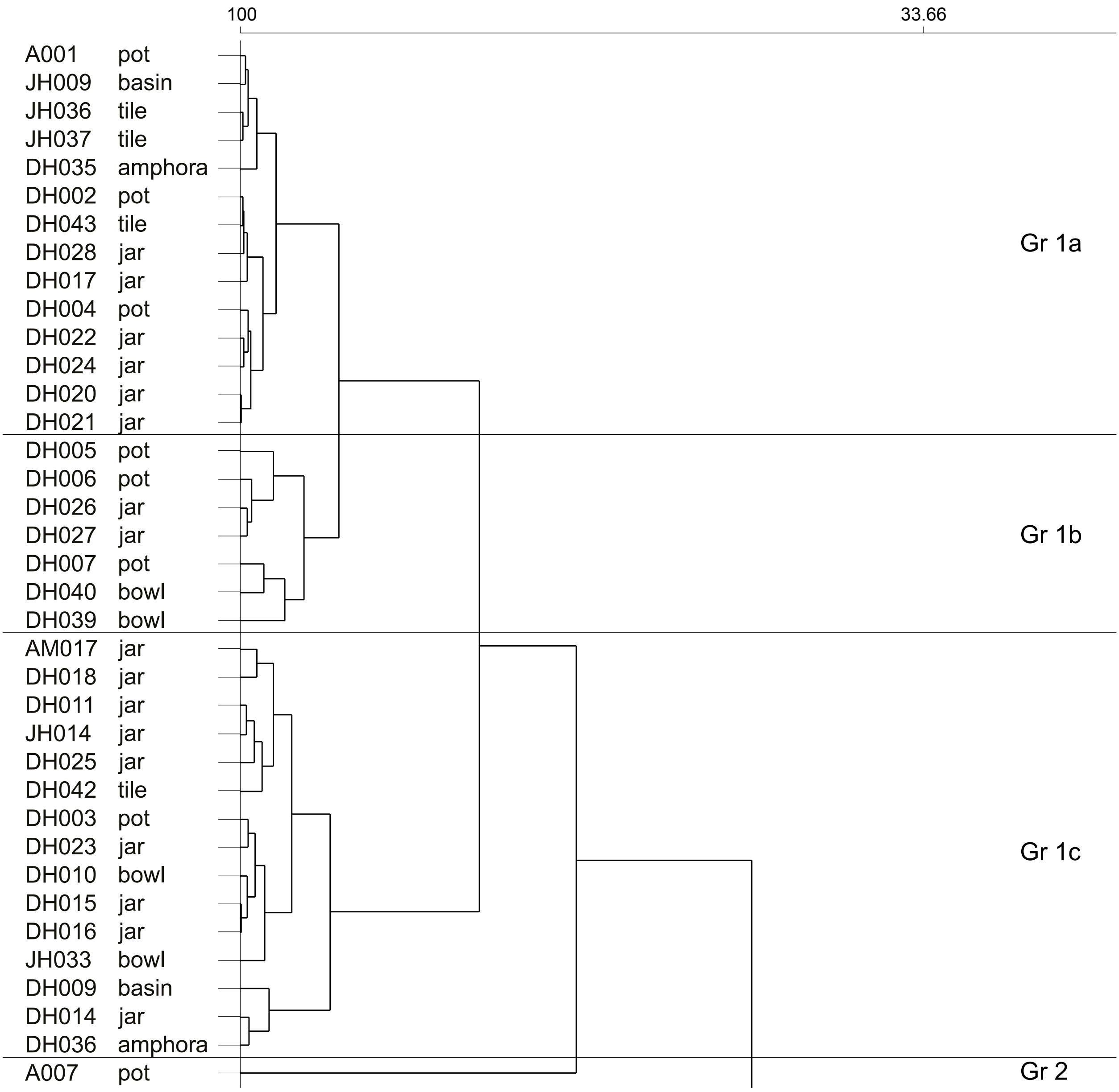

Figure 6.3: Detail of the ED-XRF data cluster analysis dendrogram (see Figure 6.1) showing groups 1a–c and 2.

grains indicate natural inclusions and a relatively low level of material processing in the manufacturing process. Surface treatments, such as slips, were not detected in ceramics of this group in the microscopic examination. Possible signs of the manufacturing technique, determined tentatively macroscopically, were examined in further detail with SEM.

The wheel-thrown ceramics, A001, DH025, DH028 and DH011 show grain orientation parallel with the vessel surfaces and elongated voids also orientated parallel with the surfaces, whereas the coil-built vessels DH020, DH026 and JH033, and the hand/mould-made tiles JH036 and JH037 show more irregularly shaped pores and random grain orientation (see Courty and Roux 1995 for an experimental study of manufacturing technique identification on the basis of ceramic microfabric characteristics). The analyses of the ceramic matrices by SEM-EDS confirmed that the group 1 samples are generally non-calcareous (CaO 2–4.6wt %), except in the case of three samples clustering in group 1c, JH033, DH011 and DH025 with a calcareous ceramic matrix composition (CaO 9.8–17.9wt %) (see Table 4 and Appendix VIII). Apart from the CaO content variation, the other concentrations of the ceramic matrices of group 1 samples show consistent values, with Al_2O_3 content of 15–22.6wt %, relatively low MgO and K_2O concentrations (1.3–3wt % and 2.9–4.5wt %).

The minor variation between the compositional patterns in subgroups 1a–c can be considered as natural variation occurring in ceramic fabrics produced from similar raw materials. As this group is clearly dominated by the Khirbet edh-Dharih samples, forming the main compositional group in the sample assemblage of the site, it can be concluded that this group is local to the Khirbet edh-Dharih area, or that the production centre for these ceramics was located relatively close to the site. On the geological map of the Khirbet edh-Dharih region, the area within a 10km radius from the site shows

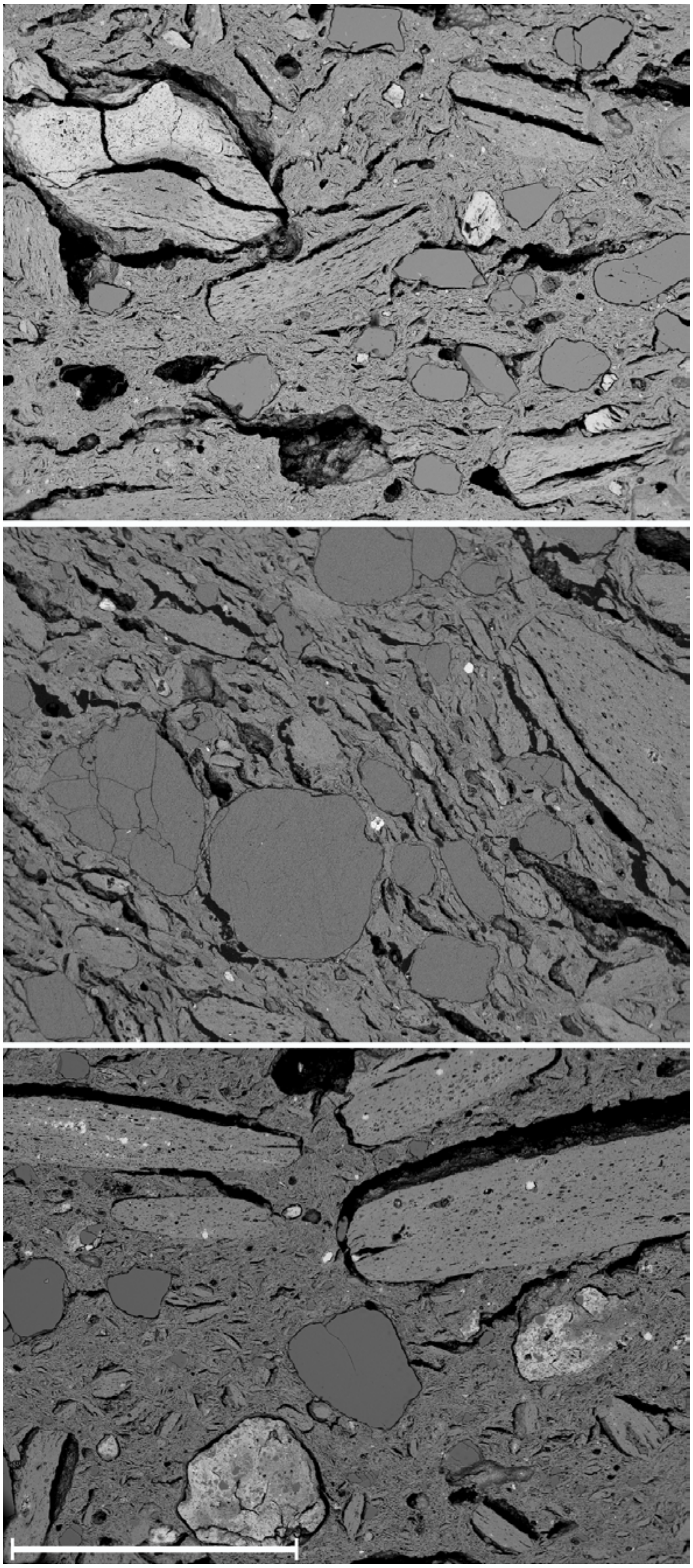

Figure 6.4: SEM-BSE micrographs of ceramic fabrics of group 1 samples (scale bar 1mm, the long axes of the images are parallel with the vessel surfaces), from top: an open-form cooking pot A001, a roof tile JH037 and a bag-shaped amphora DH028, showing poorly sorted quartz and natural clay pellets.

Table 3: Mineral identifications of the compositional groups (Gr 1–15), based on SEM-EDS analysis.

For each mineral, the first row indicates the number of samples in which the mineral is present, and the second row indicates the same as a percentage of the total number of samples analysed in each group.

	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 7	Gr 8	Gr 9	Gr 10	Gr 11	Gr 12	Gr 13	Gr 14	Gr 15
	(n=9)	(n=1)	(n=17)	(n=1)	(n=1)	(n=5)	(n=1)	(n=6)	(n=2)	(n=6)	(n=1)	(n=1)	(n=1)	(n=1)	(n=1)
Apatite	6	1	7			1		1	2	2	1	1			
	67%	100%	41%			20%		17%	100%	33%	100%	100%			
Augite		1			1	1		6	1	3		1	1		1
		100%			100%	20%		100%	50%	50%		100%	100%		100%
Ba-rich pellet					1										
					100%										
Barite										1	1				
										17%	100%				
Biotite mica		1						5			1	1	1		1
		100%						83%			100%	100%	100%		100%
Calcite								1	1	4				1	
								17%	50%	67%				100%	
Chromite						1		1				1	1		
						20%		17%				100%	100%		
Clay pellet	9	1	17	1	1	2	1	3	1	2	1	1		1	1
	100%	100%	100%	100%	100%	40%	100%	50%	50%	33%	100%	100%		100%	100%
Garnet						1		3		5	1	1		1	1
						20%		50%		83%	100%	100%		100%	100%
Garnet (Almandine)						1							1		
						20%							100%		
Garnet (Andradite)									1	1					
									50%	17%					
Garnet (Grossular)						1			2						
						20%			100%						
Hornblende										1		1		1	1
										17%		100%		100%	100%
Ilmenite	4		7		1	5	1	5	2	6	1	1		1	1
	44%		41%		100%	100%	100%	83%	100%	100%	100%	100%		100%	100%
Iron oxide	7		15		1	2	1	5	1	4	1	1			1
	78%		88%		100%	40%	100%	83%	50%	67%	100%	100%			100%
K-feldspar			2			5	1	4	1	3	1				1
			12%			100%	100%	67%	50%	50%	100%				100%

Table 3 (continued)

	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 7	Gr 8	Gr 9	Gr 10	Gr 11	Gr 12	Gr 13	Gr 14	Gr 15
	(n=9)	(n=1)	(n=17)	(n=1)	(n=1)	(n=5)	(n=1)	(n=6)	(n=2)	(n=6)	(n=1)	(n=1)	(n=1)	(n=1)	(n=1)
Magnetite	1							1			1				
	11%							17%			100%				
Mg-rich pellet								1							
								17%							
Mn hydroxide						1									
						10%									
Mn-rich pellet					1	3									
					100%	60%									
Perowskite									1	1			1		
									50%	17%			100%		
Plagioclase feldspar		1			1			4	1			1			
		100%			100%			67%	50%			100%			
Quartz	9	1	17	1	1	5	1	6	2	6	1	1	1	1	1
	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Rock fragment 1[1]															1
															100%
Rock fragment 2[2]	1					1						1			
	11%					20%						100%			
Rock fragment 3[3]												1			
												100%			
Rutile	3		11	1		1	1	3	1	5				1	
	33%		65%	100%		20%	100%	50%	50%	83%				100%	
Sandstone					1										
					100%										
Titanite		1	1		1	1		2	1	3			1	1	1
		100%	6%		100%	20%		33%	50%	50%			100%	100%	100%
Titanomagnetite						2		2	2						
						40%		33%	100%						
Ulvite									1		1				
									50%		100%				
Zircon	2	1	4	1	1	3	1	1	2	3				1	
	22%	100%	24%	100%	100%	60%	100%	17%	100%	50%				100%	

[1] Rock fragment 1 aluminium silicate-iron oxide

[2] Rock fragment 2 basalt (olivine-plagioclase)

[3] Rock fragment 3 albite, melted

Table 4: SEM-EDS microchemical analysis of the ceramic matrices. Results given are mean values (n=4), normalised to 100%.

	Gr 1									Gr 2	Gr 3																
	JH033	JH036	JH037	A001	DH011	DH020	DH025	DH026	DH028	A007	JH001	JH003	JH005	JH007	JH008	JH013	JH016	JH019	JH020	JH021	JH022	JH023	JH024	JH025	A002	DH001	DH029
Na_2O	0.6	0.3	0.3	0.3	0.8	0.4	2.6	0.4	0.3	0.5	0.6	0.4	0.5	0.6	1.4	0.4	0.3	0.4	0.7	1.0	0.3	1.2	0.7	0.5	0.8	0.3	0.2
MgO	3.0	2.4	2.2	1.3	2.1	3.1	3.0	1.7	1.5	0.9	2.2	2.2	2.7	2.3	2.1	1.7	1.6	1.6	1.6	1.3	1.6	2.6	2.1	3.2	1.7	1.7	1.4
Al_2O_3	20.9	22.1	21.0	22.2	16.8	20.5	15.1	20.6	22.6	28.3	20.9	19.5	22.4	20.0	22.9	20.1	23.5	22.8	23.0	22.2	23.4	20.8	19.4	21.6	19.3	22.0	20.9
SiO_2	54.9	61.4	62.0	60.6	49.4	58.9	49.6	61.5	58.7	54.5	65.1	59.5	60.0	58.6	59.9	68.3	62.4	65.6	62.2	65.5	64.3	63.2	63.1	61.5	63.9	60.6	63.9
P_2O_5	0.2	0.1	0.4	0.2	0.3	0.2	0.1	0.6	0.1	0.4	0.2	0.5	0.2	0.2	0.2	0.4	0.2	0.2	0.5	0.2	0.3	0.3	0.3	0.1	0.5	0.2	0.2
SO_3	0.4	0.1	0.2	0.1	0.3	0.1	0.3	0.1	0.8		0.2	0.3	0.7	0.4	1.4		0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.1	
K_2O	3.0	2.9	2.9	3.2	4.5	3.5	3.1	4.1	3.1	8.6	2.4	2.9	3.1	3.3	2.7	2.0	2.5	2.1	3.1	2.1	2.4	2.5	3.0	3.3	2.4	3.1	3.9
CaO	9.8	2.0	2.3	2.2	15.3	4.6	17.9	2.5	4.2	1.7	1.9	6.8	2.2	5.4	2.5	1.6	1.6	0.7	0.8	0.6	0.8	2.0	4.2	1.7	3.0	2.3	1.8
TiO_2	0.9	1.0	1.2	1.4	1.5	1.1	1.2	1.2	1.4	0.2	1.0	1.1	1.1	1.2	1.1	0.9	1.3	1.2	1.1	1.4	1.2	1.0	1.1	1.0	1.0	1.6	1.7
FeO	6.4	7.8	7.5	8.7	9.2	7.6	7.2	7.3	7.5	5.0	5.5	6.9	7.1	8.0	6.0	4.6	6.6	5.2	6.9	5.7	5.7	6.2	6.1	6.8	7.3	8.3	6.0
	Gr 4	Gr 5	Gr 6					Gr 7	Gr 8						Gr 9		Gr 10						Gr 11	Gr 12	Gr 13	Gr 14	Gr 15
	DH030	JH035	E001	E005	E010	AM001	AM006	AM014	JH028	A008	A020	DH032	E013	E014	AM016	AM019	JH029	E006	E008	E015	E018	AM010	AM013	DH041	A018	JH034	AM020
Na_2O	0.5	0.7	1.2	1.1	1.5	0.7	0.9	0.3	1.5	1.3	1.7	0.9	1.5	1.4	1.3	0.6	0.9	1.5	2.8	1.0	1.3	0.9	1.2	1.5	0.5	1.1	0.3
MgO	1.0	0.8	1.7	1.9	2.6	1.5	1.8	0.9	4.3	2.9	3.4	3.5	3.1	2.8	2.4	1.4	2.9	2.5	3.5	2.9	3.1	3.0	2.9	4.8	13.7	3.0	0.6
Al_2O_3	18.0	26.7	18.4	18.7	13.0	17.2	18.4	25.5	15.2	15.5	15.6	14.4	11.9	15.1	9.9	10.8	10.8	11.0	9.6	10.8	11.2	10.4	12.7	11.9	8.4	10.4	27.7
SiO_2	66.0	62.4	62.6	61.8	61.2	64.2	62.7	52.9	50.0	51.4	49.0	50.9	51.0	52.2	47.0	50.3	48.9	50.5	48.8	56.0	53.0	59.4	51.4	50.3	53.3	67.2	61.8
P_2O_5	0.3	0.1	0.2	0.3	0.1	0.3	0.3	0.6	0.5	0.6	0.6	0.5	0.1	0.4	0.7	1.6	0.2	0.5	0.3	0.1	0.2	0.3	0.6	0.3	0.4	0.2	0.2
SO_3	0.6	0.1	0.2		0.2	0.1	0.2	0.1	0.5	0.6	1.3	0.2	0.2	0.4	0.4	0.2	0.3	0.7	2.3	0.1	0.9	0.2	0.3		0.5	0.2	0.1
K_2O	2.9	1.4	2.0	2.0	2.0	2.0	1.9	2.0	2.6	2.8	3.0	2.1	3.4	2.4	1.9	0.9	1.7	2.6	4.6	1.4	1.4	2.0	2.8	1.9	1.7	1.6	1.5
CaO	4.9	1.2	1.6	1.5	8.2	0.9	1.1	7.1	17.3	17.8	18.6	18.0	20.5	16.4	30.3	26.2	26.4	23.7	21.3	20.0	18.3	15.2	19.2	19.5	13.3	10.9	0.6
TiO_2	1.9	2.1	1.5	1.8	1.5	2.0	1.8	2.1	0.9	0.8	0.9	1.2	0.9	1.1	0.8	1.1	1.1	0.9	0.7	1.1	1.3	1.1	1.1	0.9	0.6	0.7	2.2
FeO	3.9	4.7	10.7	11.1	9.7	11.0	10.9	8.5	7.3	6.3	5.8	8.3	7.5	7.9	5.4	6.9	6.8	6.3	6.3	6.7	9.5	7.5	7.8	9.0	7.8	4.7	5.1

mainly limestone and phosphorite sediments and some basaltic areas. Compared to the mineralogical inclusions of group 1, apatite, commonly present in the samples, can be derived from the second sediment type or the basalt whereas the magnetite, ilmenite and apatite inclusions can relate to the basaltic areas (Bender *et al.* 1968).

Furthermore, the chemical composition of group 1 shows clear similarities with group 3 (formed mainly by Jabal Harûn samples, see below), indicating that geologically similar raw material sources were exploited in the production of the ceramics belonging to groups 1 and 3. It is also noteworthy that very different ceramic forms from different phases are represented in group 1, suggesting that the same raw materials were deemed suitable for the production of different forms and exploited over a long period of time. It also appears that different production techniques were applied to the same materials, as wheel- and hand-made vessels and tiles are included in this group. It is particularly noteworthy that two tiles found at Jabal Harûn belong to this compositional group (see more detailed discussion in the next chapter).

Group 2

This compositional category contains only one sherd, a cooking pot (A007) found at ʻAqaba. The bulk chemical composition of sample A007 obtained in the ED-XRF analysis (see Figure 6.3, and Tables 1, 2 and Appendix V) is clearly different compared to the other samples analysed. This sample has a low MgO and CaO contents (both at 1wt %), relatively high Al_2O_3 (28.6wt %), higher K_2O (5.4wt %) and Rb_2O (*c.* 200ppm) concentrations compared to the other samples, and relatively low SrO (*c.* 200ppm) and ZrO_2 (*c.* 270) and relatively high BaO (*c.* 645ppm) values. The position of this sample as an outlier is also visible in the PCA (see Figure 6.2).

SEM-EDS analysis reveals an unsorted ceramic fabric with abundant quartz (particle size < 0.5mm) and frequent apatite (20–80μm), Fe-rich clay pellets (< 0.4mm), plagioclase feldspar (< 0.4mm) and biotite mica (< 0.3mm), and rare augite (0.1mm), zircon (30μm) and titanite (~20μm). This sherd has a non-calcareous ceramic matrix (CaO 1.7wt %), high Al_2O_3 concentration (28.3wt %), and relatively high K_2O content (8.6wt %) (see Figure 6.5, Table 3, Appendices VI–VIII).

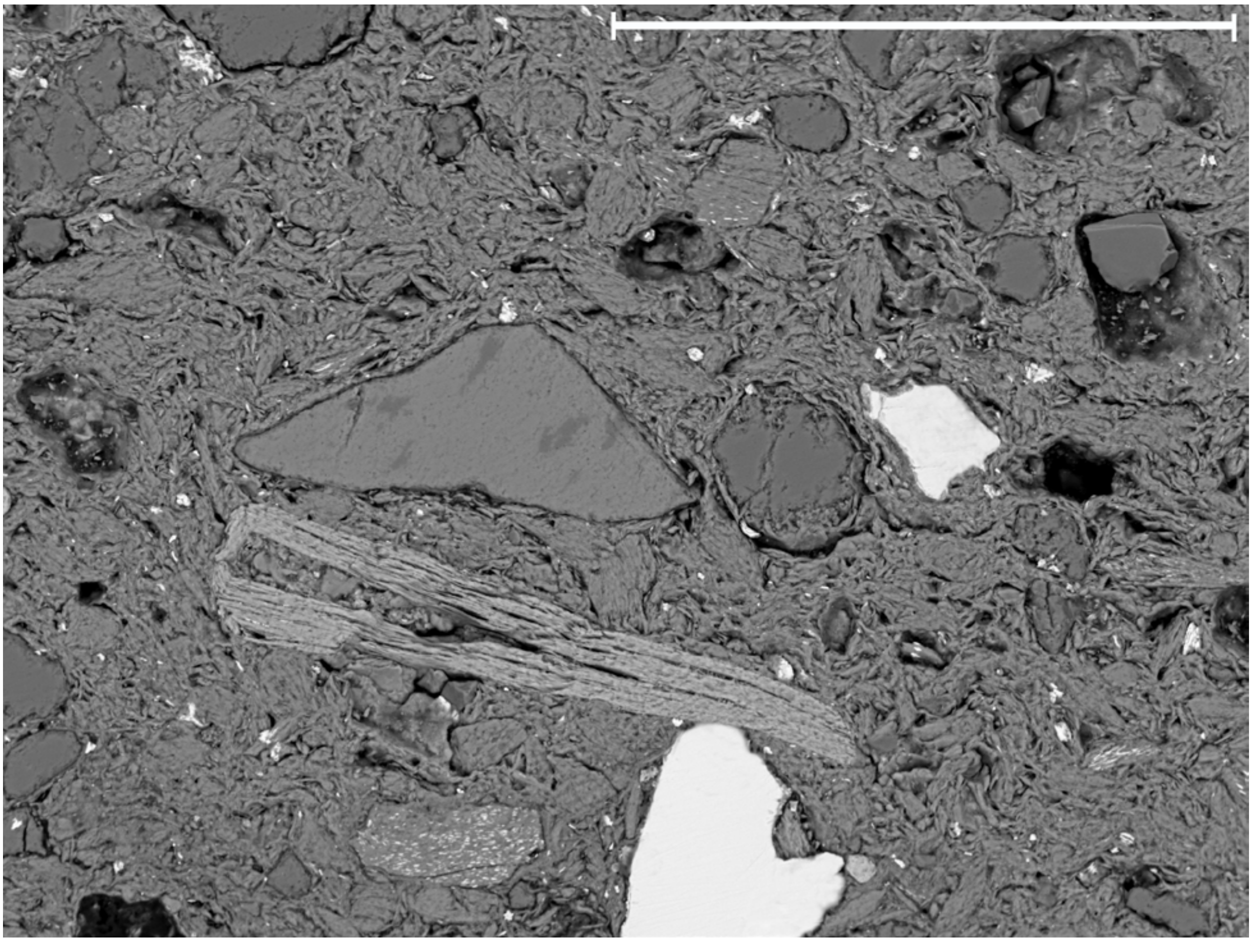

Figure 6.5: SEM-BSE micrograph of sample A007 (scale bar 300μm, the long axes of the image are parallel with the vessel surfaces), showing mineral inclusions of quartz, plagioclase, biotite, and a Fe-rich clay pellet, the bright grains are ilmenite.

This sample is different from the other analysed samples in terms of composition and therefore it cannot be associated with the other compositional groups, nor can suggestions as to its provenance be made. However, its differences compared to the other 'Aqaba samples and particularly those of group 8 (considered to be local to 'Aqaba, see below) do not necessarily mean that this vessel was not produced in 'Aqaba. It does appear to represent, however, very different production, exploiting different raw material sources than those used in the production of the ceramics considered to be local to the 'Aqaba area in this research. Despite some chemical similarity with groups 1 and 3 indicated by the CA, the compositional difference of this sample compared to the other compositional groups is also clear in the PCA. Furthermore, the microfabric of this sherd is different from those two groups, as it includes augite, biotite and plagioclase not found in group 1 and 3 samples. The microfabric of this sherd appears heterogeneous and unsorted, indicating a low level of material processing and no artificial inclusions. The pores are mainly small and elongated and parallel with vessel surfaces suggesting fast-wheel-throwing as its manufacturing technique.

Group 3

Group 3 is dominated by samples from the Jabal Harûn site. This compositional group includes 19 of the 34 Jabal Harûn samples analysed by ED-XRF (Tables 1 and 2 and Appendix V). Additionally, this group contains two sherds found at 'Aqaba and five sherds found at Khirbet edh-Dharih. Group 3 shows considerable similarity (>50 %) with group 1 (Khirbet edh-Dharih 'local' group) in the cluster analysis, and these groups can be considered related to one another, possibly representing subgroups of a larger cluster and ceramic fabrics related by their raw materials.

According to the cluster analysis (see Figure 6.6), the ceramic sherds assigned to compositional group 3 can be further divided into three subgroups, 3a–c. Group 3a includes a basin with combed decoration (JH010), a high-necked jar (JH013), and two jars with thickened rims (JH019, JH020) from Jabal Harûn, and a high-necked jar (DH013) and a jug (DH029) found at Khirbet edh-Dharih, and a closed-form cooking pot (A002) recovered at 'Aqaba. Group 3b contains an open-form cooking pot (JH001), a basin with combed decoration (JH008), a jar with painted decoration (JH016), two jars with grooved exteriors (JH017, JH018), and two jars with leaf-pattern decoration (JH021, JH022) from Jabal Harûn.

Moreover, group 3b includes an open-form cooking pot (DH001) and a basin with combed decoration (DH008) from Khirbet edh-Dharih, and a closed-form cooking pot (A004) found at 'Aqaba. Group 3c consists of two open-form cooking pots (JH002, JH003), a cooking pot lid (JH004), two basins with combed decoration (JH006, JH007), two high-necked jars (JH011, JH012) and a bag-shaped jar (JH023), and a coarse ware bowl with combed decoration (JH032) from Jabal Harûn. In addition, although not analysed by XRF, a closed-form cooking pot (JH005), a strainer jug (JH024) and an amphora sherd recovered at Jabal Harûn (JH025) were tentatively associated with this group on the basis of microstructural and chemical SEM-EDS data.

ED-XRF data show that group 3 in general is characterised by Al_2O_3 values of mainly over 20wt %. The bulk chemical compositions of samples assigned to are quite similar to those of group 1. The group 3 compositions have a slightly lower range of SrO values (76–320ppm) compared to group 1 (110–450ppm), but relatively similar ZrO_2 and BaO concentrations. The main difference between these two main groups is that samples of group 1 have higher CaO contents, the CaO values of group 3 remaining relatively low, at a non-calcareous level (*c.* 0.4–6.3wt %). Additionally, the ZrO_2 concentrations of group 1 are typically slightly lower (*c.* 119–300ppm) than those of group 3 (*c.* 190–320) (see Figure 6.7 for a bivariate plot of the CaO and ZrO_2 concentrations of group 1 and 3 samples). Otherwise the ceramic compositions between these groups show similarity in values.

The variation among the subgroups 3a–b mainly occurs in the values of SrO, which show slightly higher concentrations in group 3c (127–331ppm) compared to groups 3a and 3b (76–211 and 83–158ppm, respectively). In addition, slightly higher values of CaO are represented in group 3c, although they show some variation (1.7–6.3wt %, compared to 0.4–1.9wt % of 3a and 0.5–2.8wt % of 3b). The compositional differences among the subgroups 3a–c as indicated by the cluster analysis are minor and possibly only indicative of variation within a fabric group. The bulk compositional similarity of groups 1 and 3 probably reflects the relatively common geology of these two nearby sites, Khirbet edh-Dharih and Jabal Harûn.

Scanning electron microscopy of group 3 ceramics shows consistent mineralogical inclusions within the group. SEM-EDS was used to analyse 17 samples of this group (JH001, JH003, JH005, JH007, JH008, JH013, JH016, JH019, JH020, JH021, JH022, JH023, JH024, JH025, DH001, DH029 and A002). The ceramic fabrics of most of the samples contain abundant quartz (grain size < 0.8mm), clay pellets, often Fe-rich (< 0.5mm), iron oxides (< 0.1mm) and frequent rutile (~ 15µm) (Figure 6.8). Additionally, occasional ilmenite (20–30µm), apatite (~ 30µm) and rare K-feldspar (0.3mm) and zircon (~ 30µm), and very rare titanite (~ 50µm) occur in some samples (Appendices VI–VII).

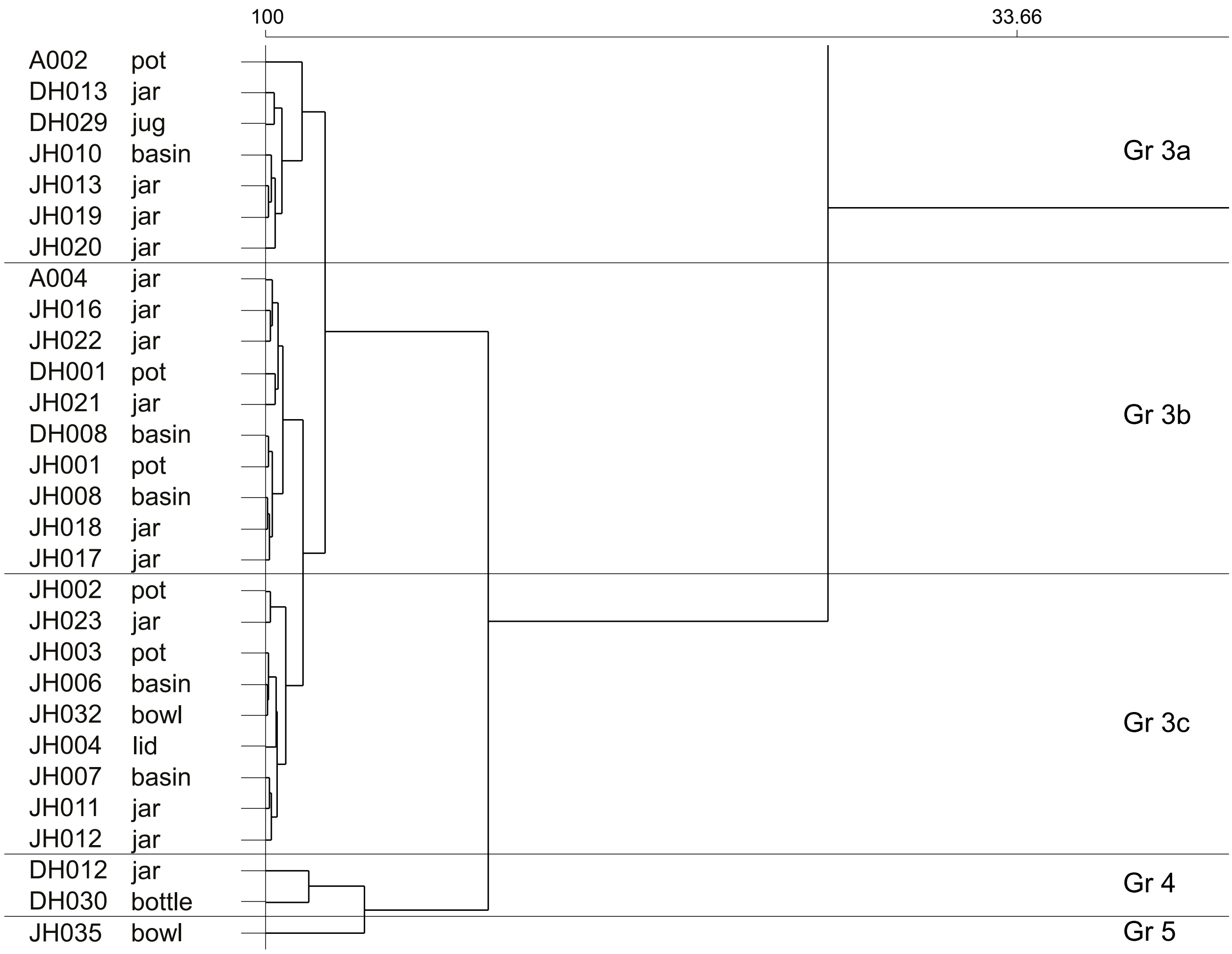

Figure 6.6: Detail of the ED-XRF data cluster analysis dendrogram (see Figure 6.1). showing groups 3a–c, 4 and 5.

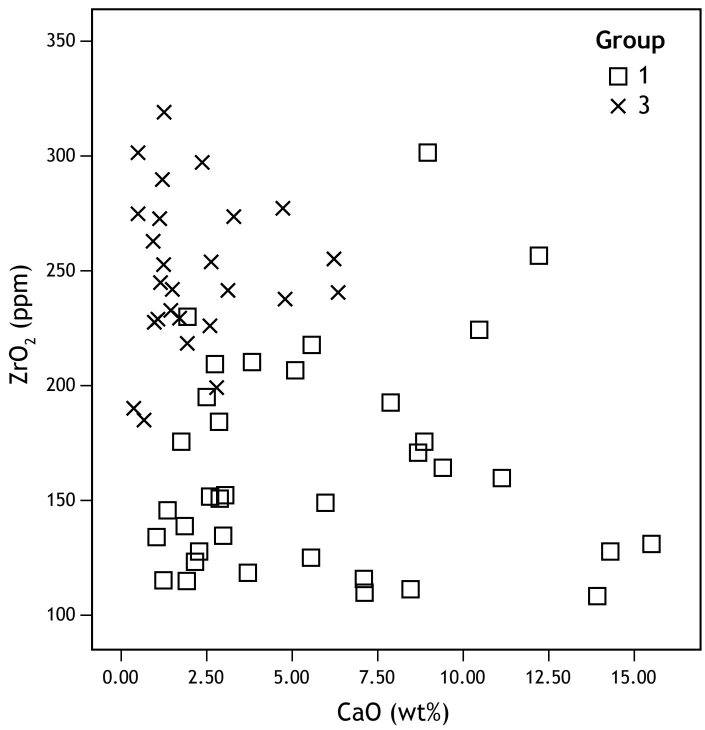

Figure 6.7: Bivariate plot of CaO and ZrO_2 values measured in ED-XRF analysis for cluster analysis main compositional groups 1 and 3.

The fabric examination showed heterogeneous, unsorted and rounded grains indicating natural inclusions. Minor compositional variations, which appear attributed to chronology, larger sized quartz and clay pellets, were detected in samples A002 and JH005 representing earlier phases (Nabataean/Roman periods, see Chapter 5), possibly indicating a change over time in the clay processing. Samples suspected of being hand-made in the macroscopic examination (JH016, JH021 and JH022) showed slightly more irregularly shaped pores compared to the elongated pores in the wheel-made samples, and less parallel orientation of pores and particles. All samples were examined for traces of slip applied on the vessel surfaces, particularly in the case of the painted sherd (JH016), and sherds with light-coloured surfaces (JH006 and JH032), but surface layers were not apparent in the scanning electron microscopy. This suggests that the surface colour of these samples is a result of firing technology, or that the possible slip has a chemical composition very similar to that

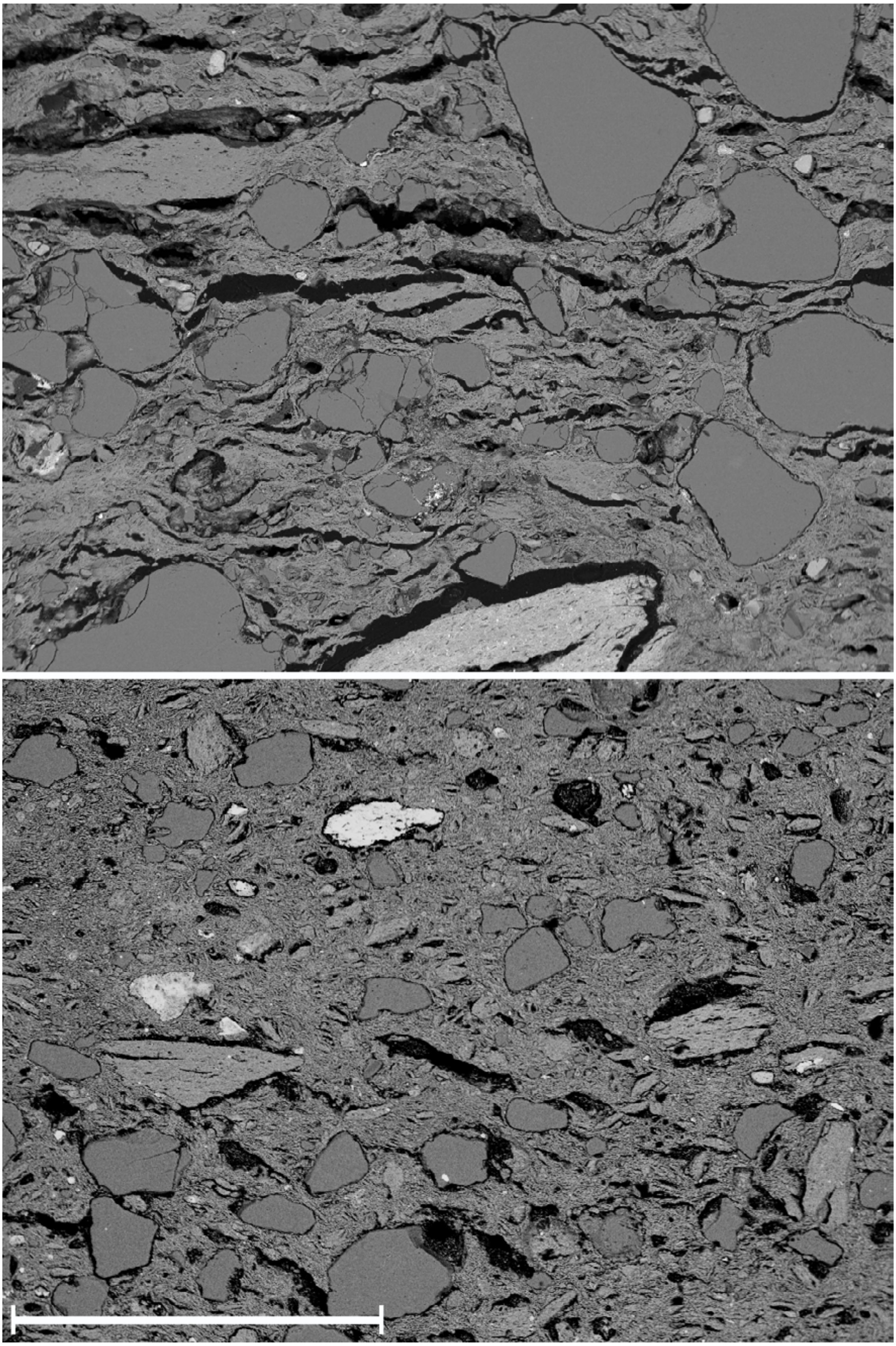

Figure 6.8: SEM-BSE micrographs of group 3 samples (scale bar 1mm, the long axes of the images are parallel with the vessel surfaces), from top: a closed form cooking pot A002, and a leaf-pattern sherd JH022, showing quartz and Fe-rich clay pellets, the bright grains are iron oxides and ilmenite. Wheelmade A002 shows elongated parallel voids, whereas the pores in hand-made JH022 are more irregularly shaped and randomly orientated. A002 also shows larger quartz and clay pellet inclusions.

of the ceramic matrix and thus is not visible in the backscatter image. The topographical secondary electron imaging, however, also failed to reveal any applied surface layers on the analysed sherds.

The microchemical analysis of the ceramic matrices of this group shows typically low CaO content (0.6–6.8wt %) and Al_2O_3 values (*c.* 19.3–23.5wt %; see Table 4 and Appendix VIII). In addition, a strainer jug from Jabal Harûn, JH024, was analysed by SEM-EDS to compare it to a very similar sherd from Khirbet edh-Dharih, DH029, assigned to group 3 according to bulk chemical compositions determined by ED-XRF analysis (see Appendix I for illustrations). The microstructure, mineralogical inclusions, and the chemical composition of the ceramic paste of these sherds show very similar characteristics, indicating that these jugs with very similar morphological characteristics found at the two sites may share a common provenance.

The majority of the analysed Jabal Harûn ceramics cluster in compositional group 3. This group is clearly dominated by the Jabal Harûn samples with only a few examples retrieved from other sites, Khirbet edh-Dharih and ‘Aqaba. Thus, it can be assigned as ‘local’ to the Jabal Harûn or Petra region. On the geological map, the area within a 10km radius of Jabal Harûn shows a mixture of sandstone, limestone and phosphorite areas (Bender *et al.* 1968). In particular, the sandstone areas can explain the mineralogy of the samples of this group, mainly containing quartz and iron-oxide inclusions. There are also areas of volcanic matrix, which can explain the occasional rutite inclusions, and aplitegranite, which can be the source of feldspar, zircon and titanite inclusions.

The compositional similarity of groups 1 and 3 may result from a situation where two or more production centres are using the same raw material sources, but the variation between the groups is due to different manufacture, possibly at different workshops. The possibility that the Jabal Harûn and Khirbet edh-Dharih ceramics are products of the same workshop and the variation is mainly caused by different post-depositional conditions at the two sites seems improbable as elements likely to be affected by burial conditions were not included in the statistical analysis. The Jabal Harûn samples that cluster in group 1, ‘local’ to Khirbet edh-Dharih, and similarly the Khirbet edh-Dharih samples assigned to group 3, ‘local’ to the Jabal Harûn or the Petra region, may be explained by material exchange between the sites located *c.* 80km apart. For example, the exchange may have happened via transportation of agricultural products in ceramic containers between the two locations (see discussion in Chapters 7 and 8).

Group 4

Compositional Group 4 consists of two Khirbet edh-Dharih samples (see Figure 6.6). These samples are a high-necked jar (DH012) and a bottle (DH030). The bulk chemical compositions of these sherds show a relatively low MgO (<1.2wt %) and CaO (0.6–3.5wt %) content, high TiO_2 concentration of 1.2–1.4wt % and high ZrO_2 values of *c.* 500ppm (Tables 1 and 2 and Appendix V). According to the SEM-EDS analysis, the mineralogical composition of sample DH030 includes abundant quartz (< 0.4mm), clay pellets (< 1mm), and occasional rutile (~ 20µm) and zircon (~ 20µm) (see Figure 6.9, Table 3, Appendices VI–VII). This sample has a non-calcareous ceramic matrix (CaO 4.9wt %) with Al_2O_3 content of 18wt % and relatively low FeO concentration (3.9wt %) (Table 4 and Appendix VIII). The rounded, unsorted particles in the fabric indicate that the minerals and the clay pellets are natural inclusions (for comparison; see grog under SEM in Holmqvist *et al.* 2018: 83, Fig. 5). Both of these samples appear wheel-made. This compositional group shows relative similarity to groups 1 and 3, but due to slight compositional differences, the samples cannot be directly associated with either group. In addition, compared to groups 1 and 3, the ceramic fabric of these samples seems finer, with fewer and smaller inclusions.

Group 5

A green-glazed sherd from a bowl found at Jabal Harûn (JH035) forms compositional group 5 (see Figure 6.6). Although it shows a relative similarity to group 3 in the cluster analysis, its microanalysis, in terms of mineral inclusions and the chemical composition of the ceramic matrix, differentiate it from the other analysed samples. The ED-XRF bulk chemical compositional results, after removal of the glaze showed low MgO at 0.8wt % and CaO at 0.5wt %, and a high Al_2O_3 content of 31.2wt %. High levels of CuO at 114ppm and PbO at 1172ppm are results of the glaze enriching the ceramic fabric of the vessel (Tables 1 and 2 and Appendix V). The SEM-EDS data show mineralogical composition of frequent quartz (grain size <0.3mm), augite (< 0.2mm), clay pellets (some of which are Ba and Mn-rich, size < 0.4mm), ilmenite (< 80µm), iron oxides (<50µm) and plagioclase feldspar (< 0.15mm), and very rare sandstone (< 0.2mm) and zircon (~ 50µm) (Figure 6.10, Table 3 and Appendices VI–VII).

The microchemical analysis of the ceramic matrix of the sherd reveals low MgO (0.8wt %), CaO (1.2wt %) and FeO (4.7wt %) content and high Al_2O_3 concentration (26.7wt %) (for mean values of matrix analysis of each sample, see Table 4, see also Appendix VIII for more details of matrix analysis of each sample). Microchemical analysis of the glaze coating of the sherd showed a *c.* 250µm thick copper-coloured lead silica glaze with high PbO content (SiO_2 26.8, CaO 0.7, FeO 0.8, PbO 68.5, Al_2O_3 2.8, CuO 1.8wt %). The fabric analysis reveals heterogeneous

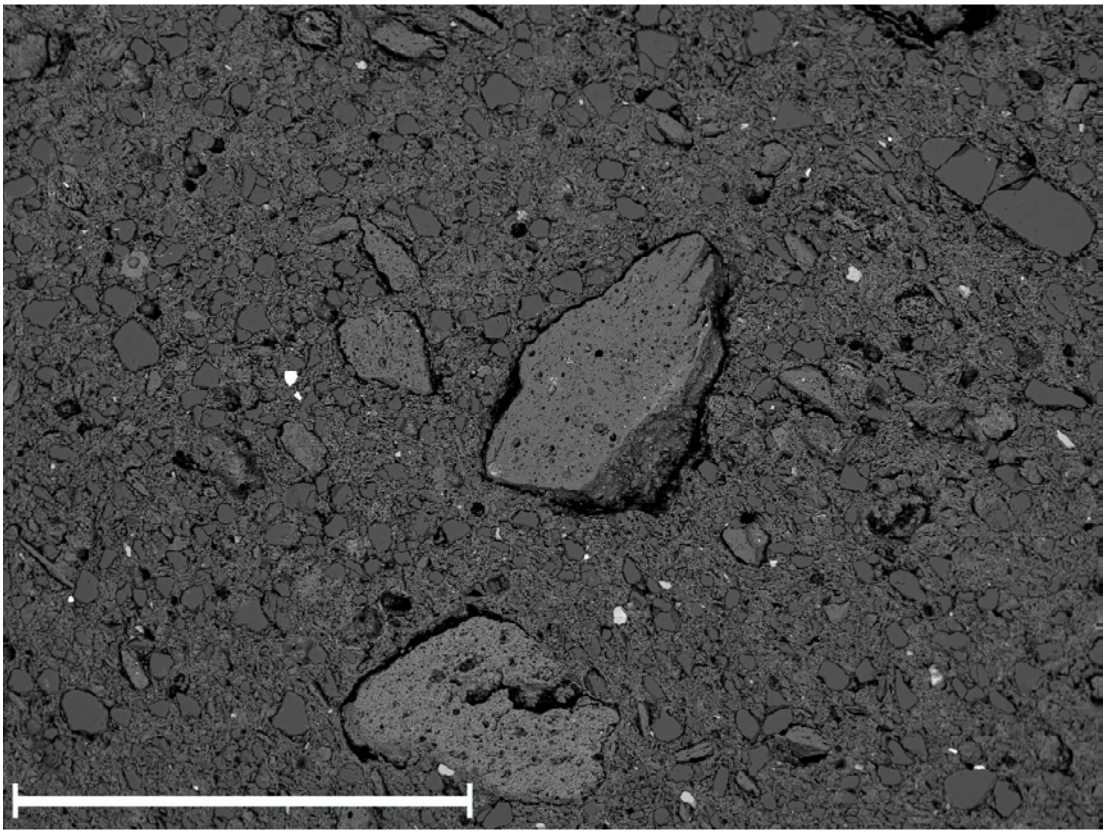

Figure 6.9: SEM-BSE micrograph of group 4 sample DH030 (scale bar 1mm, the long axes of the image are parallel with the vessel surfaces) showing clay pellets and quartz, the bright inclusions are zircon and rutile.

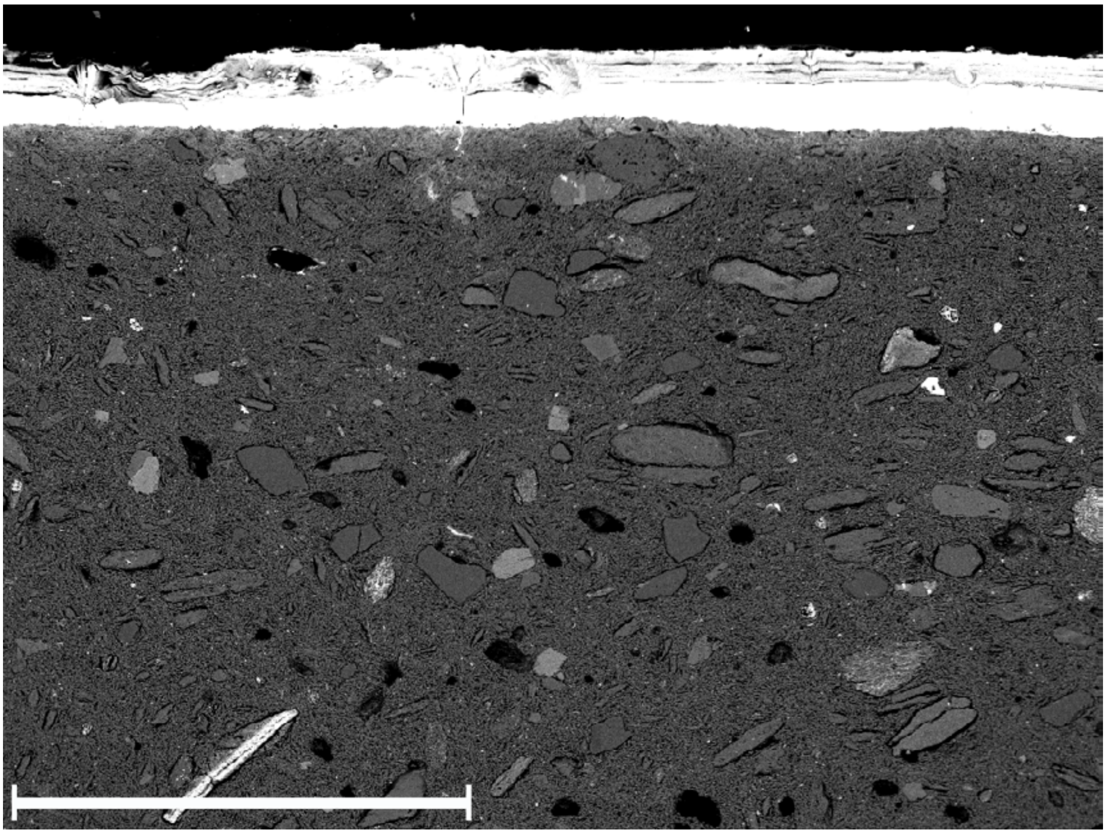

Figure 6.10: SEM-BSE micrograph of group 5 sample JH035 (scale bar 1mm, the long axes of the image are parallel with the vessel surfaces) showing poorly sorted fabric with quartz, clay pellets (Fe, Mn and Ba-rich), augite, and iron oxides and rounded pores, and a Cu-coloured lead-silica glaze (top).

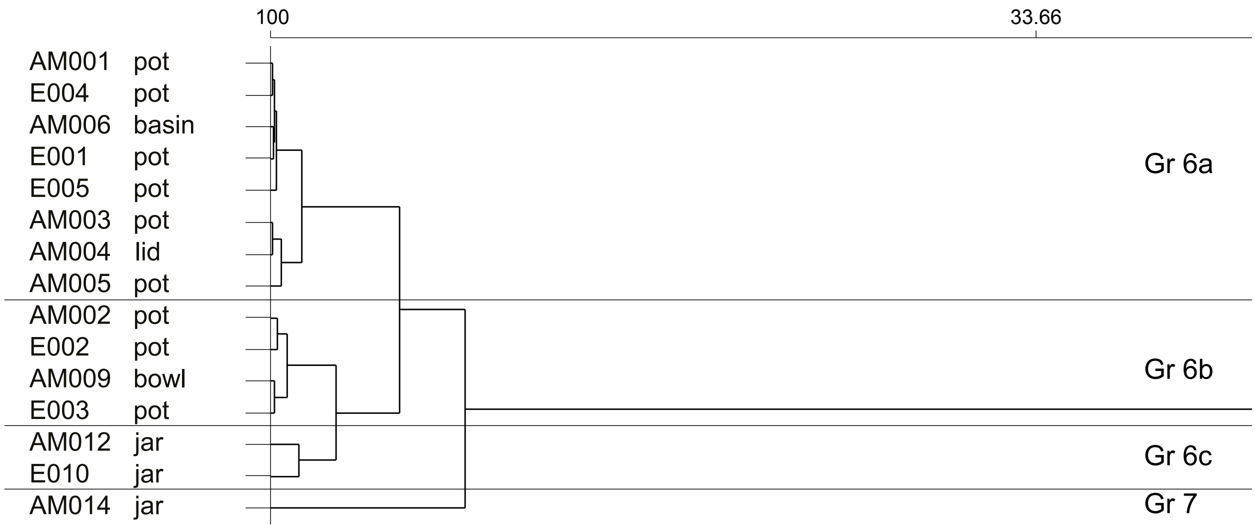

Figure 6.11: Detail of the ED-XRF data cluster analysis dendrogram (see Figure 6.1) showing groups 6a–c and 7.

and poorly sorted inclusions and roundish pores, suggesting natural inclusions and a hand-made manufacturing technique.

Group 6 (a–c)

This compositional group is composed solely of samples from the Negev sites. It can be divided into subgroups 6a–c according to minor variation within the group (Figure 6.11, Tables 1, 2 and Appendix V). Altogether, eight Abu Matar samples of the 19 analysed by ED-XRF are associated with this group in the cluster analysis, together with six of the 20 Elusa samples for which bulk chemical compositions were obtained. The ceramics belonging to group 6 show clear morphological consistency, the majority of them being cooking vessels. In subgroup 6a, there are three open-form cooking pots (AM001, AM003, AM005), one cooking pot lid (AM004) and a basin (AM006) found at Abu Matar in Beersheva, and one open-form cooking pot (E001) and two closed-form cooking pots (E004, E005) found at Elusa. In subgroup 6b, there is one open-form cooking pot (AM002) and a coarse ware bowl (AM009) found at Abu Matar, and two open-form cooking pots (E002, E003) found at Elusa. In subgroup 6c, however, there is one jar with combed decoration (AM012) found at Abu Matar, and one jar with painted decoration (E010) from Elusa.

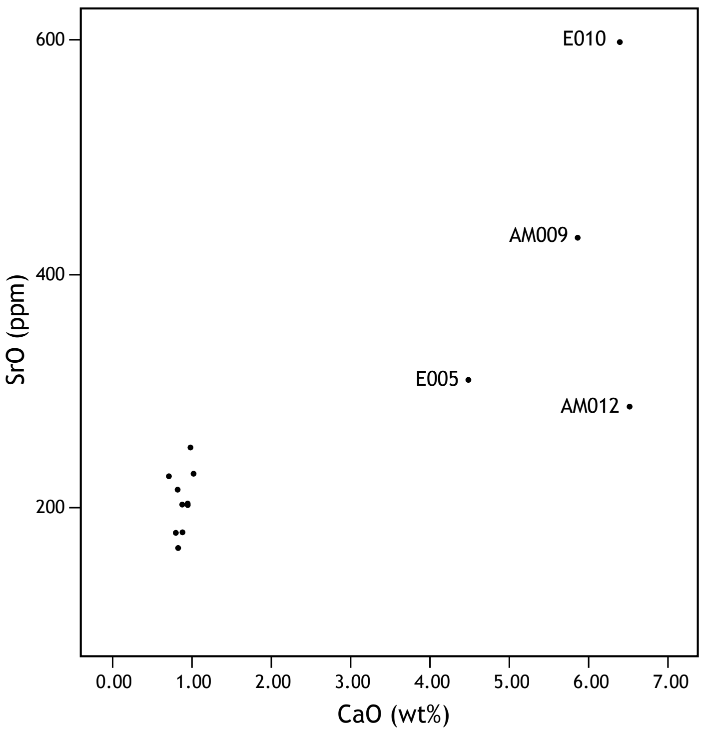

Figure 6.12: Bivariate plot of CaO and SrO concentrations of group 6 samples in the ED-XRF analysis.

The compositional group is characterised by low MgO (1.2–2.9wt %), Al_2O_3 (<20wt %), and low CaO and relatively high BaO content with some variation (0.7–6.5wt % and *c.* 330–800ppm, respectively) (see bivariate plot of CaO and SrO values measured in the ED-XRF analysis in Figure 6.12). There is only minor variation in the compositions of the samples belonging to group 6, mainly the CaO contents in group 6a are lower, consistently below 1wt %, whereas in group 6b, they vary up to 5.9wt %, and to 6.5wt % in group 6c. Particularly the cooking pots in this group share a homogeneous compositional pattern characterised with low CaO values (Figure 6.12), excluding one pot, sample E005, whereas other forms show slightly higher CaO values. In addition, the Al_2O_3 content ranges between *c.* 16–18wt % in groups 6a and 6c, but remains below 16wt % in group 6b. The differences might be due to slight differences in material processing in the production of different forms, particularly cooking pots compared to other forms, or chronological differences between the samples (see discussion in next chapter).

SEM-EDS analysis, conducted on five group 6 samples (AM001, AM006, E001, E005, E010) in order to examine their mineralogical compositions, shows abundant quartz (particle size < 0.7mm), occasional ilmenite (< 60µm) and K-feldspars (< 70µm) in all of the samples (see Table 3 and Appendices VI–VII). Clay pellets (< 50µm), some of which are Mn-rich, zircon (< 0.1mm) and garnet-group minerals (< 50µm) are present in some of them. In addition, some samples contain rare apatite (< 0.2mm), augite (< 0.2mm), chromite (~ 30µm), iron oxides (~ 20µm), manganese hydroxides (~ 0.3mm), rutile (< 30µm), titanite (< 0.2mm) and titanomagnetite (~ 20µm). Sample E010 also contains very rare barite (< 0.2mm) and basalt fragments (< 20µm) (Figure 6.13). Chemical analysis of the ceramic matrices (see Table 4 and Appendix VIII) shows generally low CaO concentrations (*c.* 1.1–1.6wt %, except sample E010 with CaO of *c.* 8.2wt %), and Al_2O_3 concentration of 17.2–18.7wt % (again, E010 shows slightly different concentration at 13wt %) and relatively high FeO (9.7–11wt %). The particles in the fabric analysis are of roundish shape indicating a natural origin. All of the sherds also show elongated voids, parallel with the vessel surfaces, resulting from wheel-throwing.

The SEM-EDS data, the mineralogy and chemical composition of the ceramic matrices, show similar patterns, although some variation occurs. In terms of the possible shared origin of the cooking pots found at Elusa and Abu Matar, it is noteworthy that samples AM001, AM006, E001 and E005 show Mn-rich inclusions, which can be considered as geologically distinctive features, thus adding to the information suggesting that the vessels were produced from the same raw materials.

The cluster analysis shows minor variation according to which group 6 can be divided into subgroups, but the similarity among these subgroups suggests that this is merely variation in production using the same raw materials. Subgroup 6c, comprised of two jars rather than cooking vessels, is most clearly divided from the other subgroups of group 6. This is likely to be the result of a more standardised production within a form category, in other words, the cooking vessels are more similar to each other than jars produced from the same raw materials. This compositional group has different characteristics compared to the group with the Elusa wasters (group 10, see below). Although this does not implicitly mean that the cooking pots were not produced in Elusa, it may indicate that the Elusa workshop specialised in the production of certain forms, such as specific jar types, whereas these cooking pots were possibly produced in another workshop. The location of the cooking pot production cannot be ascertained at this point. Furthermore, it is possible that the difference between groups 6 and 10, at least with the regard to Elusa wasters in group 10, is also a chronological one (see discussion in Chapters 7 and 8).

The geologies of the areas of the two sites, Abu Matar and Elusa, do not show great difference in the geological map (see Sneh *et al.* 1998), both containing mainly sedimentary units, such as limestone and chalk. The main geological difference between the areas appears to be that there are more igneous units in the area within a 10km radius from Abu Matar, compared to the area surrounding Elusa. Considering the mineralogical inclusions of the samples of group 6, there are titanite, titanomagnetite, chromite and augite inclusions, which relate to a basic, possibly basaltic igneous geology, although this alone cannot be used to conclusively argue for the Abu Matar/Beersheva origin of the ceramics. The other inclusions, such as K-feldspars and zircon, represent a more developed igneous geology, such as granite or similar rocks. The manganese-rich materials present in the samples are typically a secondary, sedimentary geological feature that cannot be located on the basis of geological maps. However, northern Sinai is home to a major manganese deposit, and it is not inconceivable that some of this manganese enriched geology is visible here.

Group 7

Compositional group 7 contains only one sample, a painted sherd (AM014) from Abu Matar in Beersheva (see Figure 6.11, Tables 1 and 2 and Appendix V). The chemical composition of this sample shows a calcareous clay (CaO 6.6wt %) with high Al_2O_3 value of 28.6wt %, and relatively high Fe_2O_3 (8.9wt %), ZnO over 200ppm, SrO *c.* 470ppm, and ZrO_2 and BaO values of *c.* 300ppm. SEM-EDS analysis shows a mineralogical composition of frequent quartz (particle size < 0.5mm), clay pellets (< 0.5mm), iron oxides (< 0.6mm) and ilmenite (< 20µm), and rare K-feldspar (< 50µm), rutile (< 20µm) and zircon (< 20µm) (Figure 6.14, Table 3 and Appendices VI–VII). The chemical composition of the ceramic matrix shows high Al_2O_3 (25.5wt %) and FeO (8.5wt %) values and CaO content of *c.* 7wt % (Table 4 and Appendix VIII). The fabric analysis shows irregularly orientated grains and rounded pores, suggesting that this vessel is hand-made. No indications of artificial inclusions were found, and no compositional or topographical variation on the surfaces was visible in the backscatter or secondary electron images, suggesting either no slip application or a very thin slip layer of a chemical composition similar to that of the ceramic matrix.

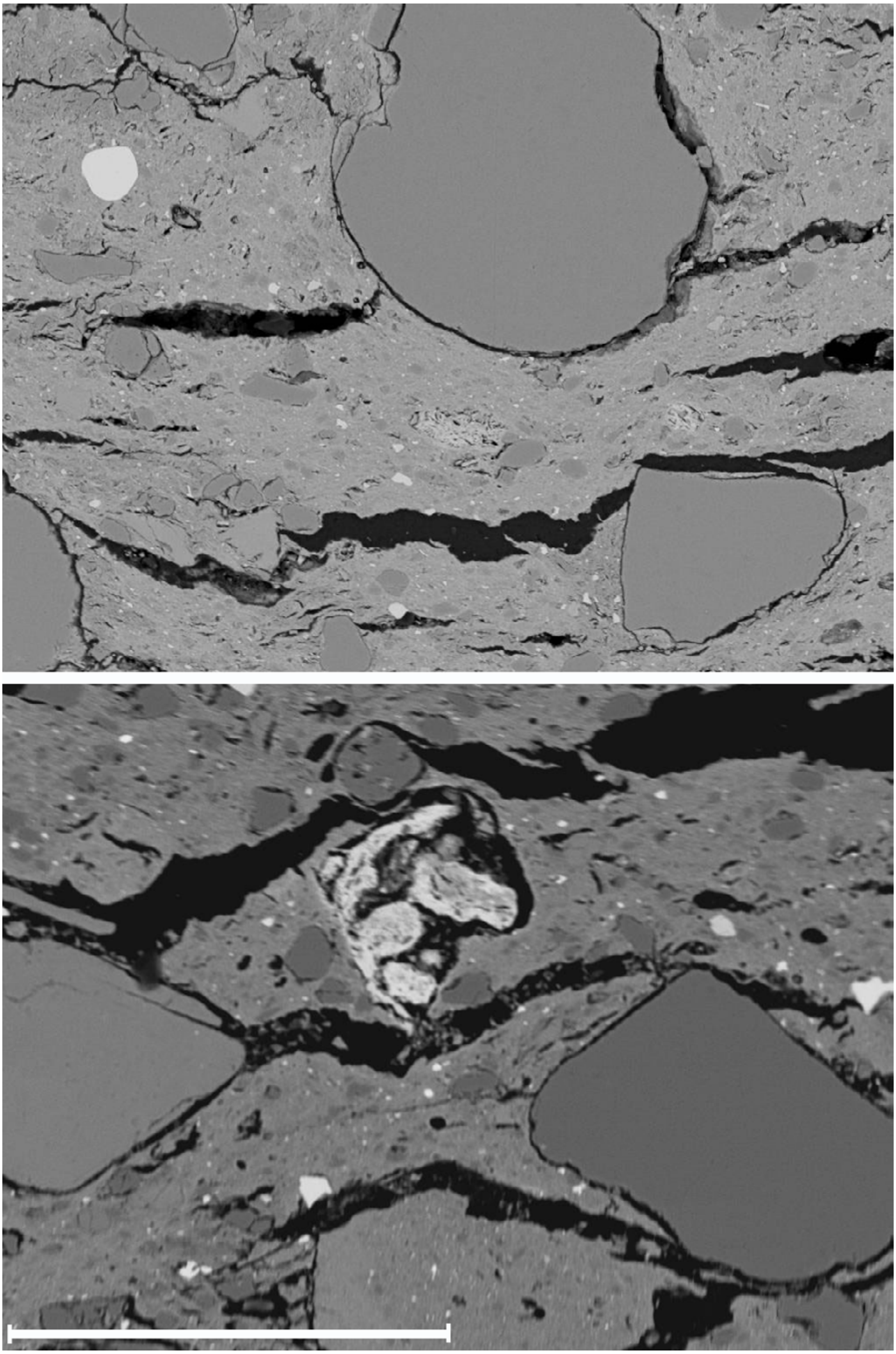

Figure 6.13: SEM-BSE micrographs of group 6 (scale bar 300μm, the long axes of the images are parallel with the vessel surfaces) samples, from top: AM001, and E005, showing rounded quartz, clay pellets, and K-feldspars (AM001), the bright grains are zircon and Mn-rich clay pellets. Both cooking pots also show elongated parallel voids due to wheel-throwing.

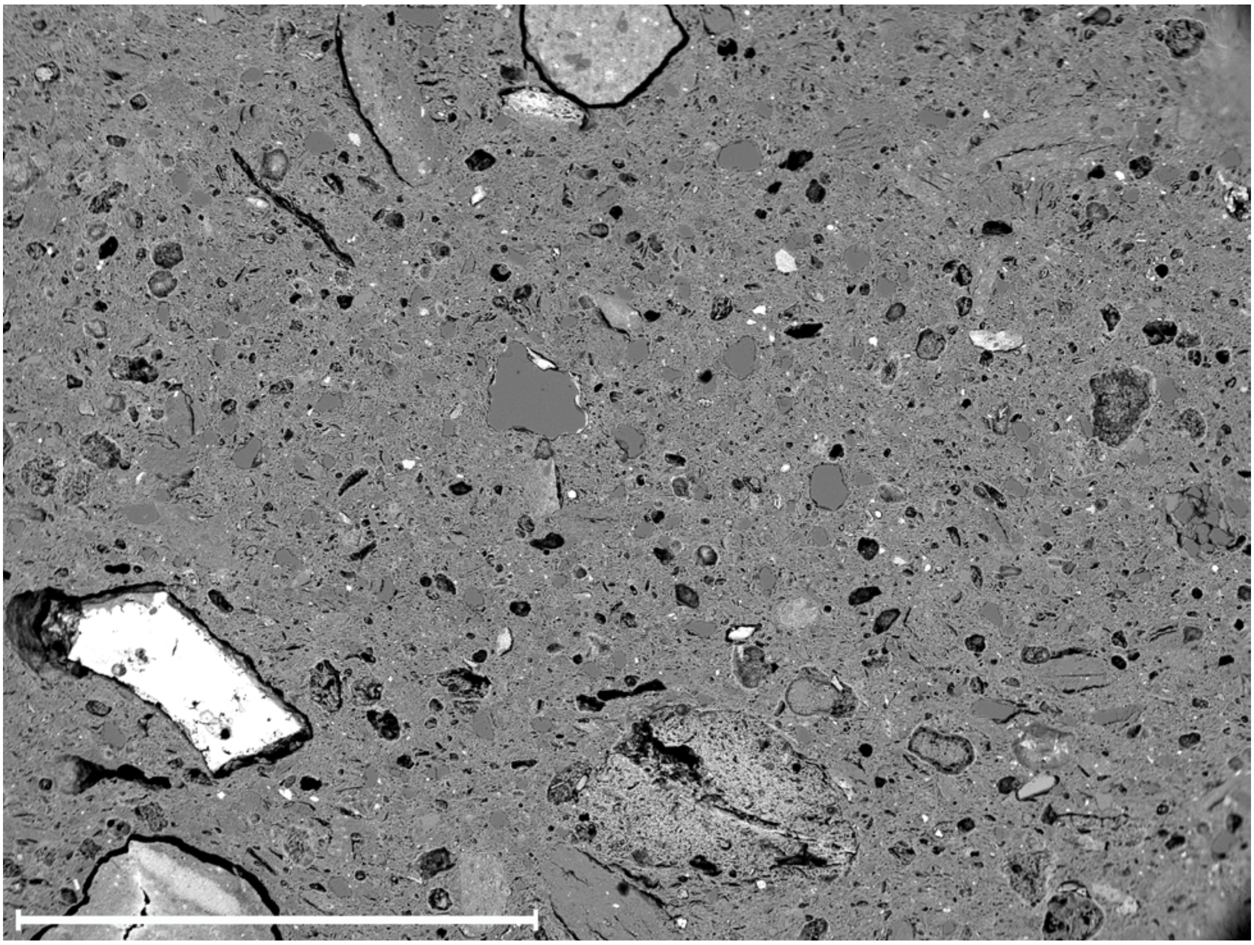

Figure 6.14: SEM-BSE micrograph of group 7 (scale bar 1mm, the horizontal axes of the image are parallel with the vessel surfaces) sample AM014 showing quartz and clay pellets and rounded pores, the bright particles are Fe-rich clay pellets, iron oxides and ilmenite.

Sample AM014 shows a relative similarity with group 6 in the cluster analysis, but is different from this group in the different mineralogy and chemical composition. In the bulk chemical composition of this sherd, NiO, Ga_2O_3, Nb_2O_5, and PbO concentrations fall outside the range of group 6. Furthermore, SEM-EDS also confirms that the TiO_2 concentration in the ceramic matrix is higher than in any of the group 6 samples, and the ceramic fabric appears finer compared to group 6 samples. As this sherd shows dissimilarity with the other samples analysed from Abu Matar, it was likely imported to the site.

Group 8 (a–f)

Compositional group 8, as indicated by the cluster analysis, is dominated by samples from ʻAqaba. This group includes 15 of the 20 ʻAqaba samples for which ED-XRF bulk chemical data were obtained. Moreover, seven samples from Jabal Harûn, seven from Khirbet edh-Dharih, and two Elusa samples cluster in this group. The samples belonging to this group can be assigned to subgroups (8a–f, see Figure 6.15) according to minor variation in the ED-XRF compositional data (given in Tables 1 and 2 and Appendix V). Discrimination among some of the subgroups is strengthened by microanalytical data.

The samples of subgroup 8a include: a closed-form cooking pot (A003), two coarse ware bowls (A008, A009, dated to Nabataean/early Roman and late Roman periods, respectively), a jar (A010, suggested date late Roman), a ʻgarum container' jar (A011, of late 1st–2nd century date), a jar (A012, suggested date early Byzantine), an amphora (A017, a typical Aila amphora type from a 5th century context) from ʻAqaba, an amphora sherd (JH026) from Jabal Harûn, and a painted sherd (DH019) found at Khirbet edh-Dharih. In addition, a painted jar (JH015) is relatively similar to group 8a but shows significant differences, and is therefore assigned to subgroup 8b (see below). According to the cluster analysis, subgroup 8c consists of different vessel forms, including an open-form cooking vessel (A006, suggested date early Roman/ Nabataean), a jar (A013, early Roman/Nabataean), and a pithos handle (A015, of late Roman–early Byzantine date) found at ʻAqaba, and one of the roof tiles (JH038) from Jabal Harûn. A jar (E013, a possible LR 1 jar) from Elusa, assigned to subgroup 8d, shows some similarity with the other subgroups of group 8, but it can also be singled out (see below).

The composition of an open-form cooking pot (A005, suggested date late Roman) of subgroup 8e is closely related to the samples belonging to subgroup 8f. This cooking pot, however, is slightly different compared to the compositionally very consistent subgroup 8f, which includes solely ceramic containers. Samples assigned to subgroup 8f as indicted by the cluster analysis of the ED-XRF bulk compositional data include: jars (A014, A016, A019; first two dated early Byzantine, the latter early Roman/Nabataean), and an amphora (A020, early Islamic, 7th century context) from ʻAqaba. In addition, six amphora sherds with grooved exteriors (DH031, DH032, DH034, DH037, DH038) found at Khirbet edh-Dharih, four similar amphora sherds (JH027, JH028, JH031, JH037) from Jabal Harûn and one amphora sherd (E014) from Elusa cluster in this group.

Out of subgroups 8a–f, 8a, 8c and 8f are the largest and archaeologically most significant, and their compositional characterisation will be addressed first (subgroups 8b, 8d and 8e will be discussed separately below). In general, these groups have a calcareous composition, CaO values varying between 8.8–16.2wt %, Al_2O_3 values typically under 20wt % and ZrO_2 content *c.* 125–240ppm. In addition, SrO content is commonly *c.* 500–600ppm in these subgroups but also varies. BaO concentration shows variation between groups, ranging between *c.* 350–510 in group 8a, *c.* 180–460ppm in 8c, and *c.* 410–1020ppm in 8f.

One of the samples assigned to subgroup 8a, the painted jar sherd found at Khirbet edh-Dharih, DH019, has an As_2O_3 concentration of *c.* 700ppm, which makes its membership in this group questionable, since this trace oxide was not detected in other samples (As_2O_3 was not included in the statistical analysis). It appears that the composition of this sherd does not share characteristics with group 1, suggested here to be local to the Khirbet edh-Dharih area; thus, this sherd is likely to be an import to Khirbet edh-Dharih, but the source remains unresolved at the moment. In addition, the tile found at Jabal Harûn (JH038) clustering with group 8c shows compositional differences compared to the other group 8c members, mainly lower ZnO and SrO and higher ZrO_2

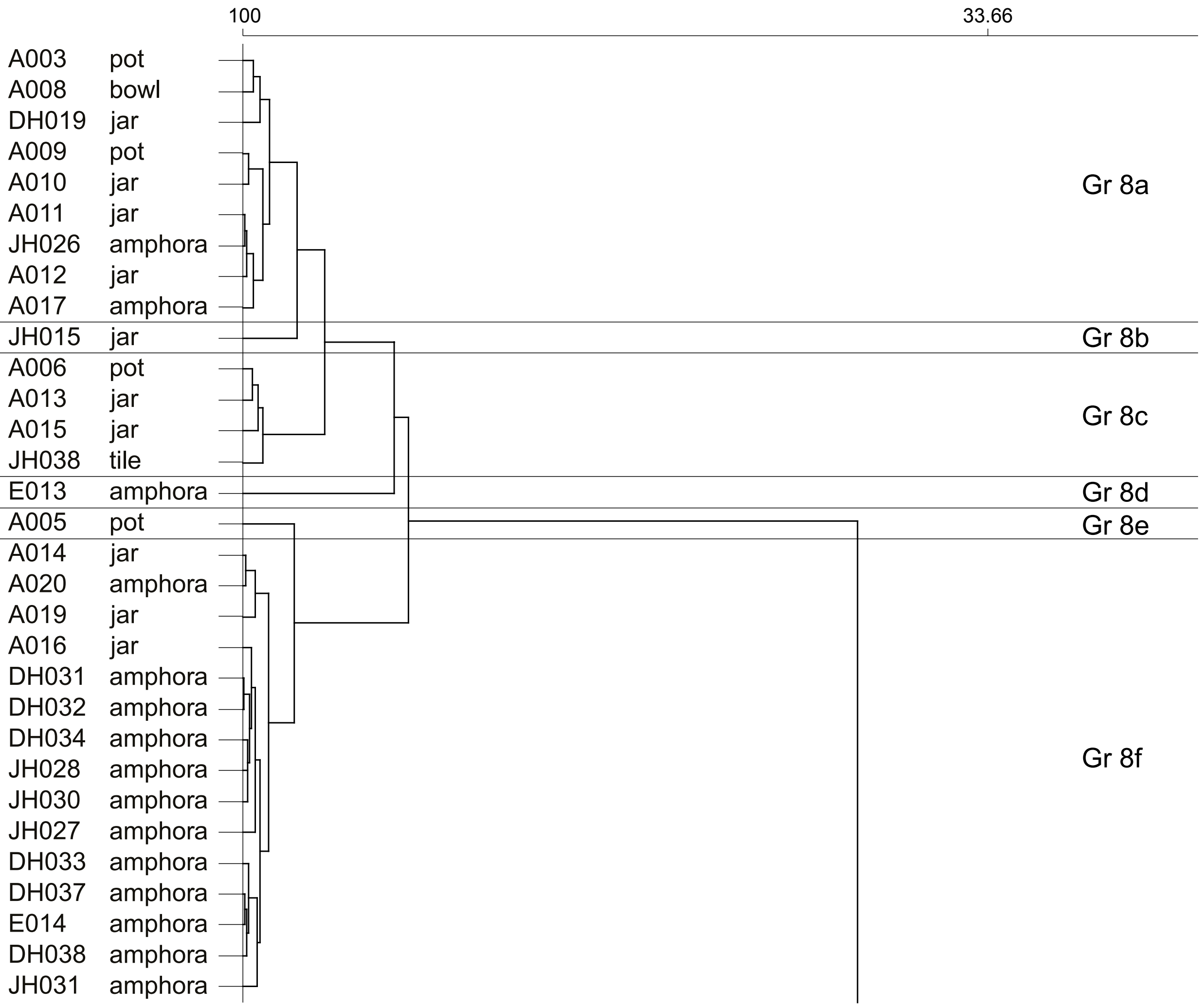

Figure 6.15: Detail of the ED-XRF data cluster analysis dendrogram (see Figure 6.1) showing groups 8a–f.

values, which, regardless of its apparent similarity to the group 8c (high CaO and MgO concentrations), make it likely to be an erroneous statistical ascription, rather than an actual member of this group. It is noteworthy that this tile does not belong to group 3, 'local' to Jabal Harûn or the Petra area, or group 1, which includes the other tiles analysed from Jabal Harûn.

Subgroups 8a, 8c and 8f are dominated by 'Aqaba ceramics. Out of the 28 samples belonging to these groups, 14 were recovered at 'Aqaba, six at Jabal Harûn, seven at Khirbet edh-Dharih and one at Elusa. The dominance of the 'Aqaba samples, and the fact that the majority of the 'Aqaba samples, 14 out of the 20 analysed by ED-XRF, are assigned to these subgroups, including also the 'Aqaba/Aila amphora sherds, known to have been produced locally at 'Aqaba (Melkawi *et al.* 1994), provide evidence that at least subgroups 8a, 8c and 8f are local to 'Aqaba. This internal coherence is supported by the SEM-EDS data.

SEM-EDS analysis was conducted on six samples (JH028, A008, A018, A020, DH032 and E014; E013 is discussed separately, see Tables 3, 4 and Appendices VI–VIII) assigned to this compositional group on the basis of the cluster analysis of the ED-XRF data. The mineralogical composition of the ceramics appears consistent in the SEM-EDS analysis, the fabrics being characterised by abundant quartz (particle size < 0.8mm), frequent plagioclase (< 1mm) and K-feldspars (< 0.6mm), biotite (< 0.4mm), ilmenite (< 0.2mm), iron oxides (< 0.1mm) and occasional augite (< 0.1mm) present in most samples. Furthermore, rare rutile (< 20μm), titanite (< 0.2mm), titanomagnetite (< 50μm), apatite (< 0.3mm), clay pellets (< 0.4mm), some being Mg-rich, garnet-group minerals (< 30μm), magnetite and zircon (< 80μm) are present in some samples (Figure 6.16). The ceramic matrices are very calcareous (CaO 16.4–20.5wt %), with relatively low Al_2O_3 concentration (11.9–15.6wt %), MgO content being *c.* 2.9–4.3wt %, and an FeO content of *c.* 5.8–8.3wt %. Furthermore, the fabrics of the amphorae appear relatively porous with no indication of artificial inclusions. The vessels also appear to have been fired at a relatively low temperature, and the roundish pores are not vitrification voids but rather empty spaces left by mineral grains that fell off the section during sample preparation, as typical of low-fired ceramics.

On the geological map, the region within a 10km radius from 'Aqaba includes geological features from both sides of the Wadi 'Arabah, the Negev side including sedimentary units as well as more volcanic and metamorphic areas with granite and gneiss areas, compared to the southern Transjordan side characterised predominantly by granite, gneiss and amphibolite (Bender *et al.* 1968). The mineralogical inclusions of the group 8 samples include plagioclase, biotite and garnet-group minerals, which can relate to the gneiss and granite areas, whereas augite and titanomagnetite are more likely to relate to the basaltic areas. All in all, the nature of the mineralogical inclusions appears to show a tendency towards the western side of 'Aqaba, although the location of the raw material sources cannot be deduced on the basis of the geological map.

Furthermore, the individual samples of the subgroups 8b (red-painted jar JH015) and 8d (suggested LR 1 jar E013) and 8e (cooking pot A005) show compositional and mineralogical variation that separates them from the main group 8 members.

The CaO content (12.4wt %) of compositional group 8b, formed by a single sherd (JH015), is consistent with the other samples of group 8, but it has a slightly higher concentration of ZnO (170ppm) and ZrO_2 (*c.* 270ppm), and slightly lower values of SrO (*c.* 350ppm) and BaO (215ppm) compared to the group 8 samples. Accordingly, compositional group 8b, represented by the red-painted jar JH015 found at Jabal Harûn, typologically distinct compared to the group 8 samples, should not be considered as a subgroup of group 8, but is more likely to be a different fabric group associated with this group by the cluster analysis on the basis of shared compositional patterns. In any case, this sherd does not show compositional resemblance with group 3, suggested to be local to the Jabal Harûn area, and therefore it seems to be an import of currently unknown origin transported to Jabal Harûn.

Another single-sample group, 8d (a possible LR 1 jar recovered at Elusa), contains compositional characteristics on the basis of which its association with group 8 can be questioned. The chemical composition of this sample displays an Al_2O_3 value (*c.* 13wt %) lower than average in group 8, and a high CaO concentration of nearly 23wt %, not represented by the other samples of group 8. The ZnO, ZrO_2 and BaO values are relatively consistent with the concentrations of the other group 8 samples, although the latter two appear slightly low, at *c.* 120 and 300ppm, respectively. On the other hand, NiO and SrO appear slightly higher than the group averages, at *c.* 235 and 880ppm, respectively. According to a detailed examination of the compositional patterns, and apparent differences occurring in the major, minor and trace elemental concentrations, it thus seems that group 8d cannot be associated with group 8 with certainty. This conclusion is also supported by the typological assignment of the sample, E013, as an imported LR 1 type jar, possibly produced in Cyprus or Antioch, and therefore unlikely to be local to 'Aqaba or Elusa. The mineralogy of the LR 1 jar (E013) does not include either type of feldspar present in the other samples examined in this group, but instead it includes

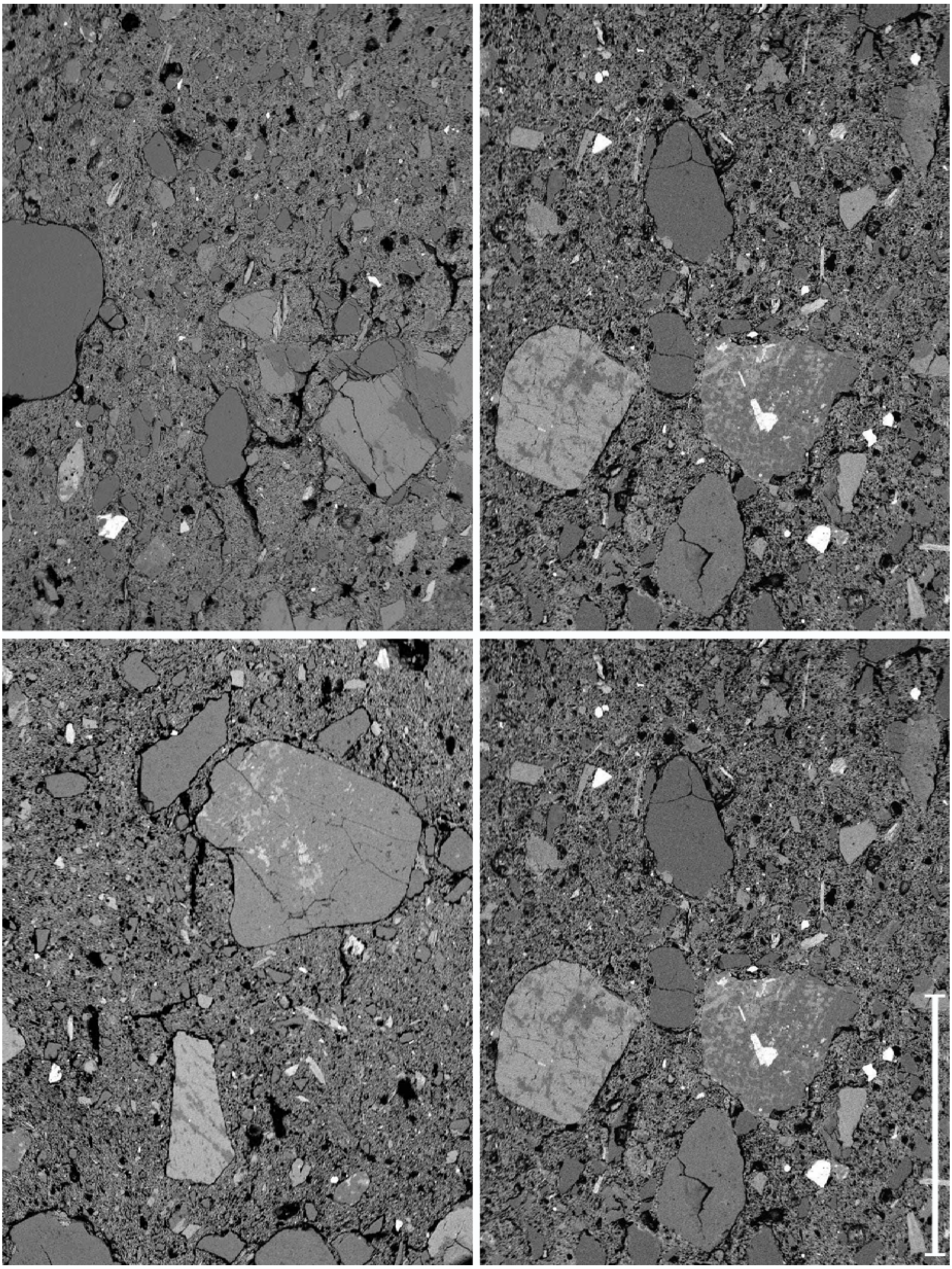

Figure 6.16: SEM-BSE micrographs of group 8 samples (scale bar 1mm, the long axes of the images are parallel with the vessel surfaces), representing the 'Aqaba amphorae, from top left A020, top right DH032, below left JH028 and below right E014, showing quartz, plagioclase, K-feldspars and biotite. The bright inclusions are ilmenite and iron oxides.

frequent calcite (< 0.5mm) and rare chromite (< 0.1mm), not found in the other samples of group 8.

Finally, subgroup 8e (a late Roman cooking pot A005 found at ‘Aqaba) shows some differences in trace elemental patterns but comparable major and minor element concentrations compared to the rest of the group 8 samples (particularly 8a, 8c and 8f). The main differences occur in the concentrations of ZnO (slightly lower than group average at 91ppm) and Rb_2O (slightly higher at 117ppm). However, despite the minor variation in trace element concentrations, the small differences are not significant enough to disassociate this sample from group 8, suggested here to represent ceramics produced locally at ‘Aqaba.

Group 9

Samples belonging to compositional group 9, as indicated by the cluster analysis of the ED-XRF data (Figure 6.17, Tables 1 and 2 and Appendix V), include three sherds found at Abu Matar: a coarse ware bowl (AM007), a jar (AM016) and a cream ware jug/bottle with moulded decoration (‘Khirbet al-Mafjar ware’, AM019). The bulk chemical compositions of these vessels are characterised by relatively low Al_2O_3 concentration at *c.* 13wt %, and high CaO concentration (*c.* 19–27wt %). The trace elemental patterns of the ceramics are characterised by slightly higher NiO, CuO, SrO, ZrO_2 and BaO values (*c.* 100–120, 170–200, 890–1120, 310–420 and 470–1120ppm, respectively) than in general found in the other analysed samples. The cluster analysis indicates that these samples are very similar to the following compositional group 10. In fact, compared to group 10, the main difference is a higher CaO (which alone cannot be used to discriminate geological groups) together with slightly higher NiO and ZnO values.

The SEM-EDS analysis of two samples of this group (AM016, AM019) shows that these sherds share mineral inclusions of frequent quartz (particle size < 0.4mm), occasional apatite (< 0.1mm), ilmenite (< 30μm), grossular (< 20μm), titanomagnetite (< 20μm) and zircon (< 0.1mm). In addition, AM016 includes calcite (< 0.4mm), clay pellets (< 50μm) and andradite (< 50μm), and rare iron oxides (< 30μm), ulvite (< 20μm) and rutile (< 20μm), while AM019 contains rare augite (< 40μm), plagioclase (< 0.1mm) and K-feldspars (< 50μm), perowskite (< 20μm) and titanite (< 20μm) (Figure 6.18, Table 3 and Appendices VI–VII).

The samples share very similar chemical compositions of the ceramic matrices, characterised by very high CaO content (26.2–30.3wt %) and low Al_2O_3 (9.9–10.8wt %) concentrations (Table 4 and Appendix VIII). The high CaO values of the matrices is in agreement with the CaO-bearing minerals present in the fabric. As noted above,

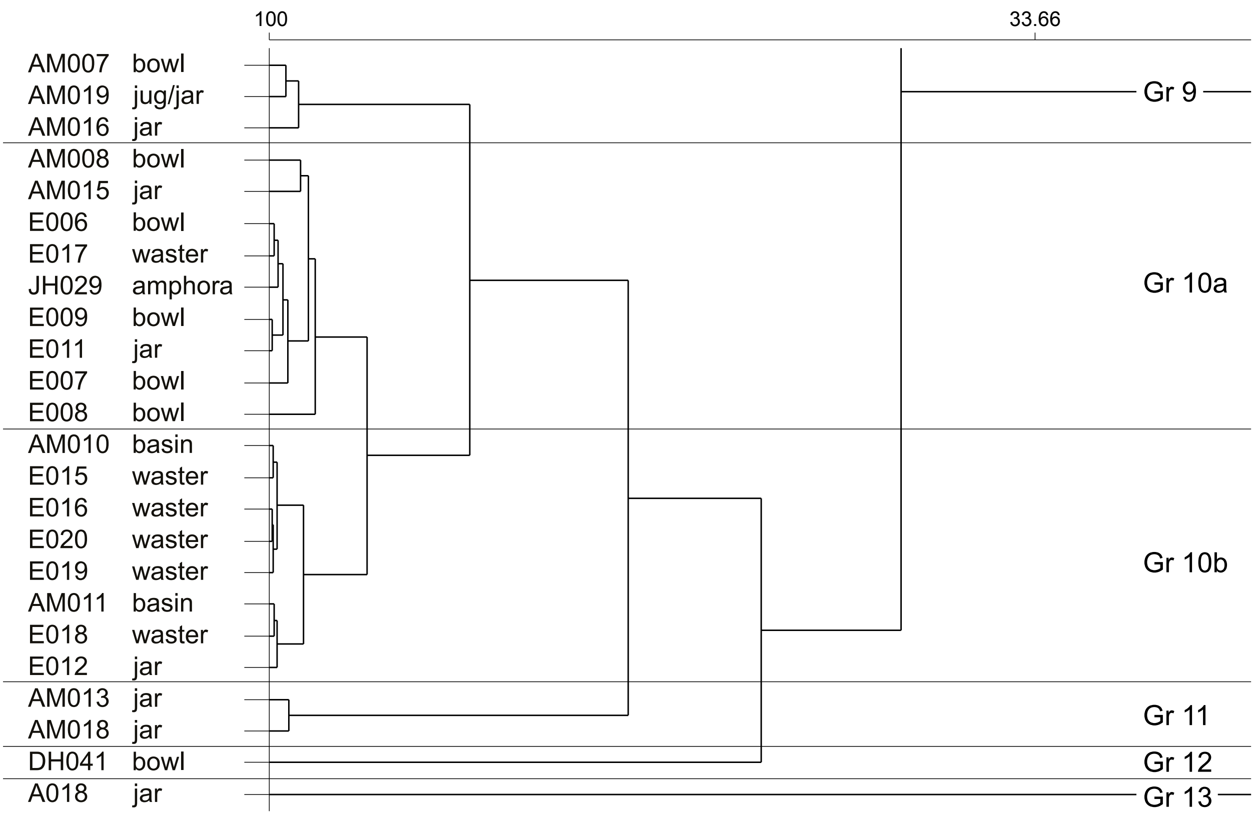

Figure 6.17: Detail of the ED-XRF data cluster analysis dendrogram (see Figure 6.1) showing groups 9, 10a–b, and 11–13.

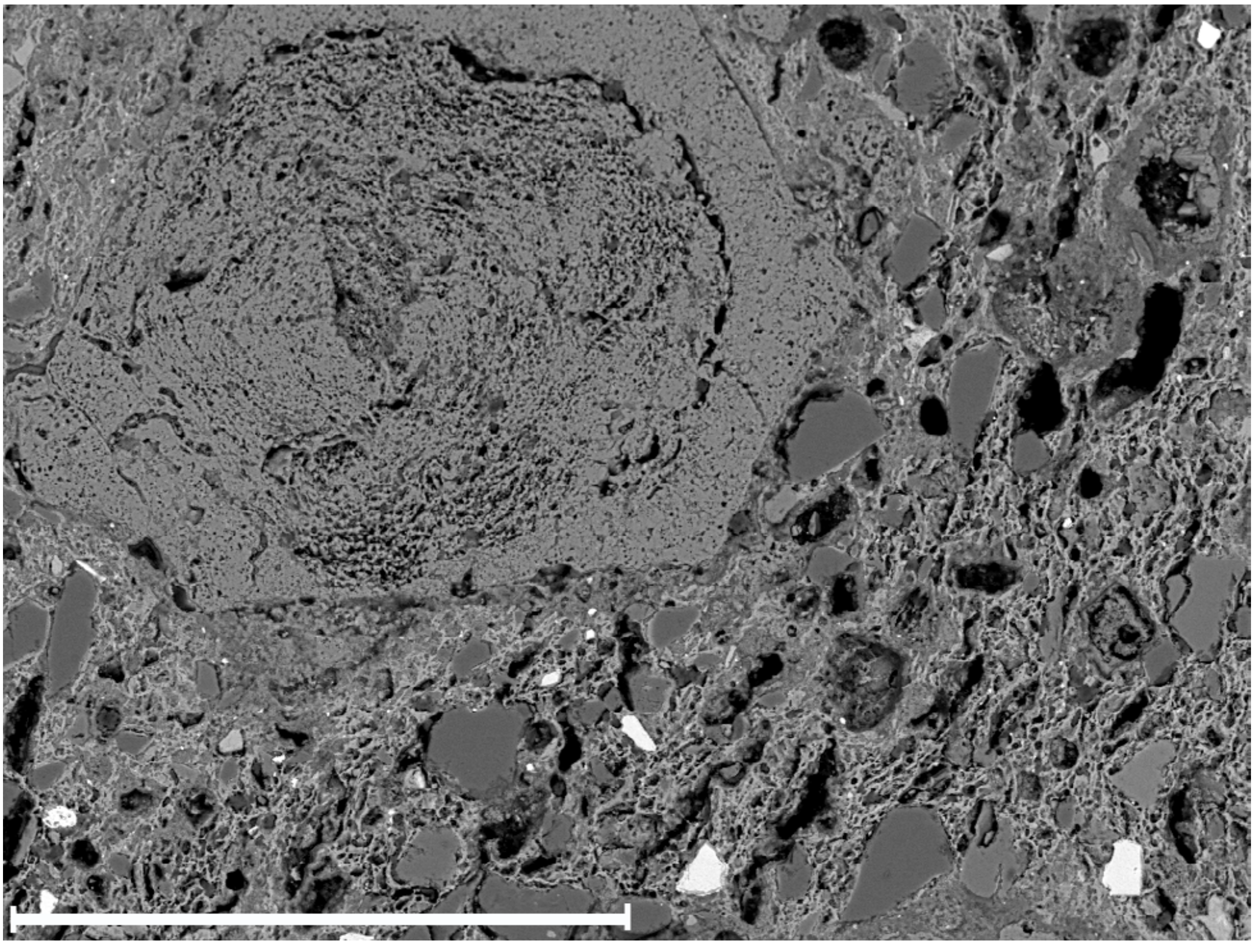

Figure 6.18: SEM-BSE micrograph of group 9 sample AM016 (scale bar 300µm, the long axes of the image are parallel with the vessel surfaces) showing calcite (top left corner) and quartz. The bright grains are zircon, ilmenite and grossular.

these samples seem related to group 10 on the basis of the cluster analysis of the ED-XRF data. Group 10b includes the ceramic wasters analysed from the Elusa ceramic workshop, and therefore the similarity with group 10 might indicate that group 9 originates from the same area, although they cannot be conclusively linked with the Elusa wasters.

Group 10 (a–b)

Compositional group 10 is dominated by samples selected from Elusa: 12 of the 20 Elusa samples analysed with ED-XRF cluster in this main group in the statistical analysis (Tables 1 and 2 and Appendix V). In addition to the Elusa samples, four samples from Abu Matar and one from Jabal Harûn cluster in group 10. Again, the main group shows minor variation, according to which the samples can be divided into subgroups 10a–b. The presence of all of the Elusa wasters in this group demonstrates that these ceramics were produced at the Elusa workshop, or at least geologically very similar raw materials were used in their production. The samples that cluster in this group include forms associated with both late Byzantine and Islamic periods.

The samples belonging to compositional group 10a as indicated by the cluster analysis by the ED-XRF data (see Figure 6.17) are four coarse ware bowls or basins (E006, E007, E009, E009) and a jar, possibly representing the ‘Elusa jar’ (E011) recovered at Elusa. In addition, the Elusa samples of this group include a ceramic waster (E017) from the Elusa workshop. The samples from the other sites that cluster in group 10a include an amphora sherd (JH029) found at Jabal Harûn, and a coarse ware bowl (AM008), and a jar (AM015) recovered at Abu Matar. The other subgroup, 10b, contains five ceramic wasters (E015 and E016 representing a ‘water jug’ type, wasters E018 and E019 of unidentified types, and a jar waster E020) recovered from the Elusa ceramic workshop. In addition, group 10b includes a sherd with engraved (*Kerbschnitt*) decoration (E012) from Elusa, and two large-sized basins (AM010, AM011) from Abu Matar.

Bulk chemical compositions of group 10a show calcareous composition (CaO 17.5–21.3wt %), with low Al_2O_3 (11.4–13.3wt %) values and relatively high trace elemental concentrations of SrO, ZrO_2 and BaO (*c.* 690–1550, 260–335, 500–1470ppm, respectively).

Compositional group 10b shows equally low Al_2O_3 (11.5–14.2wt %), lower CaO range (*c.* 10.5–15.3wt %) marking the main difference between subgroups 10a and 10b, and similar trace elemental concentrations to those of group 10a, including relatively high values of SrO, ZrO_2 and BaO (at *c.* 535–790, 260–375, 445–815).

Compared to group 6, including all of the cooking pot samples analysed from Elusa and Abu Matar, there are clear compositional differences apparent in both ED-XRF and SEM-EDS analysis. According to the ED-XRF data, the group 10 samples show higher concentrations of CaO and ZrO compared to group 6 (see Figure 6.19 for a bivariate plot of concentrations of these two elements in group 6 and 10 samples). The compositional differences between groups 6 and 10 indicate different clays used in their manufacturing, suggesting different origins for the groups. The differences might also be a result of workshop specialisation, as the cooking pots (group 6) are made of non-calcareous clays, and the other forms represented in group 10 of calcareous ones (see, e.g., Barone *et al.* 2012, for the use calcareous clays in amphorae production). Compositional group 9, however, consisting of Abu Matar vessels, appears related to group 10 based on ED-XRF and SEM-EDS analysis, and the similarities in the compositional patterns of groups 9 and 10 might indicate that their raw materials originate from the same region.

SEM-EDS was employed to analyse six samples assigned to group 10 (JH029, E006, E008, E015, E018, AM010, see Figure 6.20 and Tables 3 and 4 and Appendices VI, VII and VIII for SEM-EDS analysis data). Mineral inclusions present in all of these samples are abundant quartz (particle size < 0.5mm) and ilmenite (< 50µm). Frequent calcite (< 0.4mm; interestingly, calcite is present in one of the presumably over-fired wasters E015, but not found in the other one, E018, analysed with SEM-EDS), and occasional garnet-group minerals (andradite, < 50µm), iron oxides (< 0.1mm), and rutile (< 50µm) are present in most samples.

In addition, some of the samples include rare apatite (< 0.2mm), augite (< 20µm), barite (~ 0.2mm), clay pellets (some Fe-rich, < 0.3mm), K-feldspars (< 0.3mm), hornblende (< 50µm), perowskite (< 15µm), titanite (< 50µm) and zircon (< 50µm). It is also noteworthy that the samples of this group do not include Mn-rich inclusions (e.g., Mn-rich clay pellets), present in most of the Negev cooking pot group samples (group 6, see above), further attesting to the geological difference between these groups. In addition, augite, calcite and garnet mineral inclusions present in both groups 9 and 10 strengthen the link between the two. The chemical analysis of the ceramic matrices of these sherds revealed a very calcareous matrix composition (CaO 15.2–26.4wt %) with relatively low Al_2O_3 concentration (9.6–11.2wt %).

The fabric analysis shows heterogeneous fabric and unsorted inclusions, suggesting that the particles are natural inclusions in the clay. The interfaces between the mineral inclusions and the ceramic paste in the analysed waster samples appear slightly more blurred compared to other samples, but the fabrics of the wasters do not appear extensively sintered or glassy, indicating only moderate over-firing (see Figure 6.20 and further discussion on estimated firing temperatures below). This group can be considered local to Elusa on the basis of the wasters from the Elusa workshop in this group. The geology within a 10km radius from Elusa shows mainly sedimentary units, such as limestone and chalk (Sneh *et al.* 1998). The mineralogical inclusions of the group 10 samples display some basic magmatic signature in terms of augite and titanite, which is not apparent on the geological map of the Elusa surroundings. The local geology does, however, relate to the most common inclusions in the group, quartz and calcite. Thus, it is possible that some raw materials for the ceramic production were acquired further away from the site, particularly those containing magmatic minerals (see also Fabian and Goren 2002: 148–150).

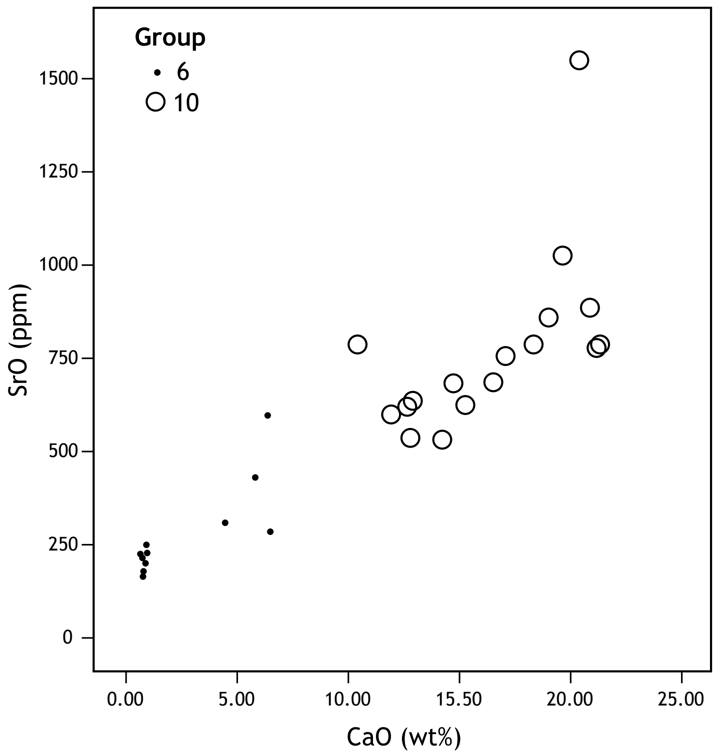

Figure 6.19: Bivariate plot of CaO and SrO concentrations of group 6 (Elusa and Abu Matar cooking pots) and group 10 (local to Elusa) samples (ED-XRF data).

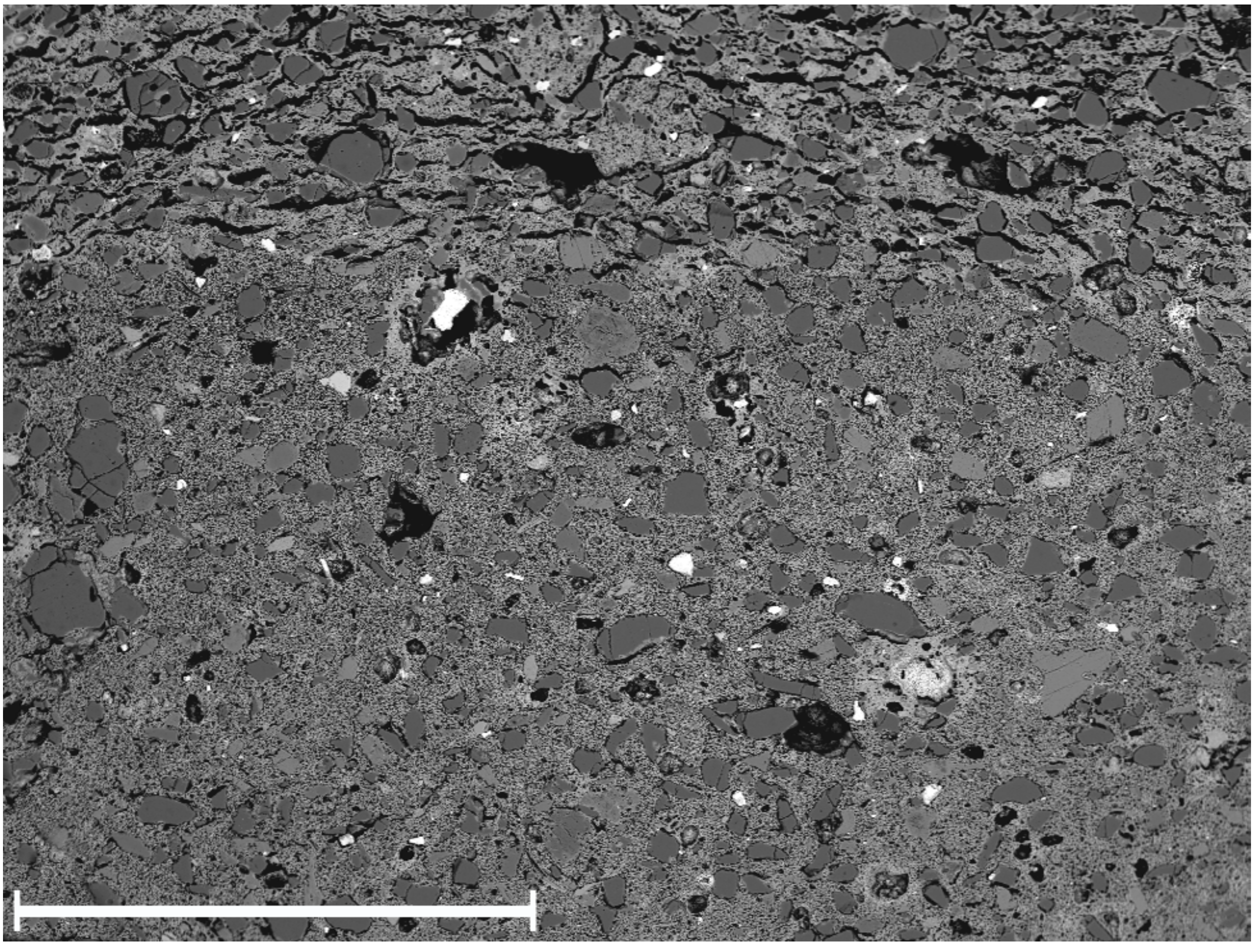

Figure 6.20: SEM-BSE micrograph of group 10 sample E018 (a waster from the Elusa workshop, scale bar 1mm, the long axes of the image are parallel with the vessel surfaces) showing quartz and Fe-rich clay pellets. The bright grains are iron oxides and ilmenite.

Group 11

This compositional group is formed by two samples from Abu Matar, which are both jars, one having combed decoration (AM013) and the other being some sort of hole-mouth jar with a ridged rim (AM018) (Figure 6.17, Tables 1 and 2, and Appendix V). ED-XRF data show these sherds contain low Al_2O_3 concentration at 12.5–14.7wt %, high CaO content at (16–25.8wt %) and high SrO and BaO contents (at 1120–1140 and 3045–3220ppm, respectively) and relatively high ZrO_2 values (*c.* 260–275).

In scanning electron microscopy (Figure 6.21, Tables 3 and 4 and Appendices VI–VIII) conducted on sample AM013, it appeared that the mineralogical composition of this sherd includes frequent quartz (particle size < 0.5mm), occasional iron oxides (< 0.3mm), ilmenite (< 0.1mm), K-feldspars (< 0.1mm), apatite (< 70μm), rare biotite (< 40μm) and clay pellets (< 30μm), and very rare garnet-group minerals (< 50μm), barite (< 0.5mm), magnetite (< 20μm) and ulvite (< 20μm). The chemical composition of the ceramic matrix is calcareous (CaO 19.2wt %), with low Al_2O_3 content (12.7wt %). No indications of artificial inclusions were found in the ceramic fabric. Again, this compositional group seems to be related to the two previous ones, although variation also occurs in bulk chemical and mineralogical compositions.

Group 12

A glazed sherd (DH041) found at Khribet edh-Dharih does not share compositional characteristics with the other sherds analysed with ED-XRF, and its composition is relatively different to the glazed one from Jabal Harûn (JH035, group 5). The mineralogical characteristics and the chemical composition of the ceramic matrix of DH041 are also different to those of a glazed sherd acquired from Abu Matar (group 15, analysed with SEM-EDS, see below). The bulk chemical composition of the ceramic fabric of the glazed sherd displays high MgO concentration at 5.2wt %, relatively low Al_2O_3 content (14.7wt %), CaO value of 13.2wt % and relatively high trace elemental concentrations of NiO (*c.* 260), CuO (*c.* 350ppm), SrO (*c.* 610ppm) and BaO (*c.* 370ppm). The high CuO value is probably due to the colourant of the glaze being absorbed into the ceramic fabric.

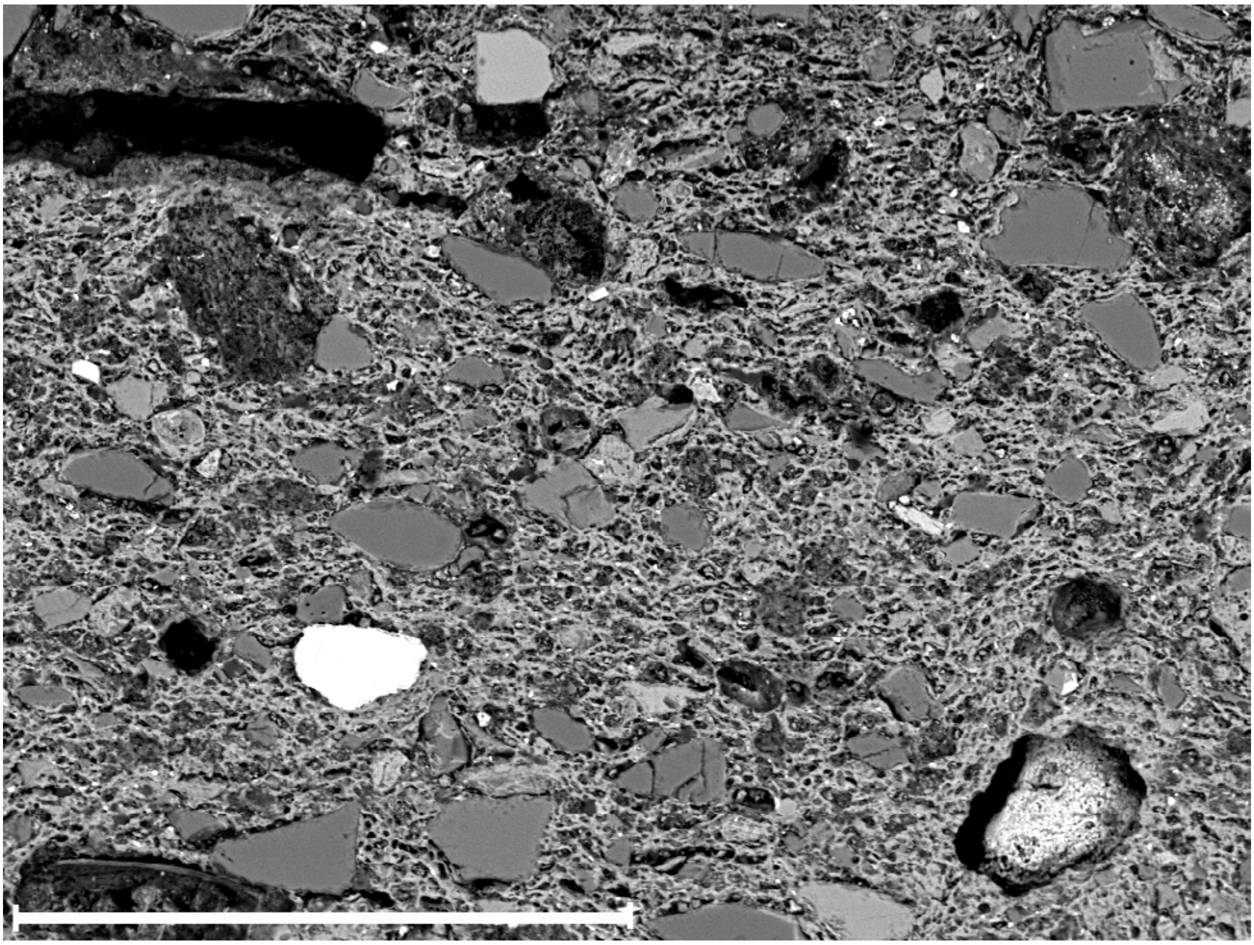

Figure 6.21: SEM-BSE backscatter micrograph of group 11 sample AM013 (scale bar 300µm, the long axes of the image are parallel with the vessel surfaces) showing quartz, K-feldspar and apatite inclusions. The bright grains are ilmenite, magnetite and ulvite.

In the SEM-EDS analysis (Figure 6.22, Tables 3 and 4 and Appendices VI–VIII), the mineralogical composition of the ceramic fabric appears to contain frequent quartz (grain size < 0.5mm), clay pellets (some Ti or Fe-rich, size < 0.3mm), ilmenite (< 0.2mm), iron oxides (< 0.3mm) and plagioclase feldspars (< 0.4mm). Apatite (< 30µm), augite (< 0.3mm), biotite (< 0.5mm), and chromite (< 20µm), garnet-group minerals (< 0.3mm), hornblende (< 40µm), spinel (< 30µm) and rock inclusions (basalt with olivine and plagioclase, and melted albite, size < 0.3mm) occur rarely. This sherd has a calcareous ceramic matrix (CaO 19.5wt %) with relatively high MgO (4.8wt %) and FeO (9.0wt %) contents. Microchemical analysis by SEM-EDS of the glaze reveals a *c.* 400 µm thick copper-coloured alkaline glaze (Na_2O_3 *c.* 11.8, MgO 3.4, Al_2O_3 2.8, SiO_2 62.4, K_2O 3.9, CaO 10.1, FeO 2.3, CuO 2.3 and PbO 1.1wt %).

This alkaline glazed vessel represents a different glazing technology than the other two glazed sherds (JH035 and AM020) with lead silica glazes. It also seems to be different than the Khirbet edh-Dharih 'local' group 3 in terms of fabric compositions, which suggests it is an import to the site (see discussion below), possibly from a specialised workshop.

Group 13

This compositional group is represented by an amphora sherd (A018) from 'Aqaba, which appears different from all of the other analysed sherds. Its composition is clearly different from those of the group designated as local to 'Aqaba, group 8, indicating that it may be an import to the site, or produced using different raw materials. The bulk chemical composition of this sample shows exceptionally high MgO (15.3wt %) and low Al_2O_3 (10wt %) concentrations (Figure 6.23, Tables 1 and 2, and Appendix V) In addition, it shows very high trace elemental concentrations of NiO (*c.* 1060ppm) and SrO (*c.* 600ppm).

Scanning electron microscopy shows that the mineralogical composition of this sherd contains frequent quartz (particle size < 0.3mm), occasional almandine (< 0.2mm) and biotite (< 50µm) and rare perowskite (< 20µm) and titanite (< 40µm) (Figure 6.23, Tables 3 and 4 and Appendices VI–VIII). The sherd has a calcareous ceramic matrix (CaO 13.3wt %), with relatively high FeO concentration (7.8wt %). This sherd has a relatively fine grained and homogeneous

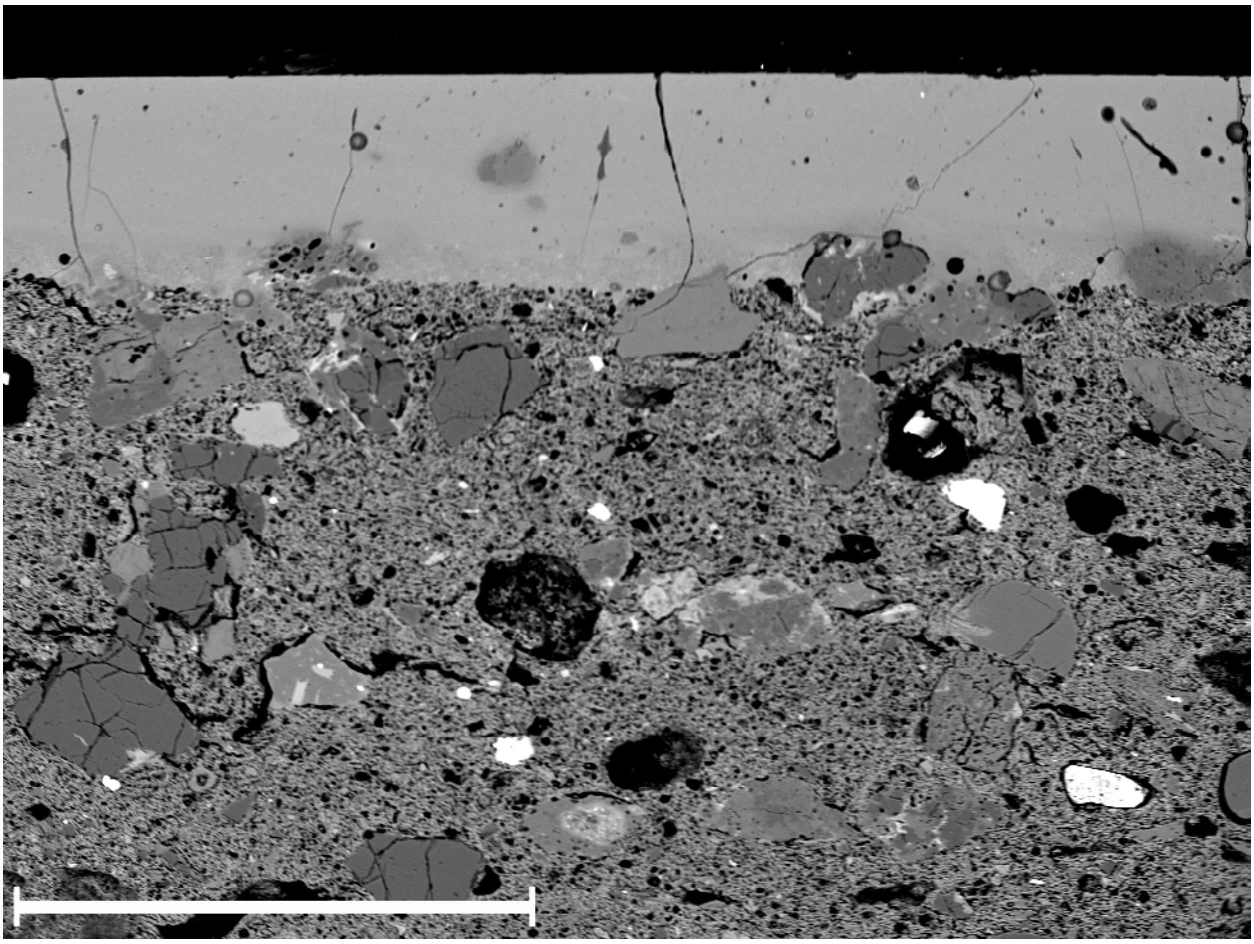

Figure 6.22: SEM-BSE micrograph of group 12 sample DH041 (scale bar 1mm), showing quartz, augite, plagioclase and clay pellets. The bright grains are ilmenite, iron oxides and Ti- and Fe-rich pellets. The vessel is coated with Cu-coloured alkaline glaze.

ceramic fabric, indicating that the clay was processed, levigated or sieved, to achieve the desired texture. Its fabric is much finer compared to that of the other amphorae analysed. The particles are rounded and the fabric shows no indications of artificial inclusions.

Group 14

The SEM-EDS analysis of a plate or bowl sherd (JH034) decorated with engraved triangular motifs (*Kerbschnitt*) found at Jabal Harûn indicates, in addition to its different decorative treatment, that also its technology and material processing are different compared to the other analysed ceramics (see Figure 6.24, Tables 3 and 4 and Appendices VI–VIII).

The ceramic fabric appears relatively well sorted with bimodal grain size, indicating that the clay was processed in order to achieve a certain texture. The particles are all relatively small grained apart from quartz and calcite. Mineralogical inclusions present in the ceramic fabric are abundant quartz (< 0.4mm) and occasional calcite (< 0.4mm), and rare garnet-group minerals (< 20μm), clay pellets (< 20μm), hornblende (< 20μm), ilmenite (< 20μm), rutile (< 20μm), titanite (< 20μm), and zircon (< 200μm).

This sample has a strongly bimodal particle size. Quartz, calcite and zircon are larger-sized up to 0.4mm, while all the other inclusions appear very small, less than 20 μm. The fact that the large-sized quartz and calcite grains are angular or subangular and rest of the particles are rounded, might indicate that the larger quartz and calcite inclusions are artificial tempers and the rest of the particles natural inclusions in the clay paste. This type of clay processing is not apparent in any of the other analysed samples, indicating specialised technology applied in the manufacturing of this object. Relatively elongated and parallel pores also characterise the fabric, possibly indicating that the vessel was wheel-thrown, but this cannot be ascertained due to the small size of the sherd. The fabric appears fired at a low temperature and the larger pores are likely to be the results of quartz grains fallen during the sample preparation. The ceramic matrix of this sherd shows a calcareous chemical composition (CaO 10.9wt %), with relatively low FeO content (4.7wt %).

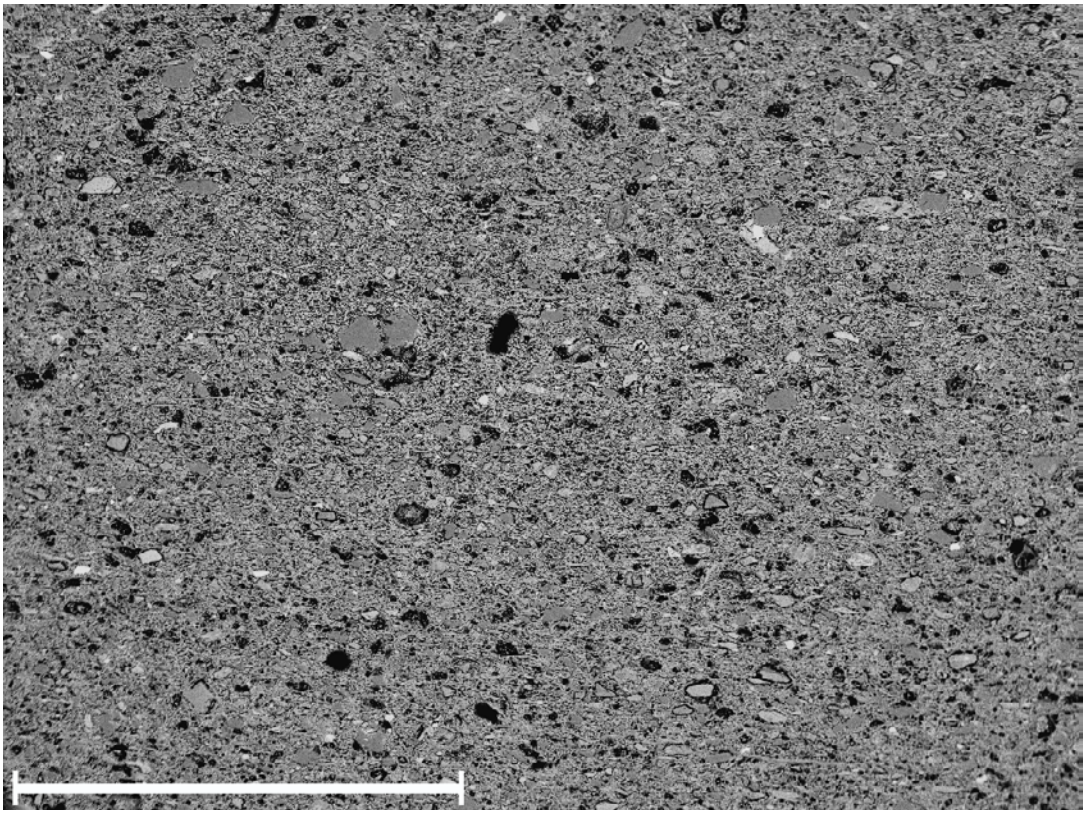

Figure 6.23: SEM-BSE micrograph of group 13 sample A018 (scale bar 1mm, the horizontal axes of the image are parallel with the vessel surfaces), showing a relatively fine grained ceramic fabric with mineral inclusions of quartz, almandine, chromite and augite.

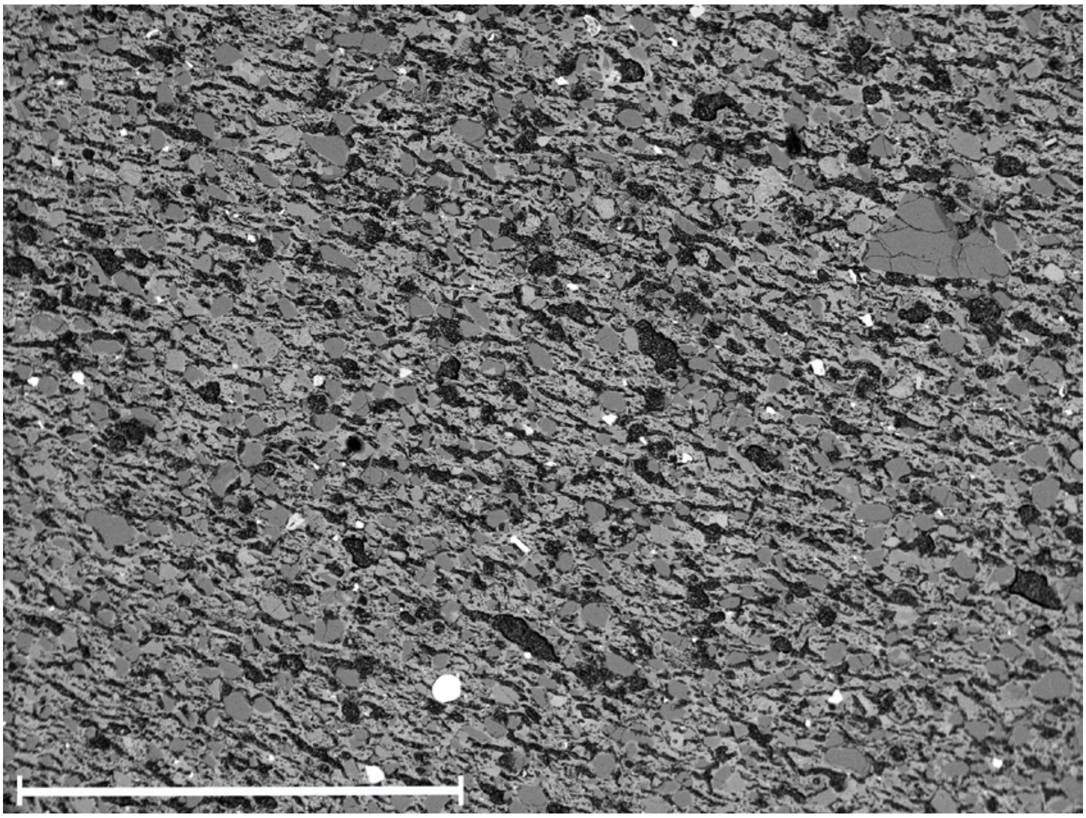

Figure 6.24: SEM-BSE micrograph of group 14 sample JH034 (scale bar 1mm, the long axes of the image are parallel with the vessel surfaces) showing bimodal mineral inclusions of angular quartz and smaller-sized bright grains of ilmenite, rutile, titanite and zircon.

Group 15

A green-glazed sherd recovered from Abu Matar (AM020) was analysed with SEM-EDS only (Figure 6.25, Tables 3 and 4, and Appendices VI–VIII). Compared to the other two analysed glazed ceramics, this sherd shows compositional characteristics different from the alkaline glazed sherd found at Khirbet edh-Dharih (group 12, sample DH041), but relatively similar compositional patterns and technology with the lead-glazed sherd found at Jabal Harûn (group 5, sample JH035).

The mineralogical analysis shows a poorly sorted mixture of frequent quartz (particle size < 0.4mm), clay pellets (< 1mm, some clay pellets Mn or Fe-rich), ilmenite (< 0.2mm), biotite (< 0.3mm), iron oxide (< 0.2mm), added by occasional K-feldspar (< 0.1mm), augite, garnet-group minerals (< 0.2mm), rare hornblende (< 30µm) and titanite (< 0.1mm) and very rare rock inclusions (~ 0.3mm, aluminium silicate–iron oxide). The various sizes of rounded particles present in the fabric indicate natural inclusions and a relatively low level of material processing in the fabric preparation. The microscopic analysis also shows rounded pores and random orientation of particles suggesting that the ceramic body was hand-made.

The chemical composition of the ceramic matrix is characterised by a very low CaO concentration (0.6wt %) and high Al_2O_3 (27.7wt %), TiO_2 content of 2.2wt % and FeO value of 5.1wt %. Microchemical analysis of the glaze coating of the sherd showed a copper-coloured lead silica glaze applied on the surfaces of the vessel (Al_2O_3 1.7, SiO_2 28, CaO 0.6, FeO 0.7, CuO 3.5 and PbO 66wt %). The nature of the fabric and the technology of this sherd, including the glaze composition, are relatively similar to those of the glazed sherd from Jabal Harûn (JH035, group 5), but the mineralogical differences make it unlikely that they originate from the same the production centre. In any case, these two lead silica glazed sherds represent technologically very different applications than the alkaline glazed sherd from Khirbet edh-Dharih (DH041, group 12).

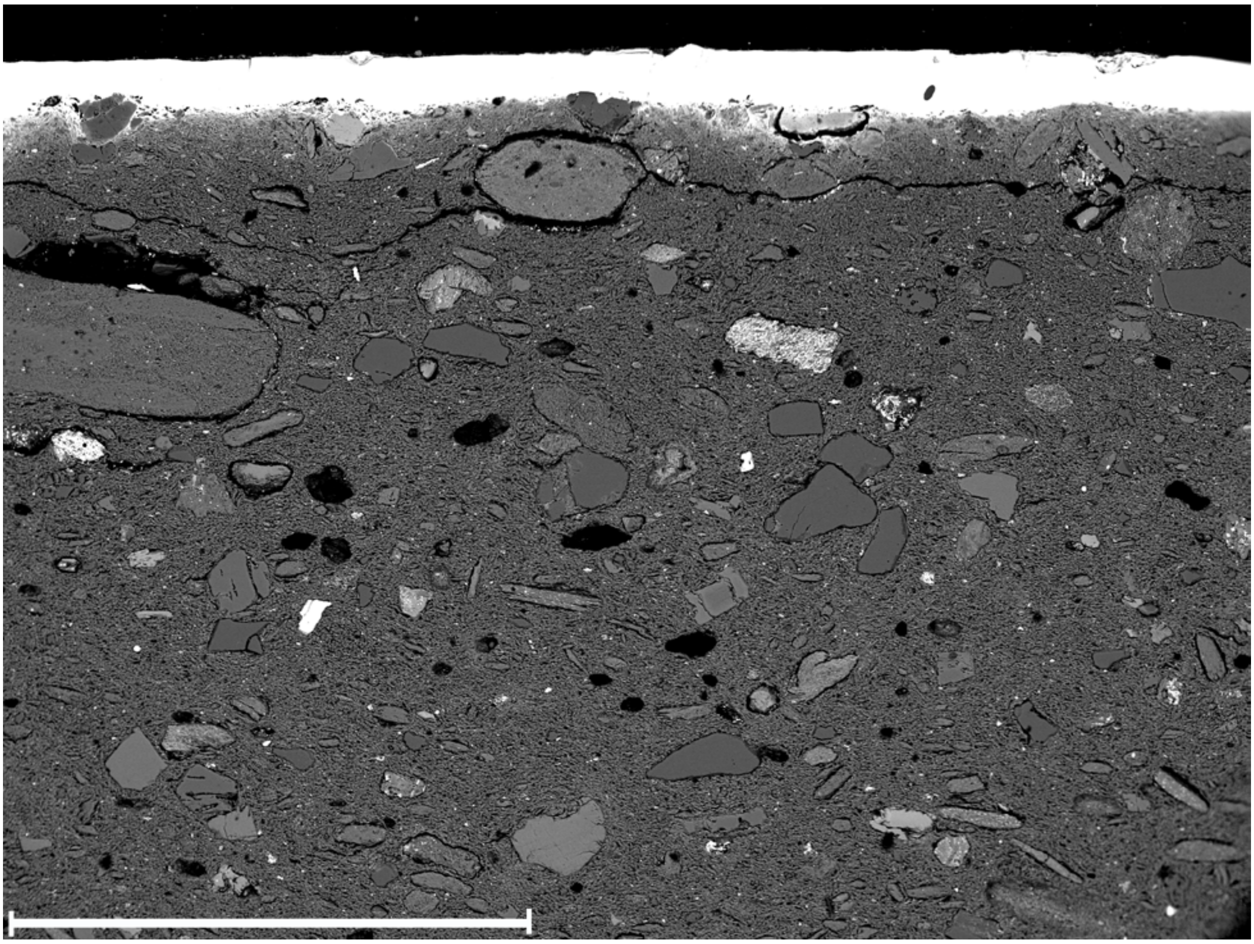

Figure 6.25: SEM-BSE micrograph of group 15 sample AM020 (scale bar 1mm) showing quartz, clay pellets, augite, biotite and K-feldspars and rounded pores. The bright inclusions are Mn and Fe-rich clay pellets, iron oxides and ilmenite. The vessel exterior shows a Cu-coloured lead-glaze.

Technological aspects and firing temperatures

Scanning electron microscopy was employed to examine technological aspects of the ceramics, including production technique, surface treatment, and firing temperature. Indications of the employed techniques employed were first examined macroscopically and then in further detail by SEM. It was possible to differentiate the hand- and wheel-manufactured vessels in most cases, apart from a few, small sherds that did not show clear signs of either technique. In the macroscopic examination, certain characteristics of the vessel walls, such as ridges, grooves and rilling and a uniform thickness can often be considered as indications of wheel-throwing. Some samples showed irregularities in wall thickness in cut sections and fingerprints on their interiors, suggesting that the vessels were coil-built (see Courty and Roux 1995). However, the manufacturing technique assignments, especially when based on macroscopic examination, should be treated cautiously, and a combination of both macroscopic and microscopic examination can produce better results. During scanning electron microscopy, orientation of particles and pores were examined as their parallel orientation to vessel surfaces might indicate wheel-made ceramics, while a more random orientation of pores and particles would suggest other manufacturing techniques. An elongated shape of voids can also be associated with wheel-throwing.

According to the macroscopic examination and scanning electron microscopy, the majority of the sherds appear wheel-made, and the hand-made technique appears linked to a few specific ceramic forms and types, such as the red-painted and leaf-pattern vessels and glazed vessels. It is noteworthy that in compositional groups 1 and 3 in particular, wheel- and hand-made manufacture were applied to similar raw materials, and hence vessels representing different manufacturing techniques appear in the same compositional groups. Regardless of the compositional similarity of the wheel- and hand-made wares in these cases, a question that will have to remain open is whether the two technologies would coexist in the same workshop. It is possible that particularly in the case of the leaf-pattern jars, apparently relatively large-sized on the basis of published complete examples, the coil building technique was applied because wheel-throwing was not suitable for producing vessels of their size. This might also be the case for the painted, hand-made sherds, although the sizes of the vessels cannot be determined with certainty.

In general, the ceramic fabrics seem to regularly contain natural inclusions, relatively poorly sorted quartz, other minerals and clay pellets, while indications of artificial, added tempers were very few. Most of the ceramic fabrics display relatively coarse, rounded and unsorted inclusions, suggesting that the materials were not substantially processed in the manufacturing procedure.

Three sherds were glazed, two of which represent very similar lead-glazing technology (JH035 and AM020), while the third appeared to be coated with an alkaline glaze (DH041). Compared to alkaline glazes, the preparation and application of the lead silica glazes with high PbO content was easier, with a lower risk of the glaze crawling or crazing. Both glazes were produced in the Islamic periods, but due to the easier production and lower costs, high-lead glazes were produced in various small centres in the Islamic world, whereas more expensive alkaline glazes were only produced in few specialised centres (Mason and Tite 1997; Tite *et al.* 1998: 257–258; see also Greene 2007; Molera *et al.* 2018).

The glazing can be considered successful if no cracking or distortion appears, and the glaze is evenly applied on the surface. In addition, the firing temperature needs to be carefully monitored in order to prevent depressions or pinholes on the surface, or running of the glaze (Tite *et al.* 1998: 246). A concentration of potassium-lead-aluminium-silicate crystals at the interface between the ceramic body and the glaze suggests that the high-lead glaze was applied to an unfired ceramic body, whereas absence of this phenomenon at the glaze-body interface indicates that the body was biscuit-fired, although also other factors can affect the crystals concentrations (Tite *et al.* 1998: 250–251). Accordingly, in the case of the glazed sherds sampled for this work, with no crystals present at the glaze-body interface, it can be suggested that the ceramics were pre-fired before the application of the glaze.

It appears that, in general, all of the sampled ceramics were fired at relatively low temperatures. This can be expected considering that the majority of the samples are utilitarian ceramics, cooking vessels or ceramic containers, the performance qualities of which, such as thermal shock resistance and higher toughness and crack resistance, would benefit from relatively low firing temperatures and coarse textures. Although it is not possible to conclude the actual absolute firing temperatures, relative differences in firing temperatures can be examined, and the characteristics can be compared to published experimental studies of effects of different firing temperatures on ceramic fabrics (see, for example, Bland *et al.* 2017; Chatfield 2010; Tite *et al.* 1990; Wolf 2002). Certain characteristics, such as the level of vitrification and the appearance of mineral inclusions in the ceramic microstructures can be considered as indicative of maximum temperatures achieved during firing.

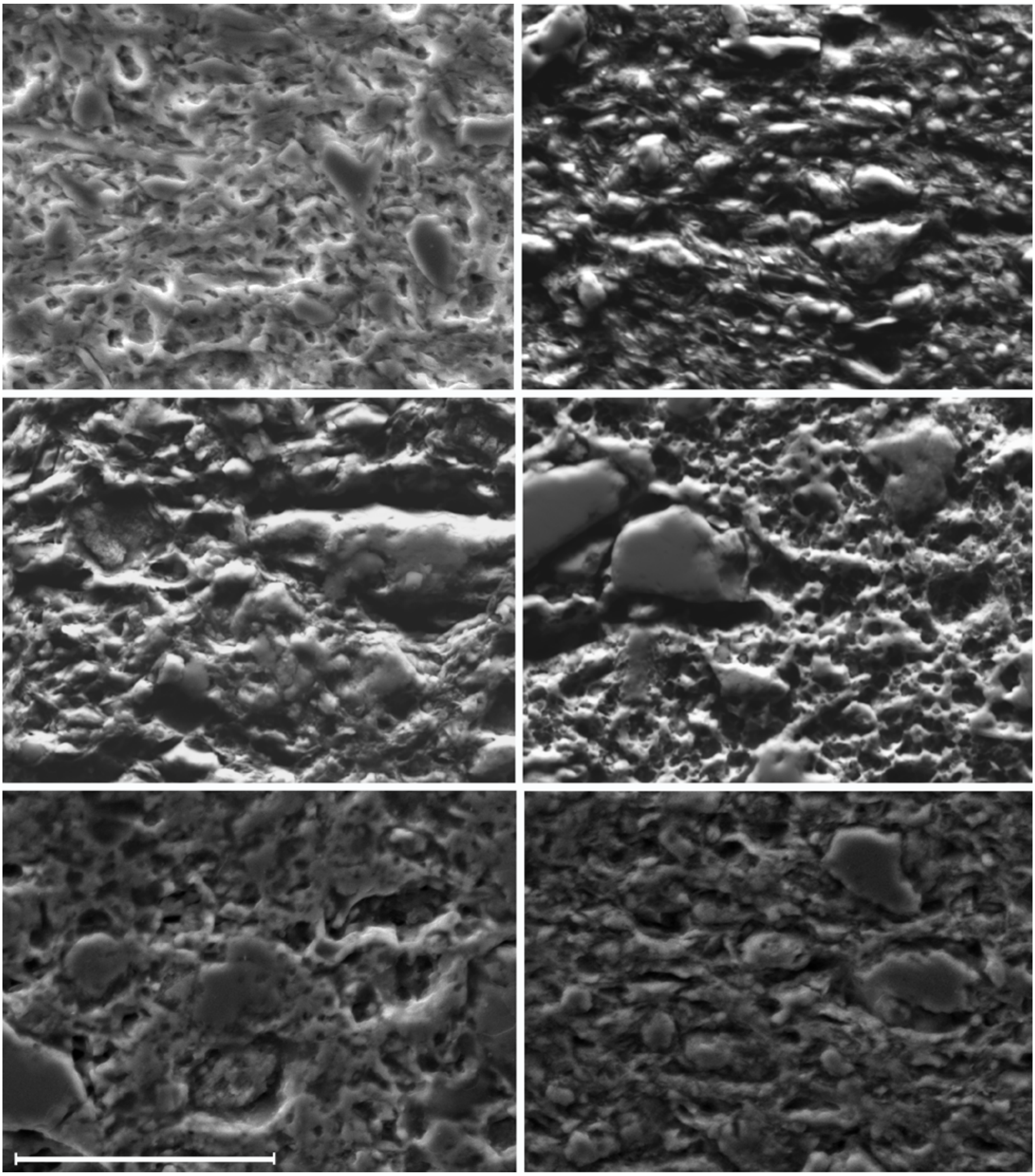

Figure 6.26: SEM-SE microsgraphs (scale bar 60µm, the long axes of the images are parallel with the vessel surfaces) showing ceramic matrices of samples A008 (top left), AM020 (top right), DH001 (middle left), E018 (middle right), JH003 (bottom left) and JH021 (bottom right).

The ʻAqaba/Aila amphorae seem to be have the coarsest grain size and the lowest firing temperatures. These characteristics may be explained by their function as transport vessels: coarse fabric and porosity due to low firing temperatures increase the toughness of the vessel and help to prevent breakage due to mechanical impact during transportation. Furthermore, the cooking pots analysed from the different sites are generally non-calcareous with relatively abundant quartz inclusions, improving their thermal shock resistance and toughness (see Tite and Kilikoglou 2002).

In order to assess the level of vitrification of the ceramic fabrics, of all of the samples analysed with SEM, high magnification (1000x) secondary electron (SE) topographic images were produced to examine the porosity of the ceramic matrix and the level of sintering and glassiness of the fabric. Experimental studies have shown that no vitrification appears at temperatures remaining below 800°C, the first signs appearing only above this limit, with advanced levels of vitrification appearing at 900–1000°C and above (see Bland *et al.* 2017; Chatfield 2010; Tite *et al.* 1990: 162–163; Wolf 2002). In the secondary electron images (SEM-SE), the analysed samples showed no development of vitrification, indicating firing temperatures below 800°C to also be the case with the ceramic wasters that show no substantial difference in the level of vitrification of the ceramic fabrics (see Figure 6.26).

Furthermore, the fact that calcite and plagioclase inclusions were present in many of the ceramic fabrics also attests to relatively low firing temperatures, as calcite would decompose at temperatures above *c.* 700°C and plagioclase at temperatures rising above 900°C (see, e.g., Franken and Kalsbeek 1969: 76–77). Calcite inclusions were present in groups 8, 9, 10 and 14 and plagioclase in groups 2, 5, 8, 9 and 12 (see Table 3). Lime inclusions can reduce the required firing temperature by making the clay hard at lower temperatures. This can be an advantage in a situation where there is a shortage of fuel, yet it affects the quality and strength of the vessel (see Franken and Kalsbeek 1969: 76–77).

Calcite was present in one of the ceramic wasters from Elusa (E015) suggesting that the over-firing of the vessels was not extensive and that their manufacture may have failed also for some additional reason, although the appropriate and presumably relatively low firing temperature usually applied in the production was clearly exceeded. The waster samples also showed increasing porosity towards the vessel surfaces, a feature that might have resulted from the unsuccessful firing, and also contributed to their discarding. In macroscopic examination, the wasters also showed signs of pressing, resulting in the misshaping of the vessels (especially samples E015 and E019). Sample E019 particularly shows two separate vessel fragments fused together. These faults were probably caused by collapsed kiln stands or other installations.

Concluding remarks

According to the data obtained from the ED-XRF and SEM-EDS analysis, the 141 ceramic samples can be divided into 15 main compositional groups and further subgroups. Groups 1–13 were assigned primarily on the basis of the cluster analysis of the bulk compositional ED-XRF data and these assignments were confirmed by SEM-EDS analysis. SEM-EDS was used to ascertain that samples assigned to a certain compositional group based on their bulk chemical composition also shared microstructural characteristics, similar mineralogical inclusions and chemical composition of the ceramic matrix. Similarly, SEM-EDS was employed to establish that these microstructural characteristics showed sufficient variation among the separate groups.

On the basis of the results, it appears that there are five large groups in the data set (groups 1, 3, 6, 8 and 10), which are also archaeologically the most significant. Samples assigned to these five groups were further categorised into subgroups on the basis of the cluster analysis of the ED-XRF data (e.g., 1a–c). However, in most cases, the minor compositional variation within a compositional group can be regarded as variation occurring in the same ceramic recipe or production. In a few cases, it was concluded that a sample interpreted as a subgroup of one of the main groups did in fact show trace elemental, mineralogical or matrix compositional differences, which resulted in the conclusion that this ‘subgroup’ should not be considered as a member of the main group in question or a product related to the same source or manufacture. In other words, the sample was more likely to be of a completely different provenance than the other samples of the associated main group. Four of the five largest main groups can be considered to be local to certain sites, on the basis of abundant representation of samples from a particular site clustered in one group and geochemical and mineralogical profile fitting with the local geology.

Group 1 is dominated by Khirbet edh-Dharih samples, whereas only a few samples from the other sites are included in this group. This allows the suggestion that these ceramics were more likely to have been produced in the relative vicinity of Khirbet edh-Dharih rather than in the vicinity of any of the other sites included in this study. Similarly, group 3 appears local to the Jabal Harûn area. Groups 1 and 3 showed considerable compositional similarities in both ED-XRF and SEM-EDS analysis, and it appears that their raw materials originate from related geological regions. However, the clear and consistent discriminating compositional patterns between the ceramics in these two assemblages indicate that they are more likely to represent different productions exploiting related raw material sources, rather than products of a single workshop. The ceramic forms representing different phases in both groups make it unlikely that these groups would represent chronological variation within a single production unit. Furthermore, the division between groups 1 and 3 was indicated by the hierarchical cluster analysis with elements not including those prone to be affected by burial conditions, and for this reason, it is also improbable that the compositional variation between the groups would be the result of different burial conditions affecting ceramics from the same source.

These two groups can, of course, instead of representing two separate production centres, be the products of different branches of the same production, or in other ways results of different 'production lines' of the same production centre. If ceramics are massproduced, this kind of variation may occur between the products produced in large series, caused by, for example, slightly different clay mixtures used at different times or by different potters. However, this scenario would seem more likely if the groups were more evenly distributed between the two sites, and not as consistently divided between the sites, the majority of samples from one site belonging to one, and the majority of the samples from another site belonging to another. In fact, it is even possible that several workshops are present within each distinct group (1 or 3), explaining the coexistence of wheel-made and hand-made ceramics. The relatively low level of raw material sorting and clay processing means that compositional differences are more likely to relate to geological origin rather than diversity of technological chains. Furthermore, the low level of modification means that even if several potters or workshops were using the same clay deposits, it is difficult to differentiate among them chemically (see discussion in Chapters 7 and 8).

Group 6 includes all of the analysed cooking pots from the two Negev sites, Abu Matar and Elusa, but shows clearly different, non-calcareous composition compared to group 10, which includes all of the wasters analysed from the Elusa workshop. Several conclusions can be drawn from this evidence. First, it seems apparent that the cooking pots analysed from the two sites originate from the same source. It seems probable, considering the compositional differences between the pots and the Elusa wasters, and the lack of cooking pot wasters reported from the kiln site, that these pots were produced in another workshop, the location of which, either in Elusa, Beersheva or elsewhere cannot be established at the moment. Furthermore, the very limited compositional variation between the cooking pot samples indicate standardised production, possibly in a specialised production centre. It is also possible that the cooking pots represent a chronologically later production compared to that of the Elusa workshop (see discussion in relation to the ceramic typo-chronologies in the next chapter).

Group 8 contains the majority of the analysed samples from 'Aqaba, including the 'Aqaba/Aila amphorae sampled from the site. As a result, this group can be considered to be local to 'Aqaba. In addition to the 'Aqaba samples, visually very similar amphora sherds found at Jabal Harûn, Khirbet edh-Dharih and Elusa also cluster in this group in the statistical analysis. These samples from the other sites appear to share very similar bulk chemical compositions, mineralogical inclusions and chemical composition of the ceramic matrix compared to those of the 'Aqaba samples belonging to this group. This demonstrates that these amphorae found at the other sites are imports from 'Aqaba, thus being 'Aqaba/Aila amphorae.

The Elusa wasters form a major part of group 10, supplemented by a few other samples from Elusa, Abu Matar and one from Jabal Harûn. Samples that show considerable compositional similarity with the Elusa wasters and cluster in this main group can be considered local to Elusa. In terms of ceramic forms, different jars, including the 'Elusa jar', water-jars, basins and a few other forms are represented in this group. The ceramic production at the Elusa workshop seems not to have continued beyond the 6th century, but it is possible, considering the dates of some of the Abu Matar samples clustering with this group, that the same raw materials were used by another workshop in a later period (see further discussion in the next chapter).

A few samples are chemically so different from the majority that they may represent foreign imports, such as the potentially Cypriot or Antiochian origin of jar E013 (group 8d), or sample A018 (group 13) with a very basic geological signature, being rich in MgO, NiO and Cr_2O_3.

The SEM results further imply that the mineral inclusions in general in the ceramic fabrics are of natural origin and artificial tempers are rare in the analysed samples. The ceramics were fired at relatively low firing temperatures, probably not exceeding 800°C. Two different glazing technologies are represented in the sampled glazed ceramics, samples from Jabal Harûn (JH035) and Abu Matar (AM020) were coated with lead silica glaze, whereas a glazed vessel from Khirbet edh-Dharih (DH041) has an alkaline glaze. Furthermore, there are some sherds that seem to represent very different manufacturing procedures, such as the engraved (*Kerbschnitt*) sherd, possibly a plate rim fragment (JH034) from Jabal Harûn, the relatively fine-grained and well-sorted fabric of which indicates washing or sieving of the clay, whereas the rest of the ceramic fabrics appear relatively poorly sorted, typically coarse grained but various grain sizes were also present, suggesting that their production did not involve substantial processing of the raw clays.

In the next chapter, the analytical results and the compositional groups, particularly the five largest main groups that can be referred to as the 'primary groups' on the basis of their dominance and archaeological significance, will be discussed further with an emphasis on the typo-chronological aspects of the ceramics. Furthermore, the inter-site relationships as demonstrated by the ceramic analysis will be highlighted.

Chapter 7

From production centres to regional and inter-regional ceramic transport

The ED-XRF and SEM-EDS analyses indicated that the 141 samples from the five archeological sites form a total of 15 compositional groups, of which the five largest are archaeologically the most significant and can be seen as primary compositional groups. The five primary groups are each related to a specific site or production system, while the rest of the compositional groups can be seen as outliers and suspected imported materials to the sites (see Figures 7.1 and 7.2). The five primary groups are group 1 (local Khirbet edh-Dharih group), group 3 (local Jabal Harûn group), group 6 (the Negev cooking pot group), group 8 (local 'Aqaba/Aila group) and group 10 (local Elusa group).

In general, the analytical data demonstrate ceramic exchange particularly on a regional level. The results show that Jabal Harûn and Khirbet edh-Dharih in southern Transjordan, and similarly Abu Matar and Elusa in the Negev, have material links, while there appears to be less ceramic exchange on an inter-regional level, between southern Transjordan and the Negev. 'Aqaba/Aila, on the other hand, seems to have material ties with both regions, a result which can be seen as in line with the more commercial role of the site and its strategic location in relation to both regions. There is, however, also evidence for ceramic transport between the two regions, which is a particularly noteworthy outcome considering the fairly limited sample size in this work. In this respect, one may expect a larger sample to reveal more substantial evidence for inter-regional contacts. The limited number of cases of inter-regional exchange may, in fact, result from the sampling strategy of this project, which concentrated on the 'typical' finds in each assemblage to examine local production, and thus fewer 'exotic' ceramics were included.

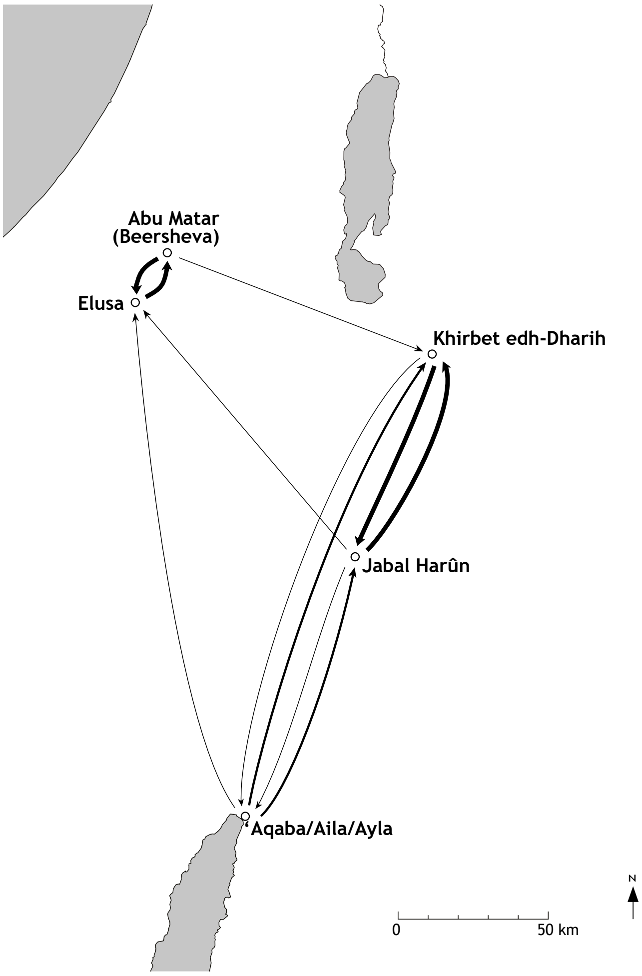

Figure 7.1: Material exchange between the sampled sites based on the analytical (ED-XRF, SEM-EDS) results. The thickness of the lines corresponds to the strength of contacts as indicated by the analysed samples.

Related ceramic economies of Khirbet edh-Dharih and Jabal Harûn (groups 1 and 3)

The results obtained from the ED-XRF and SEM-EDS analyses show that the two largest compositional groups, groups 1 and 3, have considerable similarity in terms of bulk chemical compositions, mineralogical inclusions and chemical compositions of the ceramic matrices. This evidence indicates that the ceramics of these groups are materially linked. Due to the dominance of Khirbet edh-Dharih ceramic samples in group 1, and Jabal Harûn samples in group 3, the two groups can be interpreted as local to the respective sites. Considering that ceramic workshops of this period have not been located in the vicinity of either site, it can, at least, be concluded that in the case of group 1, the products of this particular production were more accessible to the inhabitants of the village of Khirbet edh-Dharih, either directly from the production centre or via markets, when compared to the communities living in other locations included in this work.

The case of the Jabal Harûn monastery and group 3 ceramics is similar. The compositional patterns of the ceramics in these groups demonstrate that they were manufactured from very similar

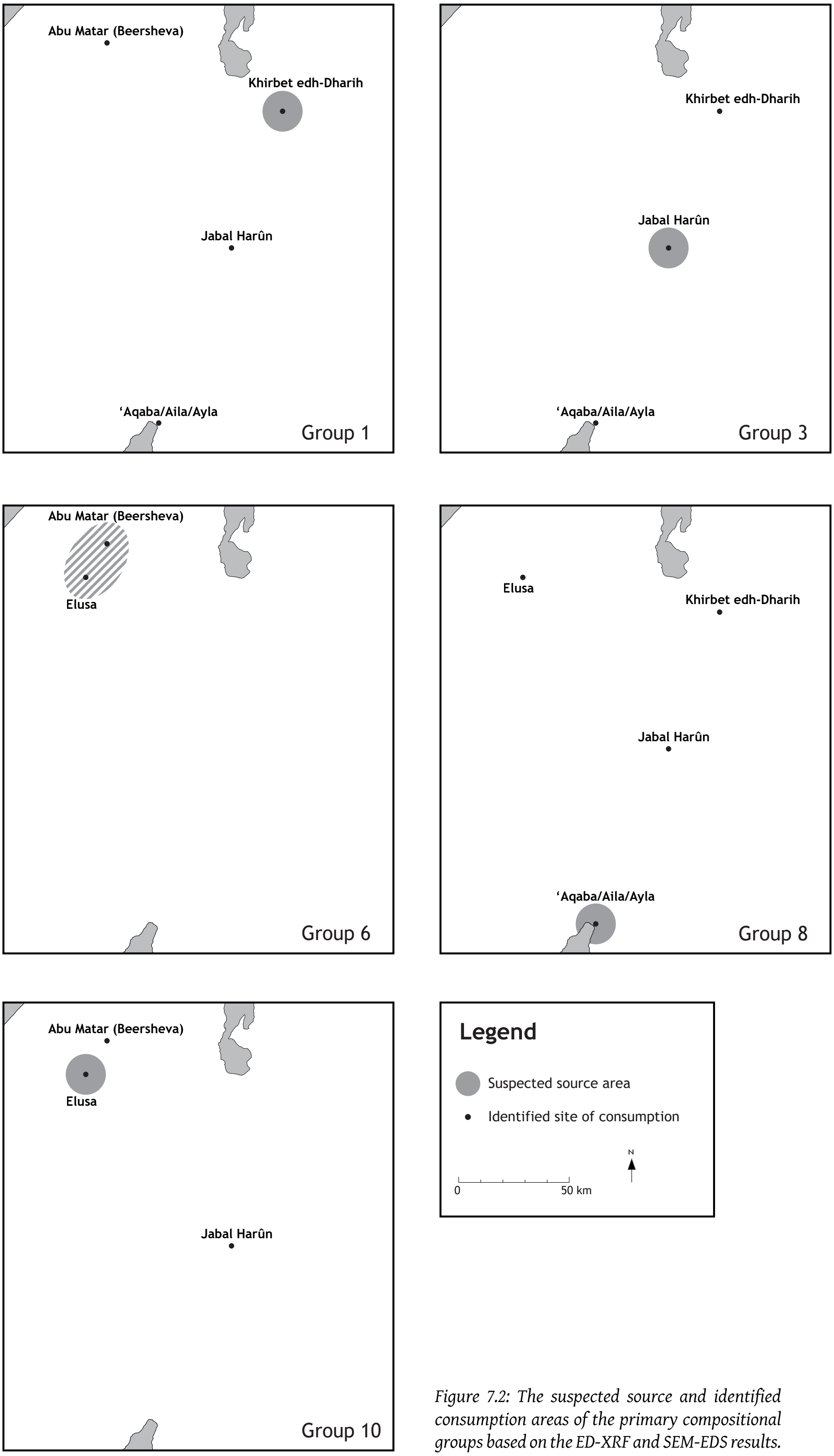

Figure 7.2: The suspected source and identified consumption areas of the primary compositional groups based on the ED-XRF and SEM-EDS results.

raw materials, the sites are located in geologically similar environments. The results, nevertheless, allow the conclusion that the ceramics in groups 1 and 3, including mainly Khirbet edh-Dharih and Jabal Harûn samples, respectively, represent slightly different mixtures of fairly similar raw materials, thus it appears that they were manufactured in different workshops which exploited the same or fairly similar raw material sources. There is also the possibility of more than two workshops (or clay mixtures) involved in the manufacture of the ceramics of these groups.

In addition to the compositional patterns, the ceramics of groups 1 and 3 also bear a striking stylistic resemblance. Another aspect of crucial importance here is that both groups are very heterogeneous in terms of ceramic forms and types, and represent a wide chronological spectrum. Considering the many forms present in these two groups, it is apparent that the same clay mixture was used to manufacture different ceramic forms for different purposes. Hence, it appears that little, if any, specialisation in raw material processing can be linked to specific forms or performance requirements, such as cooking pots or containers. It is also noteworthy that both wheel- and hand-made vessels were produced using the same clay recipe or mixture. These ceramics in general show a relatively low level of material processing, such as clay levigation. Moreover, no artificial tempers were identified in the fabric examination in SEM. It is, nevertheless, significant that all of the cooking pots in groups 1 and 3 are non-calcareous (see Tite and Kilikoglou 2002 for technological discussion). Therefore, it is possible that non-calcareous clays were specifically selected for cooking pots. The same applies for the Negev cooking pot group (group 6, see below), where this feature might also be technologically significant considering that the ceramics in this study found to be of Negev origin generally have relatively high CaO concentrations. Considering the wide chronological range of the finds in groups 1 and 3, it is also apparent that the same raw material sources were exploited for a long period of time, extending over several centuries, which, in turn, suggests a degree of economic stability.

Group 1 includes both open-form and closed-form cooking pots (DH002, DH003, DH004, DH005, DH006, DH007), jars with high necks and/or combed or painted decoration and leaf-patterns (DH011, DH014, DH015, DH016, DH017, DH018, DH020, DH021, DH026, DH027) a bag-shaped jar (DH028), amphorae (DH035, DH036), and jars with thickened, overlapping rims (DH022, DH023, DH025, DH024), basins and a coarse ware bowl (DH009, DH010). The coarse hand-made vessels (DH039, DH040, JH033) from Khirbet edh-Dharih and Jabal Harûn also cluster in this group. In addition, this group includes roof tiles, also from Jabal Harûn (DH042, DH043, JH036, JH037; see Figure 7.2). Other finds from other sites in this group include a basin (JH009) and a jar with combed decoration (JH014) from Jabal Harûn, a cooking pot from 'Aqaba/Aila (A001), and a jar from Abu Matar (AM017). On the other hand, one of the high-necked jars and a bottle (DH012, DH030, group 4) sampled from Khirbet edh-Dharih are dissimilar to these sherds and are thus likely to originate from an alternative source.

The ceramics that belong to group 3 also represent many forms. There are open-form cooking pots and a lid and a closed-form pot (JH001, JH002, JH003, JH004, JH005), basins and a coarse ware bowl (JH006, JH007, JH008, JH010, JH032), high necked jars (JH011, JH012, JH013), jars with thickened rims (JH019, JH020) and painted decoration (JH016), two jars with grooved exteriors (JH017, JH018) and with leaf-patterns (JH021, JH022), a bag-shaped jar (JH023), strainer jugs (JH024, DH029) and an amphora (JH025). Furthermore, an open-form cooking pot (DH001), a basin (DH008), a high-necked jar (DH013) and a jug (DH029) from Khirbet edh-Dharih, and closed-form cooking pots (A002, A004) from 'Aqaba/Aila belong to this compositional group (Figure 7.2). Based on macroscopic fabric comparisons between the analysed 'Aqaba/Aila ceramic samples and other cooking wares from the Aila excavations, Parker (2014: 209) has associated even a third of the closed and open-form cooking pots from the site with this fabric type, apparently originating from the Petra region.

It should also be noted that in both groups 1 and 3, there were ceramics, which, based on visual characteristics, such as colour, might be interpreted as being of a different 'ware'. However, these ceramics were proven to have very similar chemical compositions and hence probably also a common provenance (near the respective sites). Crucially, the ceramics linked here by a very similar clay mixture are far from identical in terms of typological characteristics, such as rim forms, (see, for instance, the basins), and in this light, one cannot differentiate products from different sources on the basis of the rim or the like (see typological critique in Chapter 4). Instead, there appears to have been relatively extensive variation in these details in single production systems, perhaps due to different potters operating with the same clay, or even variation in the works of one potter (see discussion in Chapter 4; Blackman *et al.* 1993: 76; Roux 2017; Roux 2003; Sillar and Tite 2000: 11–12).

Keeping this level of variability within a compositional group in mind, it is clear that one should not expect identical parallels to be found in the literature. Concentrating on the form and general stylistic trends instead, there is a vast number of comparanda that can be identified, not only from sites in the southern areas, but also from inter-regional comparisons, most importantly, with the northern areas (see Chapter 5). This allows an interpretation that there were common trends in ceramic production, and that local potters in different regions adapted similarly to the new influences, possibly arising from the need for new domestic pottery forms as a response to changing dietary customs, perhaps sometime in the 8th century. New food plants have been reported, for instance, in 'Abbasid contexts in Jerusalem markets (Amichay *et al.* 2019). As an example, open-form cooking pots, basins and high-necked jars become popular in the course of the 8th century; of course, not all of the changes are necessarily linked with preparation of new dishes or storing or transportation of new products, but may be merely changing stylistic preferences. The hypothesis of a common, 'signature style' followed by several potters would seem reasonable considering the number of sites where similar forms can be found. The production of similar forms in different workshops might also explain technological differences, such as the wheel-made basins analysed here compared to hand-made published examples, and that slips were not identified in the SEM analysis although they are often reported on similar forms in the literature.

Some of the Jabal Harûn finds cluster in group 1 and the same can be found with Khirbet edh-Dharih ceramics and group 3; thus, the results suggest some economic interaction between the sites. However, direct contact between the two communities is not necessarily required for this kind of material pattern, and there is also the possibility that the inhabitants of the two sites were supplied by the same ceramic producers independently one from the other, or purchased ceramics from the same range of merchants in the market (although, apparently, mostly they chose a specific one, perhaps the more local one). It is also probable that people living in the Petra–Khirbet edh-Dharih region visited the same regional markets where producers sold their products, including ceramics, although the material evidence for these, probably open-air markets, is difficult to find.

The notable morphological and stylistic similarity among the ceramics of groups 1 and 3 also brings up the possibility of travelling potters – there is the likelihood that the same manufactures were involved in their productions. Nevertheless, there appears to have been movement of objects (and people?) between Jabal Harûn and Khirbet edh-Dharih. It is possible, for example, that Christian or Muslim pilgrims, carrying ceramics as personal items, stopped at the village of Khirbet edh-Dharih on their way to visit Jabal Harûn or *vice versa*.

One likely option is also transportation of agricultural products from one region to the other in ceramic containers. The Khirbet edh-Dharih area, as well as the Petra region, may have been producers of agricultural products transported to other locations. The fact that containers, local versions of both amphorae and bag-shaped jars associated with the transport of agricultural products, were among both of the local groups implies that the Khirbet edh-Dharih and the Petra area were involved in the export of agricultural products, and there was local production of containers to facilitate these activities. On the other hand, the containers from other origins found at the sites show that goods were also imported there. The aspect that both of the communities were Christian might also explain the material relation between the ceramics, as they might have favoured the same Christian producer, although the religion of the Khirbet edh-Dharih population in the Islamic period is unknown, and Jabal Harûn was at least visited by Muslims as well. There is evidence from Roman period Galilee, that Jewish communities purchased cooking vessels from the same producer, in some cases located dozens of kilometres from the consumer community, because these specific products were considered ritually pure (Adan-Bayewitz 1993). Although it is not implied here that Christians had similar purity laws, this example illustrates that cultural and religious factors may play an important role in seemingly non-religious everyday choices.

Considering the utilitarian nature of these products, it is also likely that in addition to the ceramic suppliers of these two sites, there were other workshops as well. Evidence for early Islamic ceramic production has not been found in the Khirbet edh-Dharih or Petra areas, or, for instance, from Humeima or Udhruh, but the results presented here strongly imply that there were, in fact, at least two ceramic workshops in southern Transjordan in addition to the 'Aqaba/Ayla kilns. Perhaps, in contrast to the northern kiln sites located in the town centres (see, e.g., Bar-Nathan and Atrash 2011; Bar-Nathan and Mazor 1993; Schaefer 1986; Tsafrir and Foerster 1997), these kilns were located in more of a rural environment, or they have yet to be identified in urban contexts, such as in Petra. In Elusa, for instance, the Byzantine workshop is on the edge of the Byzantine town, and this may have also been the case in the early Islamic period.

Some typological categories deserve a special discussion here, in terms of the relations of the two sites, their ceramic suppliers and the clay sources/mixtures. Starting with the coarse hand-made vessels of later, probably post-11th century date, all three of them found at both sites fall into group 1. This might be indicative of the fact that the raw material source, clay mixture, or manufacturing tradition of group 1 was longer lived, but the three sherds included in this study are completely inadequate to evaluate chronological differences between the productions. Similarly sparse evidence is available for the tiles, none of the ones from Jabal Harûn clustering in group 3, but speaking of tile import would probably be far-fetched. Perhaps some ceramic forms, such as roof tiles, were supplied by a specific production centre, although this was not necessarily the case – in Jerash tiles were manufactured in the same workshop as domestic ceramics (Kehrberg 2009: 498; Schaefer 1986: 427–429).

One noteworthy category present in both groups are hand-made jars with painted or leaf-pattern decoration. For some reason, these jars were hand-made, while wheel-made jars were also produced. The leaf-pattern jars from Jabal Harûn and Khirbet edh-Dharih are very similar in terms of general appearance, although each of them has a unique decoration pattern. In light of their shared characteristics, it is of interest that they divide into different groups, the leaf-pattern jars from Khirbet edh-Dharih, DH026 and DH027, belonging to group 1, whereas sherds of a similar type from Jabal Harûn, JH021 and JH022, belong to group 3. This indicates that despite the apparent similarities among these vessels, such as decorative motifs, wall thickness and colour, they appear to originate from different sources, although from the same region. This jar type seems to be a phenomenon typical of southern Transjordan; no published parallels were found elsewhere, and if there was no single source for these jars, it is likely that they were produced in various workshops in the area, following similar stylistic and functional attributes. It is also possible that we have here one workshop imitating another. Although the four sherds analysed here divide into two compositional groups, a larger sample is needed to confirm whether there were one or more sources for these jars. The sample of four analysed in this study is inadequate to exclude the possibility that the variation in their composition is merely variation in one clay mixture or production sequence.

The different manufacturing technique of painted and leaf-pattern jars could be a technological choice for practical reasons made by a potter rather than an indication of a separate, hand-made manufacturing tradition. The necessity for the hand-made manufacturing technique in the case of the jars might be explained by the fact that at least the leaf-pattern jars seem to be relatively large-sized containers. For example, complete leaf-pattern jars from the Petra church, providing a very close parallel to the decoration of the sherds sampled for this study, were nearly 80cm high ('Amr 2001a). This kind of size requirement for a vessel may have forced the potter to use the coil-building technique, as it would have been difficult to produce a vessel of this size on a wheel. In addition, at least the painted jar sherds sampled from Khirbet edh-Dharih seem to belong to large containers. The different jars may have been for separate purposes, and characteristics such as handle placement, rim and neck form, and vessel size and wall thickness can also be determining functional factors. Different decorations might also be indicators of not just style but also the expected content of the vessel.

The painted sherds recovered at sites in the southern areas, as sampled for this study from Khirbet edh-Dharih, Jabal Harûn, Elusa and Abu Matar are of particular interest for inter-regional ceramic transportation as they might be of northern origin. In this respect, it is perhaps surprising that the two painted sherds found at Khirbet edh-Dharih (DH020 and DH021) belong to compositional group 1 and thus can be considered to be of 'local' origin. Similarly, a painted jar sherd from Jabal Harûn (JH016) belongs to compositional group 3. This might indicate that reddish-brown painted jars were also manufactured in the southern areas, possibly imitating the northern tradition. There are, however, also painted sherds that are outliers and thus probable imports. This is the case of one of the Khirbet edh-Dharih sherds (DH019), which does not share compositional characteristics with the other samples. Painted sherds from Jabal Harûn and Abu Matar (JH015, group 8b; AM014, group 7) are also outliers in the data set and apparent imports to the sites. A painted sherd from Elusa, E010, does not cluster with the local Elusa ceramics (group 10b), but its composition is closer to the Negev cooking pot group (6). At the moment, the provenance of these sherds remains unknown, but it is possible that their origin is further north, since painted wares are known to have been produced at least at Jerash (Schaefer 1986). Possible future analysis including samples from northern sites might shed further light on this matter. If the sherds were found to be northern exports, they would provide evidence of material exchange as well as stylistic imitation and influence diffusion between the regions. Furthermore, inter-regional exports brings up the aspect of two-way traffic, in this case, the possibility of ceramics or other products of southern origin transported further north. The results of this study have shown that ceramic exchange between two sites often appears to flow in both directions.

A further aspect of interest is the larger size of the Jabal Harûn cooking pots compared to those from the other sampled sites, and this may well be linked to the socio-economic nature of the site, and the food preparation practices of the communal kitchen of the monastery in contrast to household cooking wares at the other sites. In addition, other large kitchen utensils, such as basins, also appear more regularly in the Jabal Harûn assemblage than at the other sites. The samples in this study are, however, insufficient in number to draw conclusions on differences in vessel volumes between the sites, but the possibility that the apparent difference in volume between the Khirbet edh-Dharih and Jabal Harûn cooking pots is linked with the compositional differences between groups 1 and 3 cannot be ruled out.

Perhaps the monastery ordered specially made larger vessels, which might explain the slight material variation between the assemblages. For instance, perhaps the ceramics came from the same producer, but minor differences occurred in the clay mixture of the specific batch; e.g., the clay mixture was manipulated to produce larger vessels (large quantities of similarly cracked cooking pot bases were found during the excavation of Trench Z, and this might indicate that the strength or the thermal-shock resistance of the large pots was not always adequate).

In terms of chronology, the majority of the ceramics in groups 1 and 3 can be dated to the 2nd half of the 8th–early 9th centuries. This date most likely concerns the open-form cooking vessels, basins, and the high-necked jars, combed and painted decoration, and probably also the leaf-pattern jars. The coarse, hand-made vessels in group 1 are likely to date to the mid-11th century or later, but as these vessels cannot not be associated with HMGPW, or other related traditions, their date will have to remains ambiguous, possibly extending up to the modern period. Nevertheless, it is of crucial importance that these vessels share compositional patterns very similar to those of the earlier vessels. Both groups also include earlier variants, closed-form cooking pots that can date from the 1st to 4th/5th centuries, and jars, such as those with a thick, folded rim and the bag-shaped jars, probably dating from the 6th century through the Umayyad period.

To conclude, these results indicate that local ceramic production continued in the environs of both Jabal Harûn and Khirbet edh-Dharih at least into the 9th century, and later, as is attested by the later, probably post-11th century coarse ware vessels. Similar evidence is available from Jerash, where ceramic manufacture continued unaffected throughout the late Byzantine–early Islamic transition, and the same raw material sources were exploited from the 6th throughout the 7th and 8th centuries (Duerden and Watson 1988; Watson 1989). Furthermore, an analogy can also be found from Jerash for the various forms produced in a single workshop – different forms from utilitarian wares to lamps were recovered in a failed, unfired kiln load (Kehrberg 2009; see also Heidemann 2006; Henderson *et al.* 2005: 138–141).

Similar evidence for production of different forms with different techniques at the same workshop is also available from ʻAbbasid al-Raqqa (Heidemann 2006; Henderson *et al.* 2005: 138–141). Most of the ceramics in both groups are high-quality utilitarian wares, which may be indicative of industrialised ceramic production. The quality of these ceramics indicates that they were manufactured on a communal level instead of household manufacture. There appears to have been a strong tradition of utilisation of the same, traditional, raw materials in ceramic manufacturing in the area, and although new ceramic forms were introduced in the course of the early Islamic period, these ceramic innovations were materially very much part of the earlier, local ceramic manufacturing traditions.

Thus, these two rural communities, Jabal Harûn and Khirbet edh-Dharih, appear to have had a ceramic producer that supplied them preferentially. The precise locations of these workshops remain unknown. Nevertheless, the results provide evidence for ceramic production in southern Transjordan in the Umayyad and ʻAbbasid periods, continuing at least into the 9th century and beyond as is shown by the hand-made coarse wares, although it cannot be established here whether the production continued uninterruptedly throughout the 9th–11th centuries. In terms of the chronology of groups 1 and 3 ceramics, a date of later 8th–early 9th centuries is suggested here for the majority of the samples, with earlier, Umayyad, Byzantine and Nabataean/Roman and later, post-11th century variants. However, some forms, such as the basins, have parallels from 11th century contexts, and thus it cannot be completely excluded that some of the samples, in addition to the coarse hand-made vessels, date, in fact, to the 10th and 11th centuries.

Elusa and Abu Matar cooking pots (group 6)

Compared to the situation with Jabal Harûn and Khirbet edh-Dharih – apparently separate sources for domestic and utilitarian vessels, and little indication of specialisation involved in the manufacture of different functional forms – the results gained from the Negev sites provide another perspective on cooking ware economy. The ʻNegev cooking pot group', compositional group 6, includes all the cooking vessels analysed from Elusa and Abu Matar (AM001–005, E001–005), and some other forms (basin AM006, bowl AM009, jar AM012, painted sherd E010), but none of the wasters from the Elusa workshop. Hence, these results illustrate that these two sites had a shared supplier of cooking pots (Figures 7.1 and 7.2). The cooking vessels clearly share a common geological source, and represent a relatively standardised form of production as is demonstrated by the very limited variation in the chemical compositions of the cooking pots. The open-form cooking pots recovered from the sites are also typologically very similar.

It is intriguing that wasters from the Elusa workshop (group 10b, see below) represent a very different clay mixture, and thus the manufacture of the cooking pots cannot be linked with the production at the Elusa workshop, and their provenance remains unresolved at the moment. Nor can the source of the cooking pots can be associated with Abu Matar, since its ceramic assemblage appeared compositionally varied with no distinctive and dominant compositional characteristics identifiable as local to the site. Another aspect that suggests that the cooking pots were part of a specialised production regime is that they are of non-calcareous fabric, the opposite of the Elusa products and the majority of other samples from the Negev sites, with a relatively high CaO content (similar to the Jabal Harûn and Khirbet edh-Dharih pots, see above). There is evidence also from elsewhere that calcareous clays were used in amphorae production, possibly for technological reasons, e.g., to ensure stronger vessels for transport (see, e.g., Barone *et al.* 2012: 20–21).

According to the excavators, the terminal date of the Elusa workshop, specialised in the production of containers, such as the Elusa jars, was not later than the 6th century (Fabian and Goren 2002; Goldfus and Fabian 2000). The town was inhabited, however, at least into the early 8th century, and may also have had an administrative role in the early Islamic period. Thus, in addition to being a separate production system, there appears to be a chronological difference compared to the Elusa workshop, since these products were found in later contexts at Abu Matar. Proposing a start or a terminal date for the cooking pot production presents us with a problem, and the production may well have continued from the Byzantine period into at least the 8th century. The closed-form cooking pots (E004, E005) in this group may be indicative of a Byzantine date (although it is not suggested here that this form cannot date to the early Islamic period), while the open-form pots from the same source found in early Islamic contexts at Abu Matar (AM002, AM003, AM005) clearly indicate that this production was active at least into the 8th century, and probably later. Stylistically, the open-form cooking pots from both sites belong to a category which seems to have been favoured for a long time, in the Byzantine–early Islamic periods. Thus, it is possible that the cooking pots found at the two sites represent a relatively wide chronological spectrum.

The ‘cooking pot group’ also includes a basin with finger-impressed decoration, and one bowl found at Abu Matar (AM006, group 6a; AM009, group 6b). Furthermore, some other forms, including a jar with combed decoration from Abu Matar (AM012) and a painted sherd from Elusa (E010), appear related to this group in terms of compositional patterns, although somewhat different from the uniform compositions of the cooking pots. Typologically, these samples may be associated with the early Islamic period, further attesting to the chronological continuation of this production in the 8th–9th centuries, but they are derived from unstratified contexts.

The compositional differences between the Elusa wasters and the cooking pots implies that the cooking pots were produced in another workshop, especially as cooking pot wasters were not found in the deposits related to the workshop activity (P. Fabian, personal communication, 2007). If the cooking pots were produced in a separate, unidentified workshop, its location in Elusa, or Beersheva, cannot be excluded. It can be concluded that the two sites, Elusa and Abu Matar in Beersheva located *c.* 20km apart, shared, at least to some extent, cooking pots from the same source. The very uniform compositional patterns of the cooking pots largely exclude the possibility that different manufacturers used related raw material sources – as appears to have been the case with groups 1 and 3.

Furthermore, the lack of evidence for cooking ware manufacture at the Elusa workshops, and the compositional dissimilarity between the cooking pots and the ceramics produced at the Elusa workshop, indicate specialised production of different ceramic forms. Thus, it appears likely that the cooking pots were produced in a workshop other than those identified in Elusa, specialised in containers, such as the so-called Elusa jars and water jugs (see Fabian and Goren 2002). The question of whether the cooking pot source, shared by at least Elusa and Abu Matar, was a centralised place for the production of cooking pots and a principal supplier of cooking pots for Elusa, Abu Matar, Beersheva or a larger network of communities in the Negev, cannot be answered on the basis of this evidence. It seems clear, however, that the Elusa community acquired non-calcareous and hence probably better quality cooking wares from a producer unrelated to their local container-manufacture, exploiting local, calcareous clays.

The apparent standardised level of production of the cooking pots, as illustrated by the very slight compositional variation among them, might, in fact, explain the shared cooking pot supplier between Elusa and Abu Matar. Cooking pots of standardised quality and production, with consistent performance qualities, such as thermal shock resistance, crucial to the usability of the pots, would probably have made them desirable products for a larger consumer base (see Kingery 1996: 175, 195–200; Kilikoglou *et al.* 1998: 261; Schiffer and Skibo 1997: 27–30; Tite and Kilikoglou 2002; Tite 1988: 11–13). Other forms also seem related to the cooking pot raw materials and manufacturing, although on a less standardised level or perhaps employing a slightly different clay mixture. It appears that the same production centre was also involved in the production of other forms, exploiting very similar raw materials, but the production procedure was slightly different compared to the cooking pot manufacture (subgroups 6a–b vs. 6c).

The communities of Elusa and Abu Matar may have acquired at least some of their cooking vessels from the same production centre, either directly from the supplier or via markets. Future analysis of cooking vessels from other Negev sites might provide further information concerning these cooking vessels supply, in terms of where the production was located and whether the supplier was shared only by Elusa and Abu Matar, or a larger network of communities in the Negev. These results highlight the fact that technical specialisation also played a role in domestic ceramics, and that these ubiquitous finds can reveal important economic evidence. In light of the results, it seems unlikely that the cooking pots were domestically produced, but rather that they were manufactured in a specialised workshop, at least on a communal, if not on a regional, centralised level.

‘Aqaba/Aila production (group 8)

Group 8 is clearly dominated by ‘Aqaba finds, as 15 of the analysed 20 ‘Aqaba sherds fall into this group on the basis of their chemical composition, and therefore this group can be considered to be local to ‘Aqaba. Furthermore, the ’Aqaba/Aila amphorae (A017 and A020), known to have been produced locally at ‘Aqaba (Parker 2014; Melkawi *et al.* 1994), belong to this group, attesting that this compositional group is most likely of ‘Aqaba origin. The sherds belonging to this group recovered at the other sites, Jabal Harûn, Khirbet edh-Dharih and Elusa (Figure 7.2), are thus very likely to be imports from ‘Aqaba (with some exceptions, see below). The ceramics assigned to group 8 on the basis of the bulk chemical compositions obtained from the ED-XRF analysis also showed similar mineralogical inclusions and ceramic matrix composition in the SEM-EDS analysis.

In addition to the composition, the suspected ‘Aqaba/Aila imports at the other sites also share other characteristics. All of these samples are containers, mainly grooved amphora body sherds of greenish ware that can be associated with the ‘Aqaba/Aila amphora type (DH031, DH032, DH034, DH037, DH038, E014, JH027, JH028, JH031 and JH037). The fabric characteristics of the amphorae, with large quartz inclusions, may also be intentional, to increase the toughness of these containers (see Sillar and Tite 2000; Vekinis and Kilikoglou 1998; and Chapter 4 for technological discussion). In terms of chronology, these finds can be dated from the Byzantine period to the 8th/9th centuries (for discussion, see Chapter 5), while the dates of the finds from the ‘Aqaba/Aila excavations in the group range from the Nabataean/Roman periods into the Umayyad period. Based on macroscopic fabric examination, it appears that 75 % of the pottery finds from the Roman Aqaba project’s excavation represent this fabric type (Parker 2014: 209).

Forms other than amphorae represented in group 8 and its subgroups, such as cooking pots, are all finds from the ‘Aqaba excavations. The different ceramic forms in the group indicate that the same raw material sources were used to produce different vessel forms for different functions. Hence, in contrast to the evidence of groups 1, 3 and 6, cooking vessels in these groups (A003, A005, A006 and A009) are also of calcareous fabric. Therefore, the same clay recipe with little variation was used in the mass production of the amphorae, as well as in cooking pot production (cooking pot wasters were also found in the excavation of the kilns, see Melkawi *et al.* 1994: 456, 458; Whitcomb 1989b: 181). In this respect, it is interesting that vast quantities of Petra region cooking pots (made of non-calcareous clay with better thermal-shock resistance) were also transported to Aila, which might imply that the Petra origin pots were preferred for their quality.

In addition, the analytical data combined with chronological evidence again shows that similar raw materials, possibly the very same raw material sources, were used for centuries in the ceramic production at ‘Aqaba, since ceramics belonging to this group represent different chronologies extending from the early Roman/Nabataean period into the early Islamic period, at least to the mid-8th century. As also appears to be the case with groups 1, 3, and 6, the chronological diversity of finds in group 8 further attests to the picture that political changes have little immediate effect on local ceramic manufacturing traditions and craft organisation, especially on the material side of things. Furthermore, here again we have evidence of ceramics of very different functional categories (open-form cooking pots and amphorae) belonging to the same compositional groups, and likely to originate from the same workshop.

In terms of ceramic export, it is intriguing that the amphorae of ‘Aqaba origin were transported overland inter-regionally, even stretching over long distances. These results show evidence of the presence of the ‘Aqaba amphorae at Jabal Harûn, Khirbet edh-Dharih and Elusa, the latter two located approximately 200km from the production centre of these vessels. The results demonstrate that this amphora type was not only used in sea transportation, but also to carry goods in the inland distribution network. This study shows that the ‘Aqaba/Aila amphorae, previously thought to have been used to re-pack land transported agricultural goods for the Red Sea trade (Melkawi *et al.* 1994: 463–464; Whitcomb 2001a), were also transported as far as Khirbet edh-Dharih and Elusa, being the northernmost locations where these amphorae have been identified so far. Furthermore, the results presented here provide a material confirmation to the earlier suggestions that these amphorae were found in Petra, by attesting that amphora sherds unearthed at Jabal Harûn are of ʻAqaba origin (see also Holmqvist 2013 for Aila-origin pottery from Humeima).

For profitable overland transportation over such extensive distances, these amphorae probably contained relatively valuable products, making their transportation worthwhile. There is evidence of the remains of high-quality *garum* recovered in an early Roman period jar at ʻAqaba (Van Neer *et al.* 2010; Van Neer and Parker 2008), and a similar content might explain the wide distribution network of the amphorae. The suggested export of Red Sea fish products from ʻAqaba is also supported by the remains of Red Sea species recovered at sites in southern Transjordan and the Negev (Frösén *et al.* 2001a; Lernau 1986), fish playing an important role in the diet of Christian communities, which might explain the wide distribution network of the possibly-amphorae-borne Red Sea fish products.

The aspect of possible inter-regional or long-distance inland transportation of ceramic containers is often neglected in ceramic studies, and it is generally thought to have been economically unprofitable due to the assumed high costs of inland transportation compared to maritime shipping, and the low-value bulk goods associated with ceramic containers (see, e.g., Adams 2007; Greene 1986: 40, 169; and Jones 1964: 841–842). However, one might question high costs related to, for instance, donkey-borne land transportation, especially with the evidence of high-value products, such as *garum*, being transported in amphorae and bearing in mind that there was a long tradition of overland transportation of spices, incense and cosmetics, and an existing infrastructure for transportation. Although the content of the transported ʻAqaba/Aila amphorae cannot be known with certainty, large amounts of Red Sea fish remains at inland sites might be linked with these vessels, and may suggest that fish products were transported in these vessels. In addition, the excavators of the ʻAqaba ceramic workshop, which revealed production of these amphorae among other forms, concluded that the extent of the production, reaching the levels of industrial mass production, exceeded the requirements of the local community (Melkawi *et al.* 1994). Again, this would indicate an economic agenda behind the ceramic production regime: the exportation of specific high-value products for wide distribution would have required an established infrastructure to support the economic activity, most crucially local and specialised mass production of good quality containers for the transportation.

An expected high profit on the transported products would have covered both production and transportation costs. Therefore, it is suggested that although archaeological evidence does not provide insight into the actual transportation methods used in the distribution of these vessels, it may well be that costs related to inland transportation were not always as high as has been estimated. Historical evidence indicates a communications network and established routes continued into the early Islamic period (see, e.g., Walmsley 2000: 304, for references), and a well-maintained road system might have made the overland transportation costs lower than one might expect. In addition, ethnographic evidence shows that with high demand, even ceramic containers themselves can be subjects of profitable, donkey-carried inter-regional or long-distance trade (see Vossen 1984).

Accordingly, if the contents of the ʻAqaba amphorae, such as Red Sea fish, were in high demand, there is no reason to assume that their transportation of 200km or more on donkeys or camels would not have been a profitable trade activity. Given that amphorae have vast possibilities for secondary use (see Peña 2007 for examples; see also Pecci *et al.* 2017), the transportation of the products in ceramic containers might have added to the sale value, covering the extra costs of carrying ceramics instead of skins. Taking account of the mass of full ceramic containers and the fact that a camel can carry considerably heavier loads compared to a donkey, camel transportation would appear to be a more economical option especially for the areas under discussion – arid and hyperarid (see Adams 2007: 49–81, for donkey vs. camel discussion).

As a note to the various subgroups of group 8, the samples recovered at the other sites associated with this group in the cluster analysis of the ED-XRF data include painted sherds from Jabal Harûn and Khirbet edh-Dharih (a jar JH015 and DH019) and an Elusa find resembling a so-called LR 1 jar (E013); the latter type is usually considered to have been produced in Antioch or Cyprus (see Calderon 2000: 186–187; Calderon 1999: 139, Pl. 2:1; Demesticha and Michaelides 2001: 296; and Landgraf 1980: 81). A detailed examination of the compositional patterns of these three samples suggests that although they share some general concentration patterns with group 8, all of the examples also contain chemical concentrations that force one to question their association with this ʻlocal ʻAqabaʼ group. Accordingly, it seems that the red-painted sherds from Jabal Harûn and Khirbet edh-Dharih (samples JH015 and DH019) are imports to the sites where they were recovered, but cannot be associated with the same geological origin as the core group 8. Therefore, their origin remains unresolved at the moment. The same applies to the suspected LR 1 jar (E013) found at Elusa: this jar clearly belongs neither to the local ʻAqaba nor the local Elusa ceramic groups identified in this study, but its production area requires further examination. The composition of the sample shows a great difference with the other analysed samples, and therefore, it is possible it represents a foreign import. The other amphora from Elusa belonging to group 8, E014, on the other hand, clearly appears to be a body sherd of an ʻAqaba/Aila amphora type, thus appearing to be an import transported to Elusa from ʻAqaba as indicated by the ED-XRF and SEM-EDS data and the visual and morphological characteristics of the sherd.

One of the cooking pots sampled from ʻAqaba (A007, compositional group 2) does not share compositional characteristics with any of the other sampled sherds. The compositional difference does not necessarily mean that the cooking pot was produced outside ʻAqaba, but it may just represent different manufacture and different raw material sources than the other sampled ʻAqaba ceramics. Moreover, one of the amphora sherds (A018, group 13) found at ʻAqaba, appears as an extreme outlier on the basis of the ED-XRF and SEM-EDS results. It seems different compared to ceramics assigned to group 8, and to all of the other samples. The origin of this sherd remains unresolved for the time being, but according to its composition, it might be a foreign import.

Elusa workshop production (group 10)

Compositional group 10 is dominated by samples recovered at Elusa. The majority of the samples analysed from the site, 12 out of the 20, belong to this group as shown by the cluster analysis of the ED-XRF data. Most importantly, all of the wasters sampled from the ceramic workshop at Elusa are included in this group. Thus, it can be concluded that this group is local to Elusa. Regarding possible material resources, it appears that some raw materials may have been transported to the site, as is indicated by magmatic minerals unlikely linked with the local geology (see Arnold 1985: 39–49 for raw material transportation).

The date of the workshop encountered on the edge of the Byzantine city was associated with the 6th century (Goldfus and Fabian 2000), although it does not necessarily mean that the same clay source was not exploited beyond this date by another workshop, especially when considering the evidence provided by ceramics in groups 1, 3 and 8, the chronology of which extends over hundreds of years, suggesting that the same material sources were used, although the actual workshops probably changed over time. As discussed above, group 10 does not include any of the cooking pots analysed from Elusa or from the other sites. All of the cooking pot samples from the two Negev sites belong to group 6, probably representing a separate production. It also appears that the Elusa workshop concentrated on the production of other forms, particularly jars (see Fabian and Goren 2002).

Although the wasters appear over-fired, their microstructures do not display a very glassy or bloated structure, and particularly the presence of mineralogical inclusions such as calcite in the fabrics indicates the firing temperatures were not very high. Thus, it is likely that other, unidentified, factors contributed to the failed production of these vessels.

Group 10 (see Figure 7.2) includes the kiln wasters from the Elusa workshop, representing various vessel forms, water jugs (E015 and E016), a jar (E020), and unidentified forms (E017, E019 and E018), nevertheless likely to be some sort of container. The jar waster, sample E020, is possibly a waster of the Elusa jar type, although this one and sample E011 (Elusa jar) show some differences in their morphological characteristics. In addition, group 10 includes bowls from Abu Matar and Elusa (AM008, E006 with finger-impressed decoration, E007, E008 and E009) and two jars, one from Abu Matar, possibly a bag-shaped type with grooved exterior (AM015) and a jar from Elusa (E011). The later was confirmed to be an Elusa jar, produced locally at the site, a type relatively similar to the Gaza jars (see Fabian and Goren 2002). Group 10 also includes an amphora sherd recovered at Jabal Harûn (JH029), which appears to be an import from the Negev, or from Elusa, to Jabal Harûn. Interestingly, this group includes two large basins found at Abu Matar (AM010 and AM011), which appear to be of early Islamic date (typological parallels ranging from the 8th up to 11th century contexts, see Chapter 5). This might suggest that the same raw material sources were, in fact, exploited by another manufacturer in a later period, after the workshop that produced the wasters analysed in this study was no longer functioning. Furthermore, group 10 includes an engraved (*Kerbschnitt*) sherd found at Elusa (E012), suggesting that this typologically unusual find in the Elusa assemblage belongs to the local Elusa group. Unfortunately, the typo-chronological assignment of this sherd (as with the other engraved sherd, JH034, group 14, unknown source) is unclear and it comes from an unstratified context.

Furthermore, ceramics of compositional group 9, including a bowl (AM007, a similar to form AM008 of group 10a), the cream ware vessel (ʻKhirbet al-Mafjar typeʼ, AM019) and a jar, possibly bag-shaped (AM016), all found at Abu Matar are relatively similar in terms of compositional patterns to group 10. Therefore, although they cannot be directly linked with the Elusa production, their compositional patterns indicate that they originate from a relatively similar geological region, and might just represent variation in the material processing, particularly in the cases of AM007 and AM016, which have morphological parallels in the local Elusa group 10. The cream ware sherd (AM019), on the other hand, represents a very different, mould-made manufacturing technique, which may partly explain its compositional differences compared to the other analysed samples. Its compositional difference, particularly compared to group 10, can also probably be explained by a chronological difference, as this sherd can be dated to the 10th/11th centuries, and is thus later than the Elusa wasters. In addition, ceramics of group 11, two jars from Abu Matar, one with combed decoration likely to be of early Islamic date (AM013) and another of the hole-mouth jar type with a ridged rim (AM018), share some compositional characteristics with group 10 samples, but can only be associated very generally with a similar geological region, in this case the Negev area, from where these ceramics are likely to originate.

It can be concluded that in addition to the shared cooking pot source, there are also other material exchanges between Abu Matar and Elusa. Four Abu Matar samples cluster in group 10, local to Elusa, whereas an additional three belong to group 9, related to group 10. Hence, Abu Matar is the only one of the five sites included in this study to which even a tentative local ceramic compositional group cannot be assigned. This is not necessary surprising considering the socio-economic nature of the site as a farmhouse in a suburb of Beersheva. One might expect that the inhabitants acquired their ceramics from, for example, markets in Beersheva. The mineralogy of the cooking pot group might relate more closely to the geology of the Beersheva area compared to that of Elusa, but this cannot be stated with certainty as, in general, both areas are geologically very similar. Group 11, containing only 2 sherds, which can only be related to the Negev geology in a very generic way, are not sufficient to argue that these vessels are local to the Abu Matar area, or Beersheva. It appears that forms originating from the Elusa area, either from the identified Elusa workshop, or from another workshop using the same raw material sources, were transported to Abu Matar.

The ceramics discussed here with linked compositional patterns represent late Byzantine–Islamic forms, probably 6th–11th centuries. Thus, if the terminal date for the Elusa workshop is in the 6th century, there probably was a later period workshop that was exploiting the same raw material sources somewhere relatively close to both Elusa and Abu Matar. However, considering the material dissimilarity between groups 6 and 10, this later production may have been separate from the cooking pot provider of the two sites. The clay mixtures used to manufacture the ceramics of 6, 9, 10, and 11 are very different, although there is always the possibility that a potter used a different recipe for different forms.

Glazed vessels (groups 5, 12, 15)

The alkaline glazed monochrome sherd from Khirbet edh-Dharih (DH041, compositional group 12) represents a different glazing technology from the lead silica glazed sherd from Abu Matar (AM020, group 15) and the one from Jabal Harûn (JH035, group 5). Both glazing technologies were commonly used in the Islamic world, and although it is difficult to provide an absolute date for these bowl fragments, they are likely to date from the late 8th/9th centuries or later (a 13th century parallel was found for JH035, see Chapter 5). The differences in the technological and compositional characteristics indicate different production centres for these glazed vessels. It also appears that the glazed vessels sampled from the three sites were made of different raw materials than most of the ceramics of these sites, and therefore these sherds are probable imports, possibly originating from a workshop specialised in the productions of glazed vessels. Although, it is possible that unglazed and glazed ceramics were also produced in the same workshops (see Heidemann 2006; Henderson *et al.* 2005: 138–141).

The compositional results suggest that all of these sherds come from different sources, although the two sherds with high-lead content glazes (JH035 and AM020) considerably share similar technology and glaze composition. Considering that lead-glazed ceramics are relatively uncomplicated to produce compared to alkaline glazed ones, they might just represent technologically related productions. Trace element composition of sample AM020 could not be attained because this sherd was too small for ED-XRF sample preparation. Glazed ceramics are rare finds at the sites, but nevertheless represent ceramic imports to Abu Matar, Jabal Harûn and Khirbet edh-Dharih in the Islamic period. Imported glazed wares and other possibly 'exotic' wares at the three sites are not very frequent finds, a phenomenon which has also been found at sites with highly commercial statuses, such as Ayla (see Khouri and Whitcomb 1988: 29; Whitcomb 1989c: 270). Together with the cream ware sherd (AM019), the presence of the glazed sherds at Abu Matar suggests that the site was inhabited in the 9th–11th centuries, if these finds are not later intrusive materials in their contexts. There were also other forms, such as the basins (AM010 and AM011), which may date to the 11th century recovered at the site.

Shared ceramic traditions and socio-cultural implications

As discussed above, there are a vast number of typological parallels that can be found for the sampled ceramic forms in published site reports. In particular, the later 8th–9th century ceramics from Jabal Harûn, Khirbet edh-Dharih and Abu Matar appear to be representatives of a 'signature style' followed by locally operating potters in different regions. Stylistic attributes, such as open-form cooking pots, comb-decorated basins and jars, and painted jars are present in early Islamic assemblages in southern Transjordan and the Negev, as well as in areas located further north, although obviously there are regional differences, and ceramic traditions that are local to certain areas, such as the leaf-pattern jars (see Figures 7.3, 7.4, 7.5 and 7.6; see also in Chapter 4, and, e.g., David and Kramer 2001: 139; Franken 2005: 15; Franken and Kalsbeek 1975: 21; Gosselain 1992: 560–561).

In my view, the ceramic traditions of the southern areas are linked to the ceramic trends in the wider cultural context, brought to different regions by inter-regional movements of people, tastes and influence, through pilgrims and merchants, and then adopted by the local ceramic workshops due to changing market preferences and other factors, such as changes introduced in food preparation practices or new crops and dishes (see technological change in Chapter 4; Rice 1984a: 245–247; Schiffer 1990: 374). Hence, local or regional workshops manufactured ceramics in styles, which can be seen as members of the same, typologically related 'family'. Comparable evidence of regional workshops producing typologically parallel ceramics is already attested for transport vessels (see Reynolds 2005).

One option for the similar stylistic adaptation in separate regional productions is also travelling potters who utilised local raw material resources wherever they operated (for discussion in relation to HMGPW, see Johns 1998: 70–74), but the idea of itinerant potters alone is unlikely to explain the wide distribution of some ceramic styles.

It can be difficult to ascertain the direction of the flow of influences, but north-south, as well as east-west links can be seen, and one can expect these interactions to have been two-way, and to correspond to the existing evidence for routes crossing the regions. Thus, the southern areas were subjected to influences diffusing from numerous sources, from places such as Amman, Baghdad, 'Aqaba/Aila, al-Hijaz, the Arabian Peninsula and Egypt. Therefore, rather than being seen as characterised by 'regionalism' in ceramic traditions, a positive model would be to see the southern areas in direct contact with all these cultural centres of the Islamic world and more of a cultural melting pot, with a ceramic culture representing all these influences.

Chronologically, inter-regional ceramic evidence should be treated cautiously, but as we are dealing with an area which was possible to travel across in a few days time (see Walmsley 2009; and estimated travel times in al-Muqaddasi 1994: 175–176), there were not necessarily great chronological gaps in the flow of influences. Instead, the trigger for this development may have occurred in relatively 'real-time' in ancient terms, that is, in a few days, weeks, or months. If a traveller, for instance, saw or purchased an innovative ceramic product during his travels, and then requested a similar product from his local potter after arriving home a few days later. One can expect that the potter was able to perform this request relatively soon, especially if the adaptation of the new forms and styles did not require substantial raw material processing or new raw material resources, but that the technological modification was attainable by using practically the same clay mixture. In other words, the potter was able to maintain most of his or her *chaîne opératoire*, and had to alter only the last stages of the 'operational chain' (see Chapter 4 for this concept).

The conclusions of the typo-chronological and analytical ceramic analysis of this study and their socio-economic implications will be drawn in the following section. Furthermore, more emphasis will also be placed on the historical evidence regarding ceramic economies and market systems.

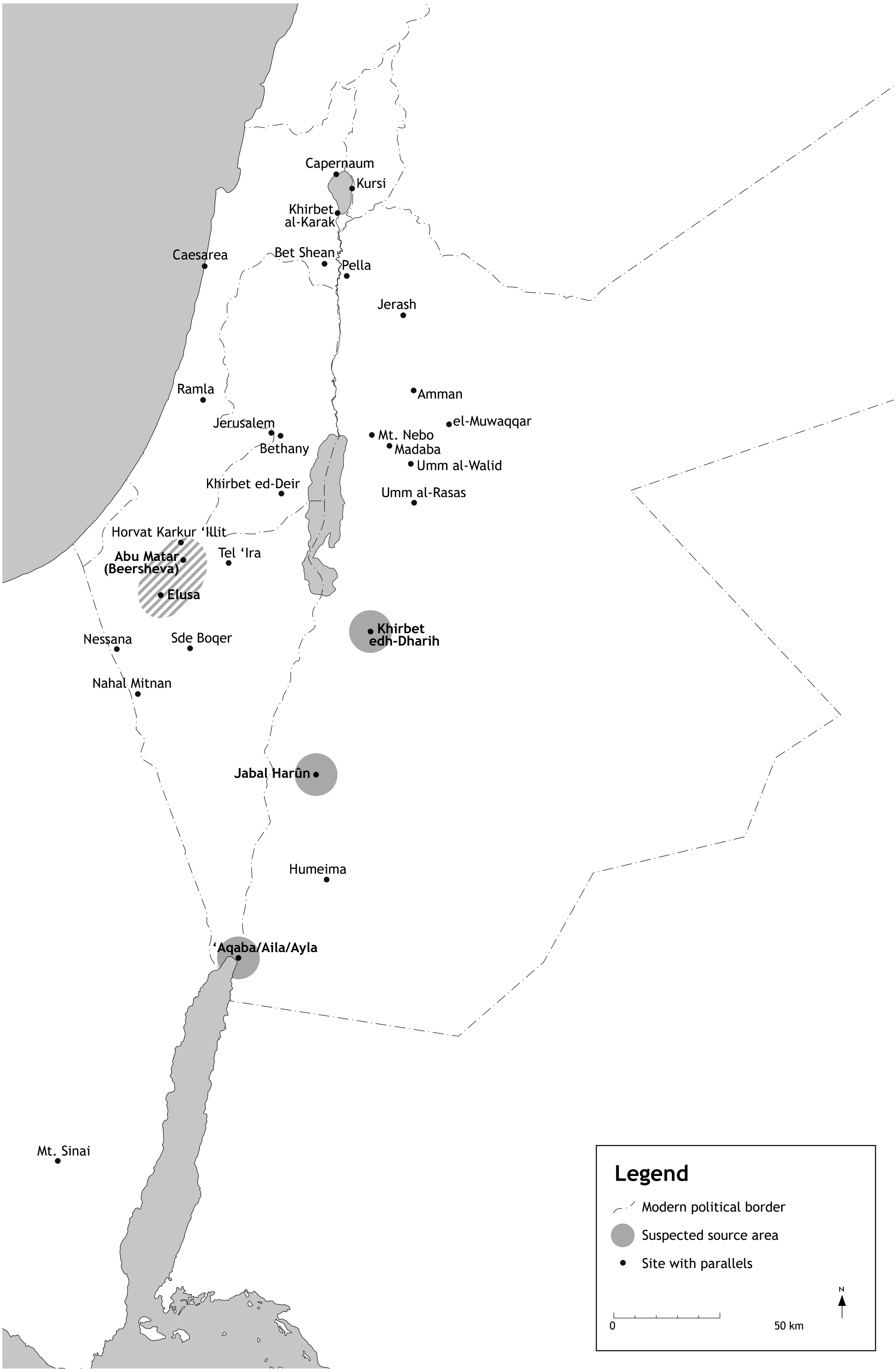

Figure 7.3: Open-form cooking pots: suspected source areas (possibly indicating local/regional workshops) and sites with typological parallels.

Figure 7.4: Basins: suspected source areas (possibly indicating local/regional workshops) and sites with typological parallels.

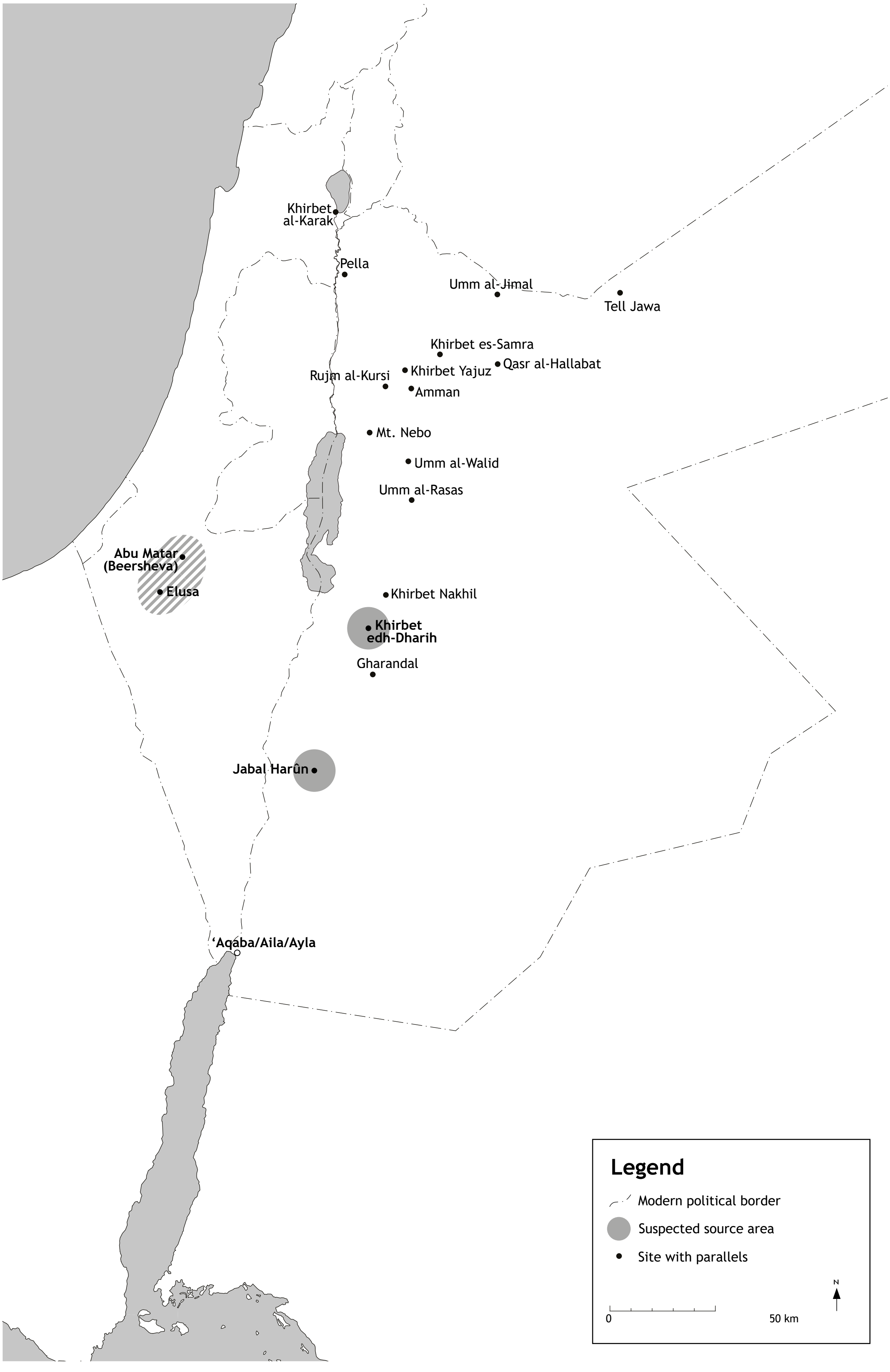

Figure 7.5: High-necked jars with painted or incised decoration: suspected source areas (possibly indicating local/regional workshops) and sites with typological parallels.

Figure 7.6: Leaf-pattern jars: suspected source areas (possibly indicating local/regional workshops) and sites with typological parallels.

Chapter 8

Ceramic data in context: analytical, archaeological and historical evidence

The main focus of this book was a typo-chronological and techno-compositional examination of *c.* 6th–9th century domestic and utilitarian ceramics from southern Transjordan and the Negev (i.e., the southern areas), and the associated ceramic production and exchange patterns. Chronologically, this book deals with the centuries of the socio-political transformation from the late Byzantine into the Umayyad and ʻAbbasid periods, the formative stages of Islamic culture. Until the mid-7th century, the southern areas belonged to the Byzantine province of *Palaestina Tertia*, but after the Islamic administrative reorganisation were attached to three separate provincial units, *Filastin, Dimasq* and *Misr*.

141 ceramic artefacts were sampled from five archaeological sites in the southern areas. The selected archaeological sites represent different socio-economic contexts, a monastery near Petra (Jabal Harûn), a village near the Dead Sea (Khirbet edh-Dharih), a port city and a commercial centre on the Red Sea coast (ʻAqaba/Aila), a town, an administrative and commercial centre in the Negev (Elusa), and a suburban farmstead in Beersheva (Abu Matar). These sites were selected to examine evidence for ceramic technologies, supply, exchange and transportation on intra- and inter-site levels. In particular, the selected sites were of interest in terms of rural-urban contacts, links between religious and secular communities, and regional and inter-regional transport networks.

In this book, the sampled ceramics were assigned to typo-chronological categories to examine their typological similarity to ceramics published from other sites. Next, compositional ʻfingerprintingʼ of the ceramic samples from each site was carried out employing X-ray fluorescence spectrometry (ED-XRF) and scanning electron microscopy (SEM-EDS). The aim of the ED-XRF and SEM-EDS analyses was to identify compositional groups. The most dominant compositional group in each assemblage was interpreted as having been produced relatively near to the site in question. Comparative data analysis was used to examine patterns of material exchange between the sites, and to identify ceramic imports in the assemblages. The manufacturing techniques of the ceramics, material processing and exploitation of raw material resources were also investigated. Finally, socio-economic implications of the ceramic analysis, such as shared ceramic industries and market systems, distribution networks, and adaptation to similar cultural and stylistic influences were examined.

This chapter provides concluding remarks on the outcome of the ceramic analysis and discusses historical evidence on ceramic economies and market systems in further detail, particularly by viewing the accounts of the 10th and 14th century Hajj pilgrims al-Muqaddasi and Ibn Battuta. These accounts can offer valuable insights, bearing in mind the chronological and, in some cases, geographical distance of their accounts (for translations, see al-Muqaddasi 1994; Ibn Battuta 1971; Ibn Battuta 1959; Ibn Battuta 1956; see also Allouche 1990; Binggeli 2006–7; Elad 1987; Ibn Jubayr 1952; Le Strange 1890; and Lopez and Raymond 1990).

Stylistically, numerous sites in the southern areas, and notably also in the broader geographical context, offer comparanda for the sampled ceramics. There is parallel ceramic evidence from secure chronological contexts, e.g., from Pella, the Amman citadel, and ʻAqaba, which can also provide a chronological framework for the ceramics of this study. To examine the typological evidence from other sites and regions, it is necessary to identify characteristics that are shared inter-regionally. These are common vessel morphology, as can be seen in the case of open-form cooking pots, basins and certain jar types, which appear widely accepted in different regions. In addition to general form, there are also other stylistic and functional shared features, such as decoration patterns (incised wavy-lines, painted decoration), handle attachments, and other vessel details. These characteristics may also show some differences, which can be expected due to technological variation, among products of different workshops, potters, and even the work of one potter. The issue of variability is underlined by ceramics of the same form, identified as originating from the same source or workshop, but which, nevertheless, have some differing characteristics, such as rim details. Thus, the cited parallels may not always be identical, but certain forms undoubtedly belong to the same typological families, and therefore inter-regional parallels from secure contexts can be used as chronological references.

Considering the numerous typological parallels listed in this study, it is impossible to label the southern ceramic traditions as ʻregionalʼ in an exclusive sense (see Chapter 5), and without inter-regionally accepted characteristics. There seems to have been a network of potters (or travelling craftsmen) that adapted their products according to common trends, and manufactured these vessels from local raw materials regionally. In addition to the shared trends, there were, of course, regional sub-traditions, specific to a certain region or production, such as the leaf-pattern jars in southern Transjordan, but these should be viewed as diversifications from the general trends of the ceramic culture.

The striking typological resemblance in ceramics from numerous locations may link to similar dietary preferences. While the impact of the new agricultural regime in southern Transjordan and the Negev in the early Islamic period cannot be ascertained, it is in any case probable that new crops were available to the southern communities, either by local cultivation or import. The increased preference for open-form cooking pots, for instance, may link to the cooking of rice, as it is known that this crop became more popular in the Islamic periods (for agricultural and dietary change, see, e.g., Amichay *et al.* 2019; LaBianca 1984; Walmsley 2007a: 113–116; Walmsley 2001a: 542–543; Watson 1983; for various crops, see al-Muqaddasi 1994; Ibn Hawqal 1964). It is not often possible to identify which products were transported in ceramic containers, but many products may have been shipped in jars, even if the role of wine transport may have diminished in the early Islamic period.

According to the compositional data, five primary compositional groups were identified in the analysed sample set. These five groups appear indicative of separate productions, and four of the primary groups were associated with specific sites. Group 1 included the majority of the samples from the village site of Khirbet edh-Dharih. Thus, the ceramics of this group were probably produced somewhere relatively near the site. Group 3 is dominated by the Jabal Harûn ceramics, and therefore it can be expected that the workshop involved in their manufacture was somewhere in the Petra region. The evidence of local production in relation to these two rural sites is intriguing, as early Islamic ceramic workshops have not been discovered in the environs of the two sites up to the present. Moreover, the ceramics from these two sites appear materially linked, i.e., the assemblages possibly represent nearby sources in a common geological environment. Chronologically speaking, these raw material sources were used over a long period of time, as the chronological span of the samples in these groups can range from the 1st century into the 9th century and later, as hand-made, coarse vessels datable to the mid-11th century and later, are also present in group 1.

The fact that the later 8th–early 9th century ceramics are high quality domestic and utilitarian wares indicates that their production was of an industrialised nature, rather than household level manufacture. These productions (the possibility of more than two workshops cannot be excluded) are characterised by a low level of material processing. The clay appears insignificantly levigated with no artificial inclusions, and also little technical specialisation with regard to vessel forms, since cooking vessels, containers, transport vessels and even tiles, both wheel- and hand-made objects, were manufactured using the same ceramic recipe.

The third primary compositional group, group 6, is dominated by cooking vessels from the two Negev sites, the farmstead of Abu Matar in the Beersheva suburbs, and the town of Elusa. Importantly, all of the cooking vessels sampled from these two sites are remarkably typologically similar, and also share a distinctive compositional pattern, demonstrating that the inhabitants of the two sites purchased at least some of their domestic wares from the same manufacturer. Based on the compositional and typological homogeneity of the cooking pots, this producer was involved in fairly standardised, or even industrialised, cooking ware production. The stratigraphic contexts of these pots suggest that this cooking ware production continued from the late Byzantine period into the early Islamic period, at least into the 8th century and probably later.

A ceramic industry has been identified in Islamic Ayla (Melkawi *et al.* 1994; Whitcomb 2001a), and it is clear that the group 8 samples are linked to this local production in ʻAqaba. This group includes transport vessels, including the well-known ʻAqaba/Aila amphorae, but also domestic and utilitarian wares, and even cooking pots. Morphological diversity at the Ayla workshop is attested by wasters of different forms from the kiln site, but the fact that the forms (amphorae, cooking pots) also share uniform composition is remarkable. Here again we have a very long chronological period when the same raw material resources were used, as these ceramics date from the Nabataean/Roman period at least to the mid-8th century.

Ceramic wasters from the Elusa workshop were included in this study, and these samples, plus other ceramics with similar composition, form group 10. The ceramics in this group are different container forms. In addition to the fact that no cooking vessels have been found in the workshop related deposits, it seems that the Elusa workshop was specialised in container manufacture, such as amphorae (Elusa jars) and water jugs (see Fabian and Goren 2002). The forms belonging to this group are mainly late Byzantine, but it is difficult to propose a terminal date for this production in light of the existing evidence, particularly as forms typical of the early Islamic period found at Abu Matar also cluster in this compositional group. The later forms may point to the same raw materials being used by another, Islamic period workshop. The end-date of the Elusa workshop in the 6th century suggested by the excavators can relate to the decreased demand for the forms produced in this particular workshop. Certain minerals found in some of the samples of this group may indicate that raw material sources other than those in the immediate vicinity of the site were also exploited.

Comparative data analysis revealed ceramic exchange between the sites, particularly on a regional level in southern Transjordan and the Negev. Examples of inter-regional ceramic transportation were also identified. The vessels that travelled the farthest are the 'Aqaba amphorae, which were transported for *c.* 120km to Jabal Harûn, and *c.* 200km to Khirbet edh-Dharih and Elusa. The wide inland transportation network of the 'Aqaba amphorae demonstrates that these vessels were not solely used in sea trade, but they also played a role in the donkey- or camel-borne caravan trade. This adds to the picture of these amphorae used to re-pack land-transported products for sea trade, and demonstrates that ceramic containers can have multiple roles in exchange systems. Considering the suggested high costs of land transportation, the contents of these vessels may have been of considerable value, such as Red Sea fish products (remains identified at excavations in southern Transjordan and the Negev, and in a Roman jar at Aila) in high demand by, for example, Christian communities. However, taking into account that there was also an established route system in the Islamic period, the costs of the over-land transportation may have been lower than previously suggested (see Greene 1986: 169; Jones 1964: 841–842; and Chapter 2 for further discussion and references).

Jabal Harûn and Khirbet edh-Dharih show a pattern of material exchange, in addition to the materially linked local ceramic productions discussed above. The two communities may have purchased their ceramics from the same manufacturer without direct contact between their inhabitants, but it may be more likely that they visited the same regional markets where potters sold their products, or that agricultural products were transported between the two regions. The ceramic records from the two sites show that both regions were involved in a system of agricultural product exchange, as both locally made and imported ceramic transport vessels were recovered at the sites. Local variants of bag-shaped jars, for instance, were present at both sites. The striking typological similarity between the two assemblages, added to the material relation, may indicate that the communities for some reason preferred the same (perhaps Christian?) ceramic producer in the early Islamic period.

It has been suggested that Christian communities became economically more self-sufficient after the Islamic expansion, and thus they would have benefited from economic ties and networks among them, although we cannot exclude the possibility that the communities had converted to Islam (see Walmsley 2007a: 120–126; and Ibn Jubayr 1952: 300–301 on Christian population, travelers and merchandise in the Karak area in the 12th century; see also Binggeli 2006–7; Le Strange 1890: 497–481, 536, 569–571; Walker 2007; and Walker 2004). Larger-sized domestic vessels (cooking pots and basins) present at Jabal Harûn probably relate to the communal kitchen at the monastery, compared to household kitchens at Khirbet edh-Dharih.

Considering that Khirbet edh-Dharih and Jabal Harûn are located *c.* 80km apart, their material links indicate ceramic transportation on a regional level, and the two communities may well have attended the same regional markets, held, for example, in Petra, near Khirbet edh-Dharih, Humeima, Jericho or elsewhere. Al-Muqaddasi describes places such as Ramla and Zughar as having vibrant market economies and surrounded by agricultural land, holy places, and villages. Among the locations he lists are also the towns of Udhruh, Ma'ab and 'Aqaba (Wayla), which he describes as a port and a depot, 'producing palms and fish' (al-Muqaddasi 1994: 150–151, 161–162; see also Ibn Battuta 1956: 82; and Binggeli 2006–7, 579–580; for Ramla markets).

It is difficult to find evidence for rural markets archaeologically, but the hypothesis of regional markets is also supported by the fact these places are well linked by routes, and only a couple of days' journey apart. For instance, 'from Sughar to Wayla is four stages...from Sughar to Ma'ab is one stage... from Amman to Ma'ab one stage' (al-Muqaddasi 1994: 175–176). Fustat, 'Ajlun and Gaza are also described as having important markets (Ibn Battuta 1956: 73, 82; al-Muqaddasi 1994: 181). Ibn Battuta also records inter-regional transportation of various products, such as fruit, possibly transported in ceramic containers, from Sidon and Beirut to Egypt. In addition, he describes a system of village-based production around Damascus, in which, for instance, milk products were transported for two-day journeys – ceramic containers with cooling ability, or skins, may have been ideal for this purpose (Ibn Battuta 1956: 85, 117, 130–131, 148 for Damascus markets; see also Binggeli 2006–7: 576–578).

The caravans and the Hajj pilgrims obviously contributed to the movement of people and goods across the regions, and benefitted agricultural and rural pastoral economies, and rural and urban markets on the route. Ibn Battuta notes that the caravan stayed near Karak for four days making preparations for travel, before continuing to Ma'an (Ibn Battuta 1956: 160). Thus, the local economies supplied goods for the caravans. Ibn Battuta also mentions Bedouin markets, where sheep, fruit and other food stuffs were sold on the way to Mecca (Ibn Battuta 1956: 187, 252–254, see also Bienkowski and Chlebik 1991; and McKenzie 1991). In addition, there are numerous listings of urban markets.

Post-stations on the caravan routes were also important places which provided water and where other goods were sold, and Ibn Battuta also gives many accounts of holy places where there was a 'religious house at which food is supplied to all wayfarers' (Ibn Battuta 1956: 71–72, 82–85). These kinds of activities can provide the links between the socio-economies of Khirbet edh-Dharih, Jabal Harûn, Abu Matar and Elusa, which probably acted as suppliers, and also consumers in the regional market systems; the first two are located on the Amman–'Aqaba section of the Hajj route, and Abu Matar and Elusa on routes crossing the Negev. Holy places also had a special role in the movement of goods, since offerings, such as fruit, were brought over considerable distances on camels (see Ibn Battuta 1956: 222–223). At Jabal Harûn, there has been a tradition until recent times of leaving cooking pots at the shrine for votive meal preparation (Miettunen 2008: 40), and other ceramics, such as lamps, may also have served as offerings (Holmqvist 2016b: 259).

Clear evidence for a shared domestic vessel economy is also provided by Abu Matar and Elusa, as perhaps surprisingly, all of the cooking pots sampled from the two sites, located *c.* 20km apart, came from the same source, possibly being a workshop specialised in cooking ware manufacture. There may have been a market where these cooking pots were purchased, perhaps an urban market in Elusa, or a rural market somewhere in the vicinity of the two sites. It may also be that the workshop was located in Elusa, Beersheva or elsewhere in the Negev. This production, however, cannot be associated with the known Elusa workshops (where no evidence of cooking ware production was found, and the wasters are of significantly different composition). Thus, the production's location, and relation to either an urban or rural context cannot be established at this point. The results demonstrate, however, that there was a link, a common pottery supplier, between the ceramic economies of these two communities, one being of a rural and the other of an urban nature. Further examination of cooking pots from sites in the Negev may illustrate a monopoly of the cooking ware supply in the region.

In relation to the evidence of ceramic exchange discussed above, al-Muqaddasi's accounts regarding ceramic products are of importance here. Interestingly, he writes, for example, that 'blessed are...the people of Isfahan with...their earthenware...from Tus, superior earthenware pots...the earthenware of al Shash' (al-Muqaddasi 1994: 33, 285, 287). The fact that he mentions ceramic products of certain areas gives an indication that ceramic vessels had a market value themselves, or, at least, an acknowledged high-quality. He also discusses goods transported in ceramic containers: 'from Harran...honey of bees in earthen wine jars...from Balad, biestings in jars, carried by boat' (al-Muqaddasi 1994: 133). He also lists 'clay for chinaware' among the imports to Oman, and similarly, 'there is nothing comparable to the...potter's clay...of Naysabur...In Tus is earthenware clay...the people of Tus make earthenware pots' (al-Muqaddasi 1994: 89, 285, 287), which indicates that some areas were known for their clay sources, and also implies raw clay transportation.

In addition to the 'Aqaba/Aila amphorae, there are also other examples of inter-regional transport that need to be highlighted here. Clearly there were amphorae-borne imports from the Negev (Elusa?) to southern Transjordan (Jabal Harûn), and vice versa, from southern Transjordan (Khirbet edh-Dharih) to the Negev (Abu Matar). The traffic between 'Aqaba/Aila and Jabal Harûn (Petra) and Khirbet edh-Dharih was obviously two-way, as vessels, and notably cooking wares, were imported to 'Aqaba/Aila at least from the Petra region (Aila pots belonging to groups 1 and 3). It appears that a significant amount of the cooking wares recovered at the 'Aqaba/Aila site are, in fact, imports from the Petra region (Parker 2014: 209, approx. 30 % of the cooking wares from the site share macroscopically similar fabric characteristics). It is possible that the Aila community preferred the (non-calcareous) Petra-region cooking pots over their local (calcareous) cooking wares because of their better quality. Nevertheless, the results confirm a two-way ceramic transport between the southern port town and the northern rural contexts, the regions of Petra and Khirbet edh-Dharih. The results of this study demonstrate that coarse wares were also transported, perhaps carried as personal items (cooking utensils) by the travelling merchants. Furthermore, the LR 1 jar found at Elusa is clearly an import to the site, but its origin cannot be established without a comparative provenance study within this typological group.

The results of this study show only a few examples of inter-regional exchange between southern Transjordan and the Negev, but in fact, considering the relatively small number of ceramics analysed here, the evidence from a data set of this size may actually indicate far more substantial economic ties between the regions than has been previously thought, and future analysis, including a larger sample from additional sites, may prove this hypothesis correct.

In addition to the exchange patterns described above, there are a number of imports from currently unknown sources, which are also atypical finds in the assemblages. The most noteworthy of these are perhaps the painted wares, the glazed bowls, and the engraved (*Kerbschnitt*) sherds. Painted wares identified as imports are present at Jabal Harûn, Khirbet edh-Dharih, Abu Matar and Elusa. These sherds reflect northern contacts in the early Islamic period, as painted wares are commonly associated with the northern tradition, produced at least in Jerash (see, e.g., Schaefer 1986). The finds analysed here, however, cannot be linked with Jerash or any other possible source without comparative provenance tests.

Intriguingly, some of the painted sherds from Jabal Harûn and Khirbet edh-Dharih belong to the local groups of these sites, suggesting that painted wares, presumably of later 8th–9th century date, were also produced in the south. Hence, this ceramic phenomenon would not be characteristic only of the northern areas. Due to chronological uncertainties, it is impossible to define here the date of the first appearance of the painted wares – whether imported or locally produced – at the southern sites. Therefore, it is not possible to distinguish whether the local painted vessels imitate the northern painted wares, or if they are the result of an influence coming from elsewhere, affecting both northern and southern ceramic traditions independently. One can also only speculate on the functions of the painted wares (the samples here appear to belong to containers), whether their appearance was indicative of certain contents or merely a stylistic preference. It appears that the painted sherds studied here are hand-made, as are their northern parallels.

The glazed sherds sampled from Jabal Harûn, Khirbet edh-Dharih and Abu Matar seem to originate from separate sources. Although in some cases glazed vessels may have been manufactured in the same workshops as unglazed wares, the compositional patterns of the glazed sherds analysed here differentiate them from the other samples and they are apparent imports in the assemblages. The glazed sherds from Jabal Harûn and Abu Matar are technologically related by their lead-glazes, a common feature in the Islamic period, whereas the glazed sherd from Khirbet edh-Dharih has a technologically more advanced alkaline glaze. It cannot be established here with certainty whether the glazed vessels originate from regional workshops, or if they are more distant imports.

Two engraved (*Kerbschnitt*) sherds, one of reddish fabric from Elusa, and another of greenish fabric from Jabal Harûn, were analysed. Curiously, the sherd from Elusa shared compositional characteristics with the local Elusa group, where as the Jabal Harûn sherd appears to be an import to the site. It appears unlikely that these sherds belong to the Islamic tradition of engraved vessels, imitating steatite vessels from al-Hijaz, as they both bear characteristics atypical of this tradition. These sherds remain typo-chronologically perplexing, and may be of 7th century date, although their date, or their relation to the early Islamic *Kerbschnitt* ware tradition, cannot be established with certainty.

A fragment of a cream ware jug or jar was sampled from Abu Matar, a representative of the mould-made ‘Khirbet al-Mafjar’ tradition, reflecting Baghdad and Samarra influences in the ceramic culture. In terms of composition and ceramic recipe, the sherd is not significantly different from the ceramics identified as of the Negev origin. Thus, it appears to originate from a geologically related area. While a provenance study of Islamic cream wares is awaited, it cannot be excluded that at least one workshop involved in the production of these wares was located in the vicinity of Jericho. According to the parallels, this sherd dates to the 11th century, and thus it may be a later intrusion to the Abu Matar deposits, or possibly indicate that the site was inhabited, at least in some form, at this time.

Other important finding to discuss here, although a minority in the sample set, are the coarse, hand-made vessels found at Jabal Harûn and Khirbet edh-Dharih. It is particularly noteworthy that these sherds belong to the local Khirbet edh-Dharih group, attesting to the vast chronological span of the raw material exploitation. It is uncertain whether these unpainted sherds can be associated with the unpainted predecessor ware of the HMGWP dating from the mid-11th century onwards (see, e.g., Johns 1998; Sinibaldi 2016; Walmsley 2008: 524–526; Walmsley and Grey 2001: 153, 158), and it is possible that these sherds are later variants. In general, the hand-made vessels represent a technological change of the middle and later Islamic periods, when hand-made wares come to dominate the ceramic repertoires, and various regional workshops appear to produce ceramics with shared characteristics (Johns 1998).

In general, the ceramics examined here are fired at a relatively low temperature (below 800°C), which is typical of utilitarian ceramics. The fabric of the ‘Aqaba amphorae is more coarse compared to other forms, and the amphorae also appear to have been fired at a relatively low temperature. These are very probably intentional technological choices in their manufacture to increase their transportation qualities, such as strength and toughness. Moreover, the cooking pots from Jabal Harûn, Khirbet edh-Dharih, Elusa and Abu Matar are of non-calcareous fabric, a quality known to improve the performance of cooking vessels. Interestingly, the locally produced ‘Aqaba cooking pots are an exception and have the same calcareous composition as the amphorae and other containers (see, e.g., Tite and Kilikoglou 2002; Chapter 4).

The calcareous fabrics of the Elusa and ʻAqaba amphorae probably link to local geologies and available clay resources, but the selection of calcareous clay may also link with the planned use of the vessels as transport containers (see, e.g., Barone *et al.* 2012). The regular high quality of the ceramics among those analysed in general indicates industrialised production, at least on a communal, if not on a regional level. Other common features in the analysed ceramics are a relatively low level of clay processing, lack of artificial tempers, and the compositional correlation between the 'local' groups and the respective geological environs (with the possible exception of some materials used in Elusa). The primary compositional groups are chronologically heterogeneous, and it appears that the clay sources were exploited over several centuries, with only minimal modification in the clay mixture. Most importantly, the same sources and technologies survived through the socio-cultural and political changes.

Thus, the *chaîne opératoire* of the potters did not change substantially over time. At least, the first stages of the operational chain, the raw material selection and processing, did not undergo any significant modification. Some time from the late 7th century onwards, stylistic changes were introduced, and new forms, such as open-form cooking pots, basins and high-necked jars, were preferred in the 8th and 9th centuries. Later on, in the course of the 9th century, more substantial modifications and new influences from Baghdad and Samarra occur (see, e.g., Magness 2003: 163; Magness 1993: 27; Matin *et al.* 2018; Walmsley 2001b: 310; Walmsley 1995a: 329–331; Whitcomb 1988b: 64–65; see also Kubiak 1998).

The open-form cooking pots, basins, high-necked jars and other related forms produced in the 8th–9th centuries were made of practically identical clay mixtures compared to the earlier, Byzantine and Roman period forms. Therefore, regardless of the morphological and stylistic changes, few other technical changes were applied at this point. In other words, the *chaîne opératoire* of the 8th–9th century potters was a combination of conservative and innovative technologies, using traditional methods and materials to create new forms deriving from changing market preferences. At this stage, both wheel- and hand-made vessels also remained in the repertoire of the potters, and both techniques may have been employed in the same workshops. Therefore, it appears that these changes, perhaps due to changing dietary customs or other cultural reasons, may have been relatively straightforward for the potter to adopt. With regard to the fact that separate regional traditions seem to have adapted to similar influences, it is also possible that itinerant potters were involved in ceramic manufacture in the regional workshops.

In this light, and considering the historical evidence of a well-organised road network, one may suggest that the southern areas adapted to the changes in the ceramic culture more or less simultaneously with the northern areas, viewed here as an analogy. Bearing in mind that the southern areas were directly linked with Egypt, Ayla, al-Hijaz and the Arabian Peninsula, there is no reason to suppose that they received only secondary influences; instead, many cultural influences may have arrived first in southern Transjordan and the Negev. It has been demonstrated here that the southern and northern ceramic cultures are, in many respects, typologically and technically linked. The potters were clearly operating in the same cultural environment. Thus, the tentative model of chronologically relatively consistent influence flow allows inter-regional comparanda from secure chronological contexts to be used as an aid for solving the chronological uncertainties of ceramics from the southern areas, where the archaeological contexts offer fewer possibilities for absolute ceramic chronologies.

This results presented in this book demonstrate that mundane ceramics contain valuable evidence of ancient economies and inter-communal and inter-regional exchange networks. Future analysis of amphorae found at sites farther north might reveal even wider distribution networks of the ʻAqaba amphorae as it is unlikely that Khirbet edh-Dharih and Elusa were the final destinations of this network. Instead, it is more likely that they served as transit points on the route to northern Jordan, Gaza and beyond. Residue analysis of these amphorae might also shed further light on this trade. Future work may also focus on some of the hypotheses discussed here, such as the possible centralised or satellite production of the leaf-pattern jars, or the cooking ware supply in the Negev. Ideally, the coarse ware provenance data should be viewed in comparison with that of other ceramic categories, and other artefact types, such as metals and glass. One future prospect could also be expanding the chronological focus by adding samples, for example, of the HMGPW tradition to examine the development of the raw material exploitation and ceramic production and exchange patterns from the 12th century onwards. Moreover, the testing of natural clays might aid in the identification of the material sources, bearing in mind the challenges of comparing raw clays and archaeological ceramics.

In sum, shared ceramic industries can be identified between Jabal Harûn and Khirbet edh-Dharih, and Elusa and Abu Matar. At least in the case of Abu Matar and Elusa, the cooking pots may have been the primary objects purchased from the same supplier, whereas the exchange between Jabal Harûn and Khirbet edh-Dharih may be linked with the transport of agricultural products. The ceramic products originating from ʻAqaba/Aila, on the other hand, appear to have the broadest distribution network, which corresponds to the commercial nature of the port city. In this case, the distribution of the amphorae was very likely a byproduct of their contents, fish products or other goods, either produced at ʻAqaba or transited through the city.

The shared ceramic industries provide evidence of interaction between different socio-economic units, such as the urban and rural communities of Elusa and Abu Matar, and communities of a clearly religious nature (Jabal Harûn) and other social groups (see Haldon 1995: 415–423; Shahîd 1995a: 115–133). There may have been a combining factor that drove the communities to employ the same ceramic suppliers, such as the location of the workshop or a market where the products were sold, the quality of the products, or cultural or religious links between the manufacturer or the merchant and the customer.

The absence of ʻAqaba amphorae at the Islamic farmstead of Abu Matar does not necessarily mean that the products transported in these amphorae were not part of the diet of the community, or bear any other socio-cultural or economic implications. It is also not possible to establish here the religion or the ethnicity of the inhabitants of the sites. This applies even to the sites with identified Christian inhabitants, as it is not known whether the communities converted to Islam, and when this may have happened. Different religious groups may also have shared changes in agriculture, diet and ceramic culture. Hypothetically, if we assume that the Abu Matar farmstead was inhabited by Muslims, while Elusa remained mainly Christian or, for instance, that the people of Khirbet edh-Dharih converted to Islam at some point, or that there were Muslims at Jabal Harûn in the early Islamic period, it would be possible to suggest supporting evidence for economic links between different religious groups. Considering the reuse of elements with Christian symbols, such as crosses, as door thresholds at Abu Matar – that is, they were stepped on – it is likely that the inhabitants were non-Christian. In addition, the Elusa church seems to have gone out of use at a certain point, judging from the robbing of stones (S. A. Rosen, personal communication 2010).

At the moment, however, the religion or ethnicity of the groups that inhabited the sites cannot be established with certainty. There were both Christians and Muslims inhabiting the areas, and certain groups, such as the *Ghassanids*, Christian Arabs who had a wide contact network with different groups, may also have played an important role in the transmission of cultural influences and their adaptation in material culture traditions (see Shboul 1996: 77–79, 81; see also Edwell *et al.* 2015; Fisher *et al.* 2015; Haldon 1995: 403–406; Liebeschuetz 2000: 67–68; Shahîd 2002: 374–393; Shahîd 2001; and Shahîd 1995b).

In general, it can be concluded that the sites, apart from ʻAqaba with its highly commercial status and international trade links, are representatives of wealthy agriculture-based economies. Imports, especially those of high value, form a minority in the ceramic records of Jabal Harûn, Khirbet edh-Dharih, Abu Matar and Elusa. Elusa and ʻAqaba/Aila had their ʻindustrialised' container manufactures, but other than that, it seems that there were no substantial differences between the ceramic supply of urban and rural contexts, which speaks for wealthy rural economies. All of the sites seem to have relied mainly on the local ceramic supply. Imported containers and local variants of transport vessels suggest that the sites were involved in exchange networks of agricultural products on both regional and inter-regional levels, the products of ʻAqaba having the broadest distribution network on the basis of this evidence. In terms of material exchange, each site had its individual contact network, reflecting its unique location and socio-economic role.

Compared to some other monasteries, the Jabal Harûn ceramic record appears relatively rich in terms of imported amphorae; there are, however, also a wide range of local variants of containers, suggesting that the site relied on both an inter-regional and regional supply of goods. Khirbet edh-Dharih also seems to have played an active role in the agricultural economy of its region, and probably interacted in the village network of the Dead Sea region. Considering the local ceramic mass production at ʻAqaba, it is interesting that cooking vessels were also imported there from the Petra region, perhaps being the cooking ware of caravans, but the possibility of greater import of cooking wares cannot be ruled out.

It appears that no single model can be applied to the ceramic economies of southern Transjordan and the Negev during the centuries under scrutiny here, but instead there were overlapping systems of regional workshops, some specialised in certain forms, while others manufactured a wide range of utilitarian forms, including tiles. The communities examined here apparently exploited the products of various workshops, and there were also complex regional and inter-regional exchange systems. The typo-chronological, technological and compositional ceramic data presented here support the evidence that the ceramic culture of the southern areas was 'in transition' not long before the beginning of the 8th century, a development identified particularly further north (see Bar-Nathan 2011b; Magness 2003: 163; Magness 1993: 27; Walmsley 2001b; Walmsley 1995b; and Whitcomb 1988b: 64–65).

One ambition throughout this work has been to look for an analogy between the southern and the northern areas, where archaeological research has yielded evidence for economically stable development throughout the early Islamic period (see, e.g., Avni 2014; Walmsley 2016; Walmsley 2007a: 76–104), a picture which currently does not have parallel evidence from many sites in the southern areas. While ceramic evidence alone cannot fill this gap, it can be concluded that several analogies can, indeed, be found.

The early Islamic workshops remain unidentified in southern Transjordan and the Negev (apart from 'Aqaba), and therefore it is impossible to determine whether the workshops were new establishments of the early Islamic period, and whether they were located in urban or rural contexts, but they appear, however, to be of industrial nature. Furthermore, one common factor is that the ceramic products from both the southern and northern areas have typological and functional similarities, suggesting similar adaptation to socio-cultural influences. Second, both areas show continuing use of the same raw materials in the ceramic production, and unchanged ceramic traditions immediately after the socio-political change. Third, in addition to the typological links, there is also supporting evidence from Jerash and other Islamic manufacturing centres that variant forms were manufactured in the same workshop (see Kehrberg 2009; and Watson 1989; for Jerash ceramic manufacturing traditions; Bar-Nathan and Atrash 2011 for the Bet Shean pottery workshop; see also Walmsley and Grey 2001: 162, for north–south links in ceramic records). While those presented here are ceramic-related analogies, unquestionable similarities in the ceramic industries of the southern and northern areas in the 8th–9th centuries probably also link to other socio-economic structures. At least, there must have been an economy viable enough to support, and perhaps more importantly, to require, industrial level ceramic production in the southern areas.

To conclude, regional characteristics and traditions restricted to certain areas notwithstanding, there are evidently shared patterns in the ceramic cultures and economies between the northern and southern areas. While regionalism is clearly the dominant pattern in raw material exploitation, in light of the evidence presented here, it is no longer viable to consider the ceramic assemblages of the southern sites as having no parallels with those of other regions. Hence, it is necessary to reassess the interpretations of the ceramic traditions in southern Transjordan and the Negev to avoid contributing to the negative image of the socio-cultural situation. This negative image is, in turn, linked to the misinterpreted settlement patterns and the chronological issues of ceramic artefacts in archaeological contexts during these periods. It is important to recognise the ceramic traditions of the southern areas as part of the greater cultural context, as receivers, transmitters and indicators of primary influences in the formative stages of the Islamic culture.

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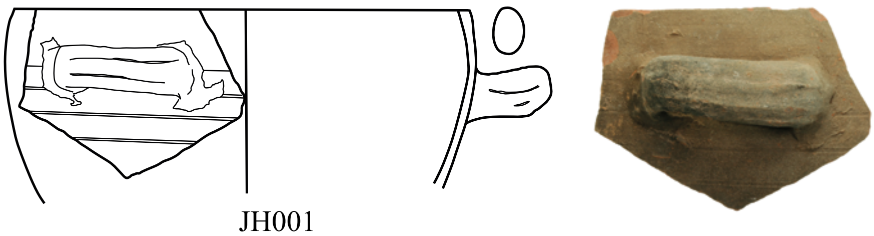
Appendices

Appendix I



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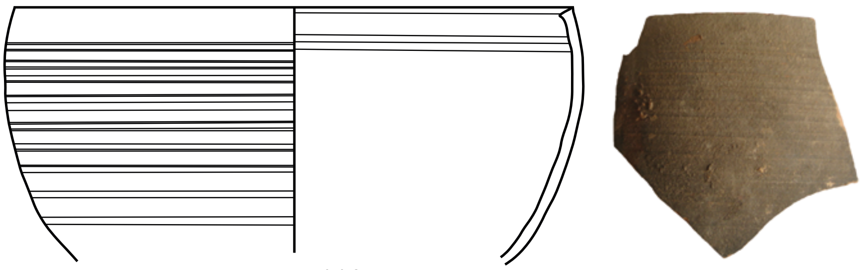

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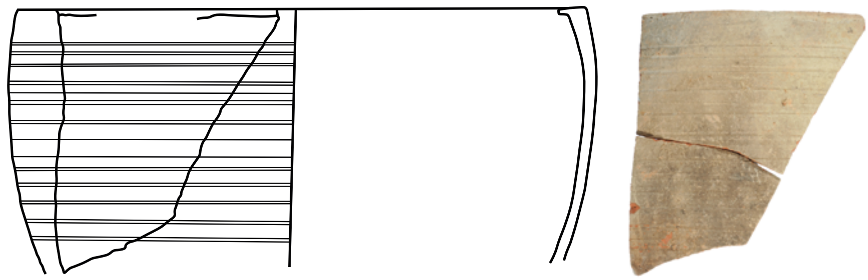

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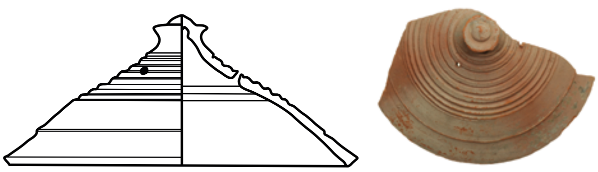

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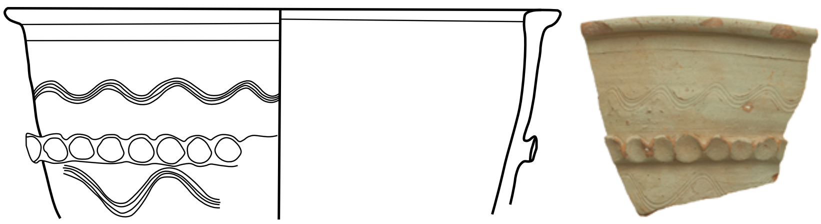

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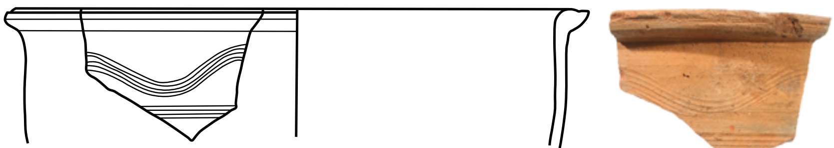
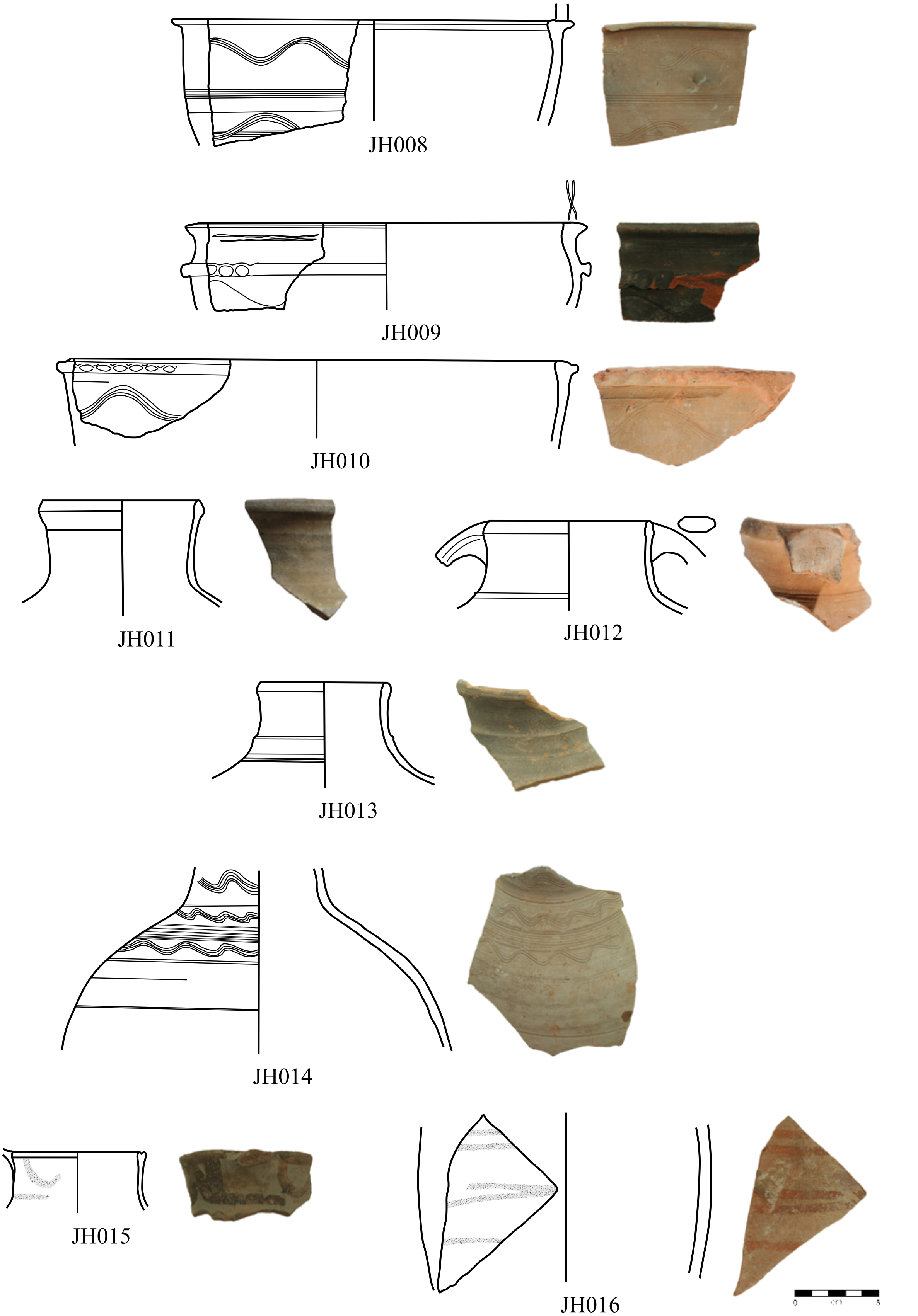


JH007

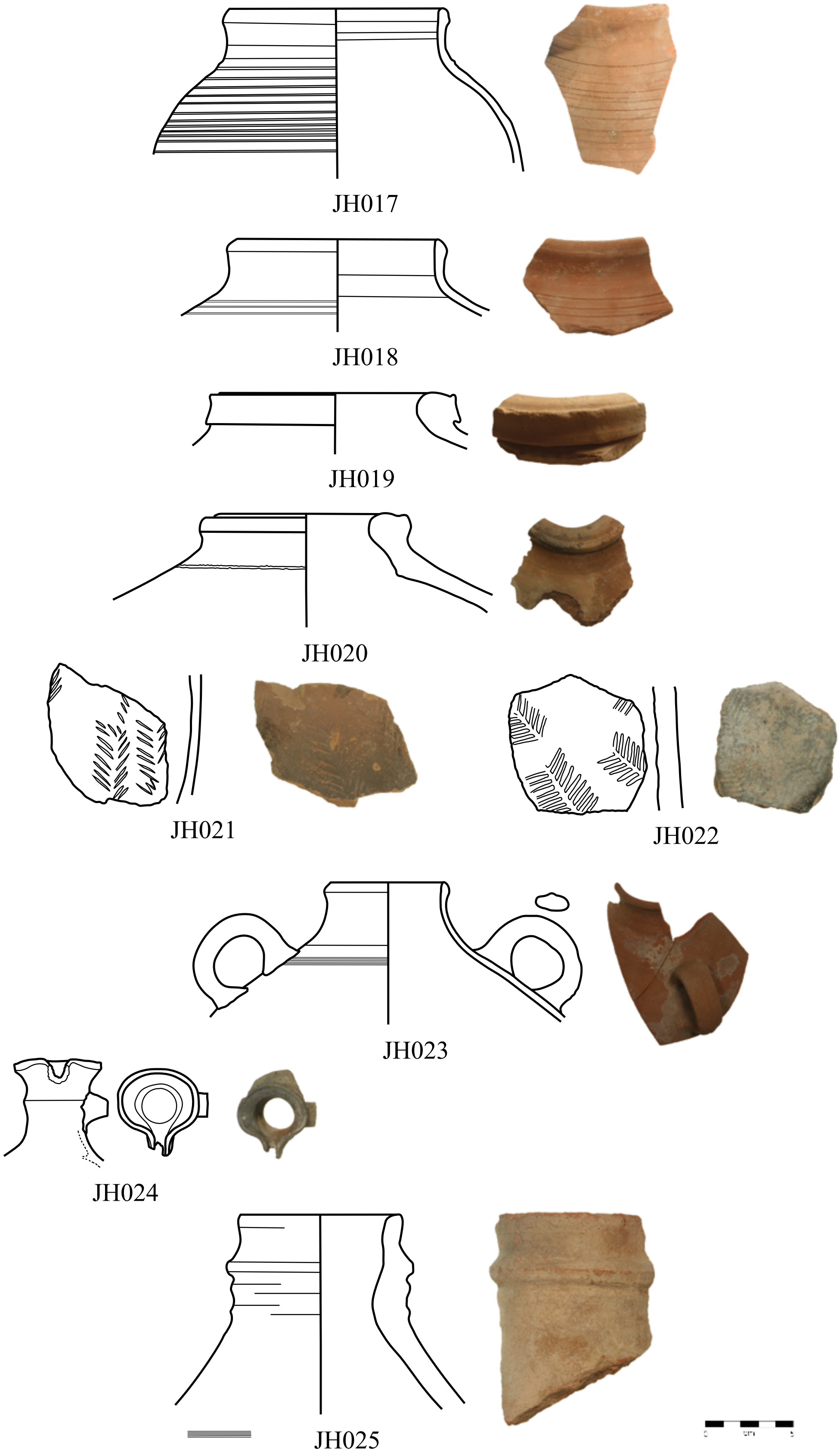
Jabal Harûn ceramics (samples JH001–JH007).

Appendix I



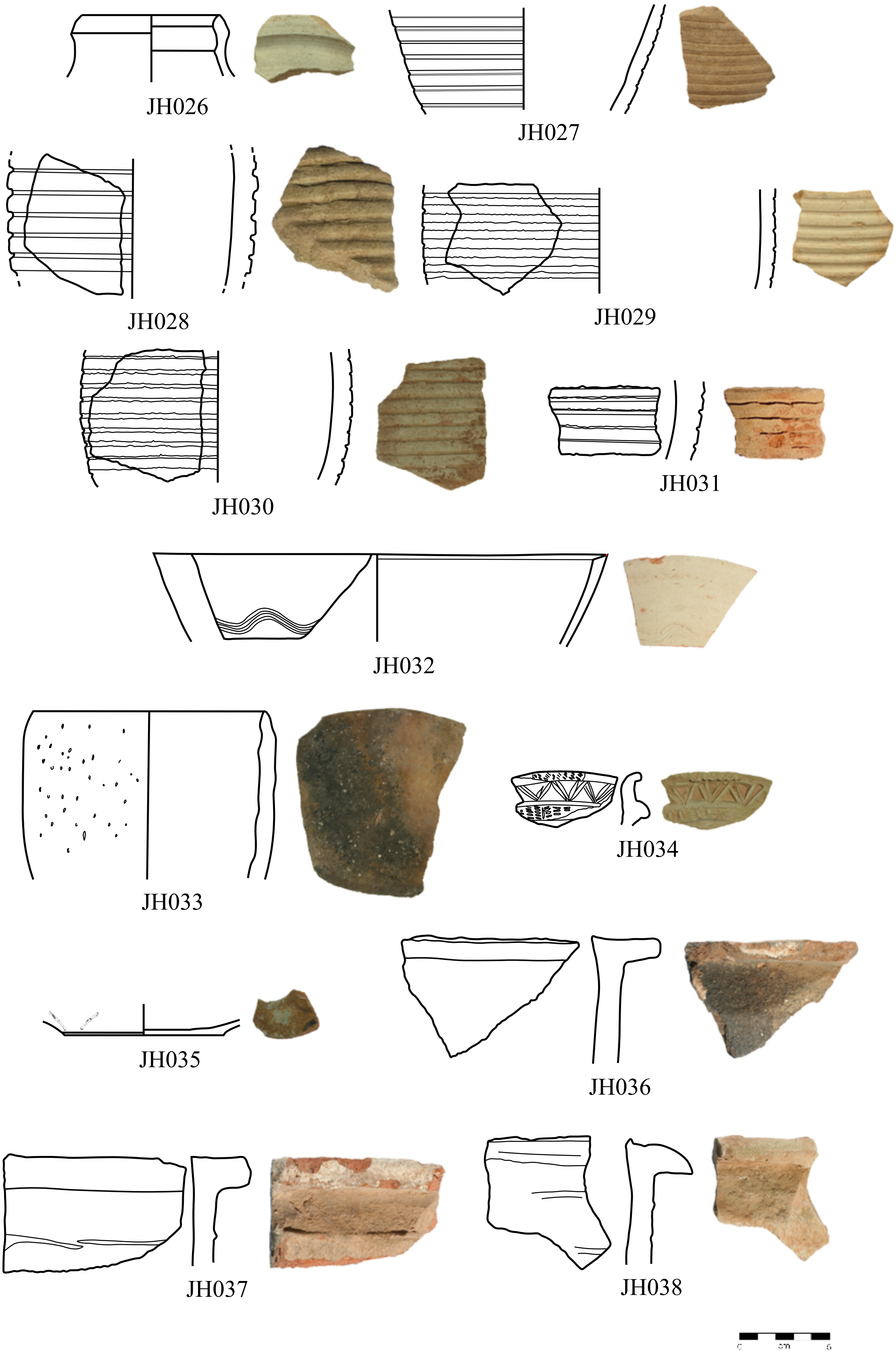
Jabal Harûn ceramics (samples JH008–JH016).

Appendix I



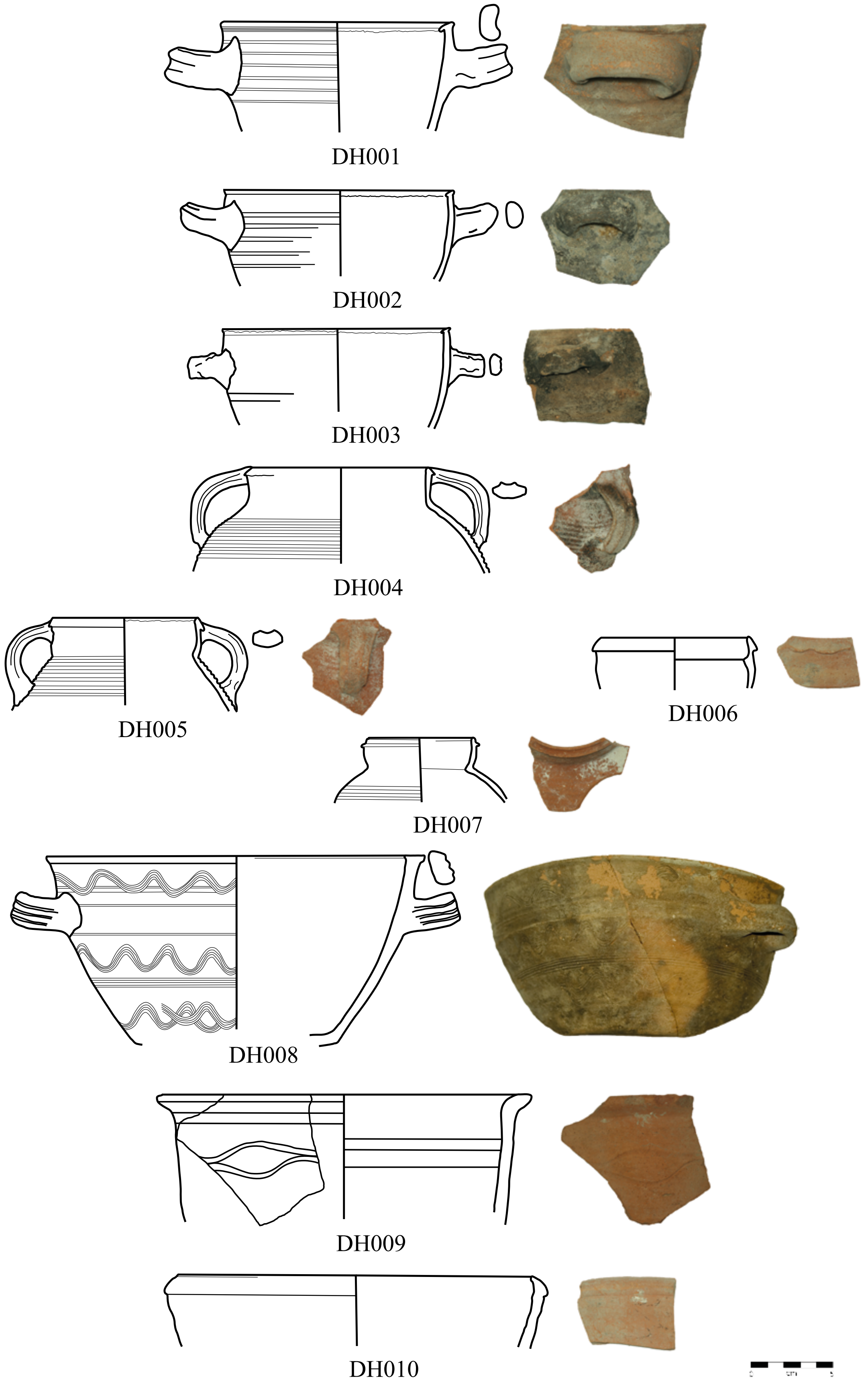
Jabal Harûn ceramics (samples JH017–JH025).

Appendix I



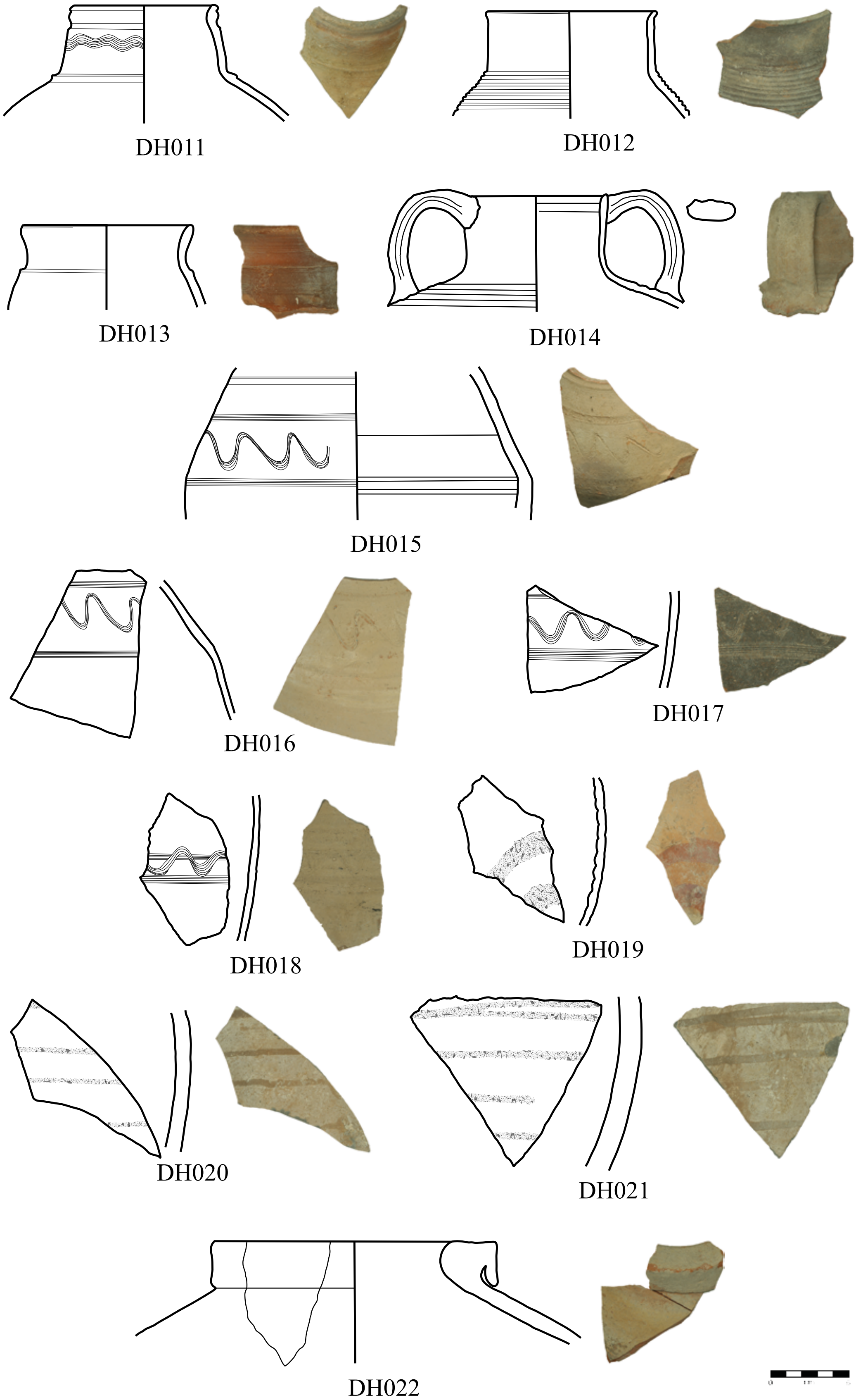
Jabal Harûn ceramics (samples JH026–JH038).

Appendix I



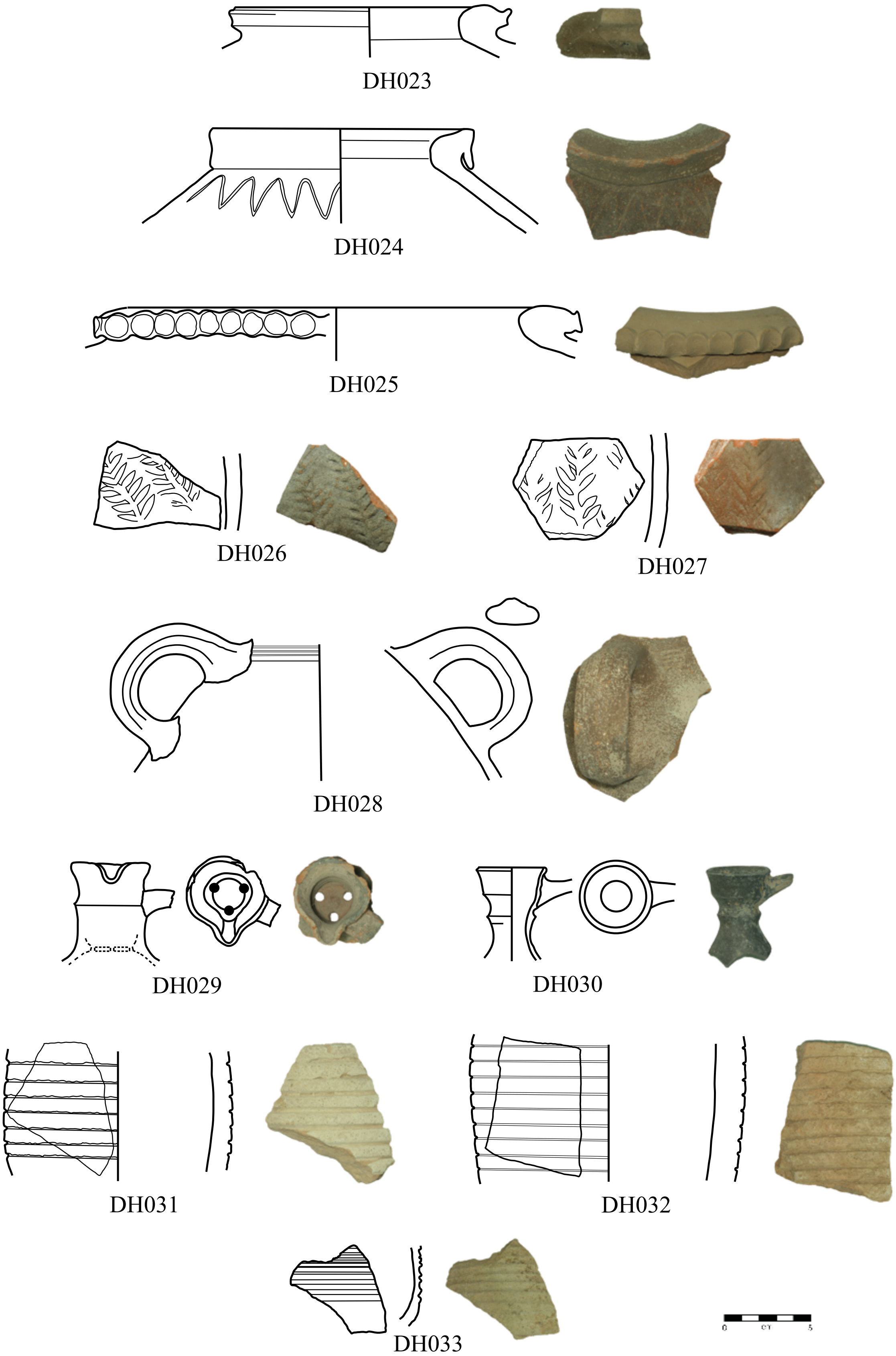
Khirbet edh-Dharih ceramics (samples DH001–DH010).

Appendix I



Khirbet edh-Dharih ceramics (samples DH011–DH022).

Appendix I



Khirbet edh-Dharih ceramics (samples DH023–DH033).

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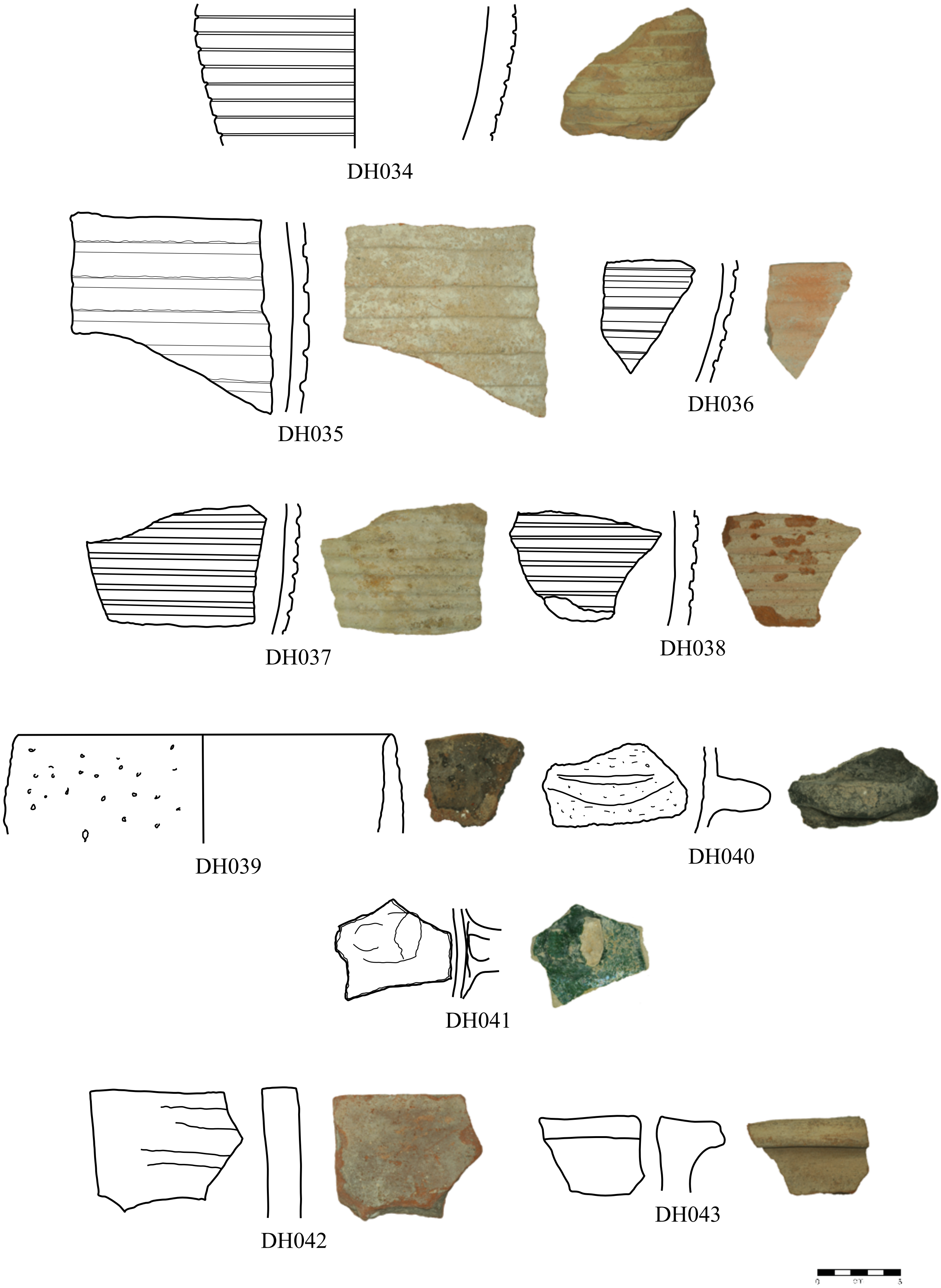
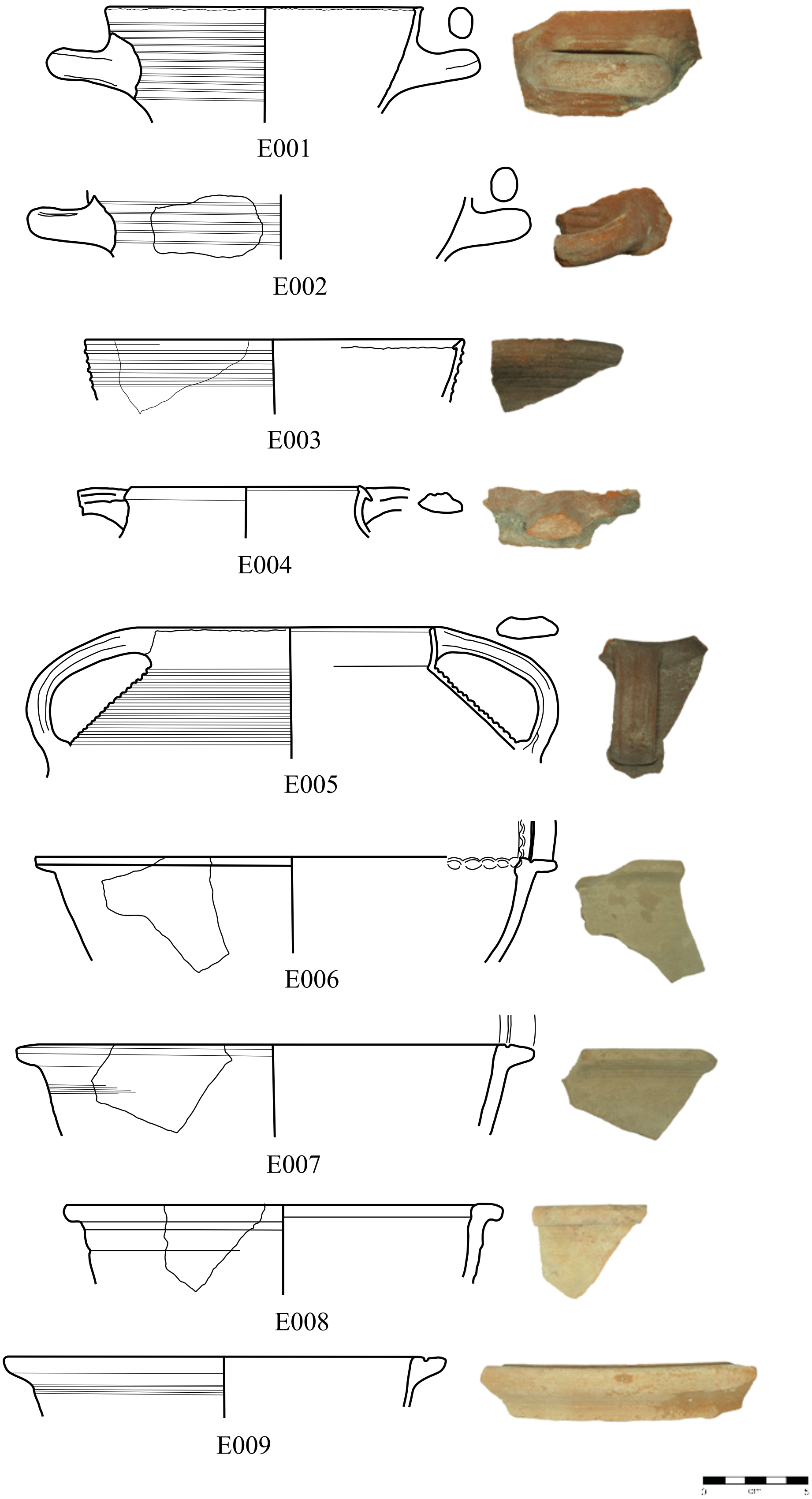


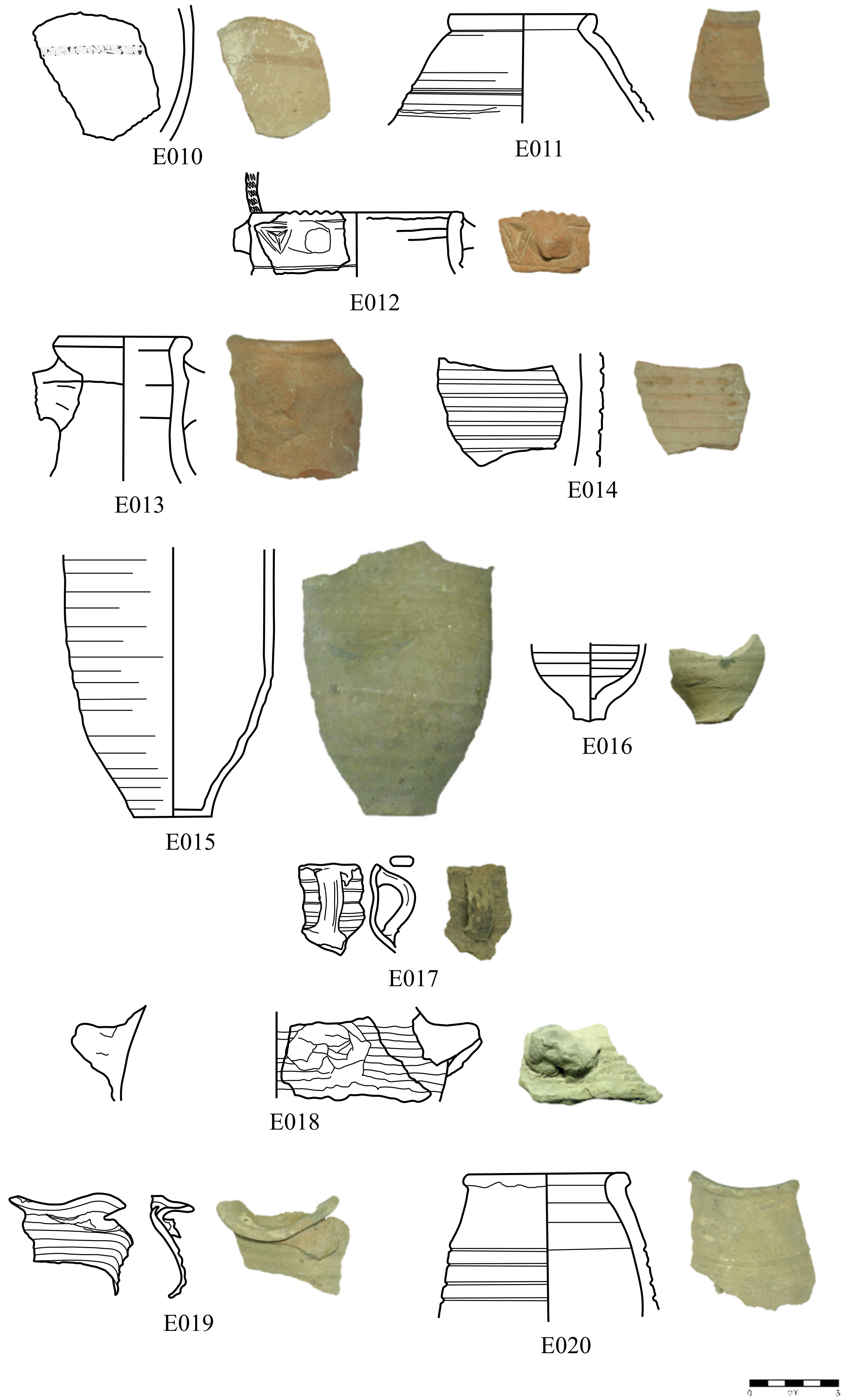
Khirbet edh-Dharih ceramics (samples DH034–DH043).

Appendix I



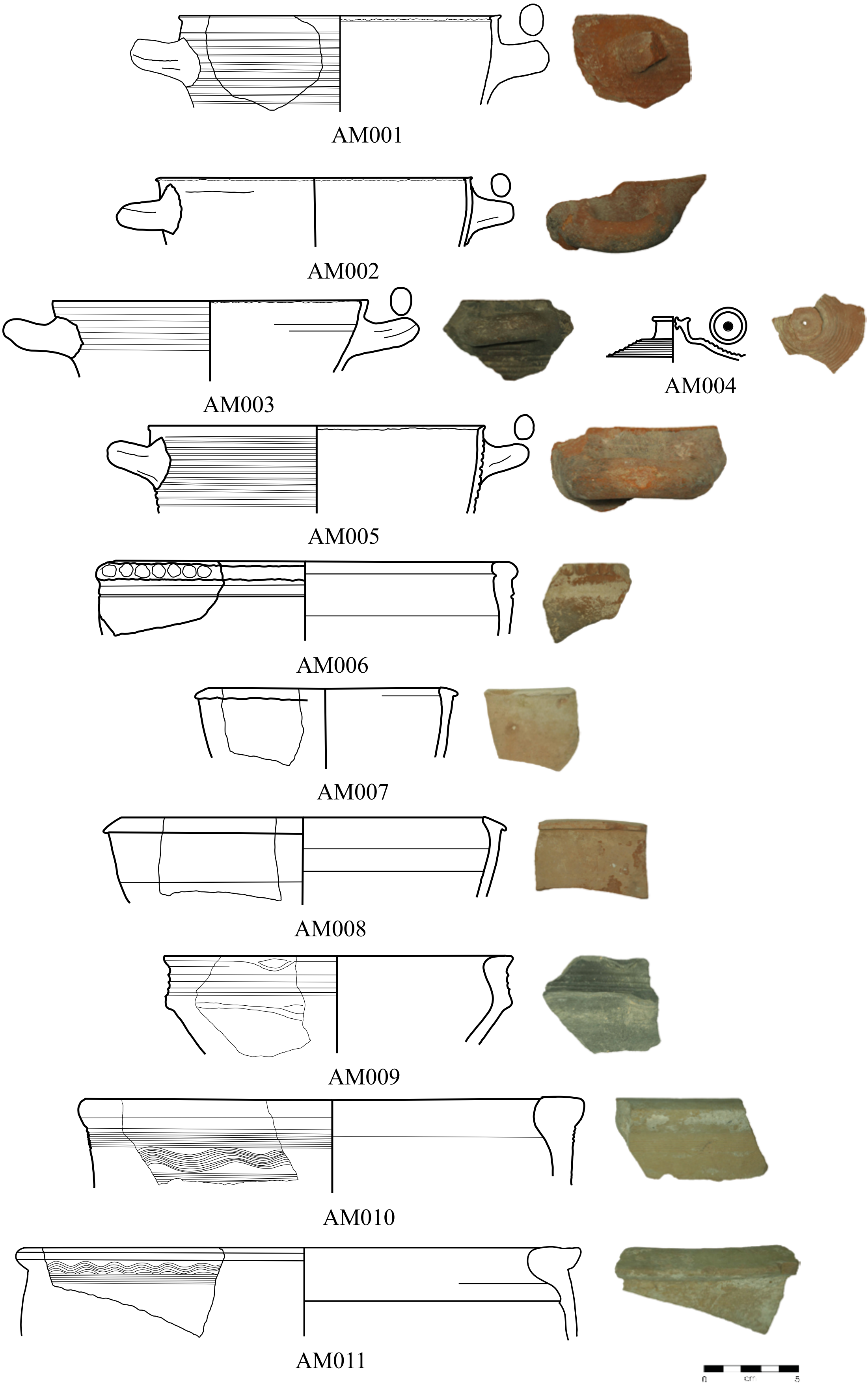
Elusa ceramics (samples E001–E009).

Appendix I



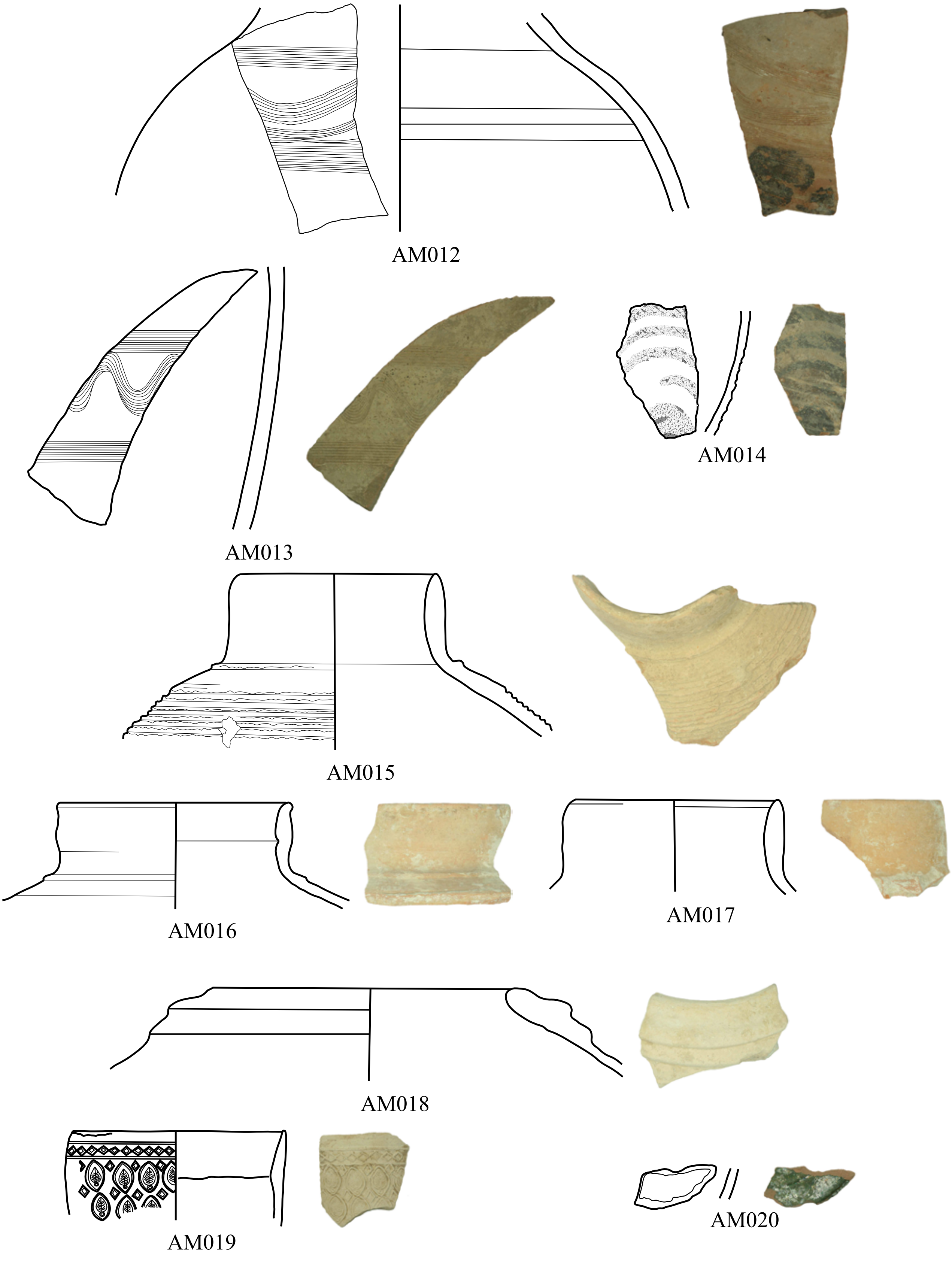
Elusa ceramics (samples E010–E020).

Appendix I



Abu Matar ceramics (samples AM001–AM011).

Appendix I



Abu Matar ceramics (samples AM012–AM020).

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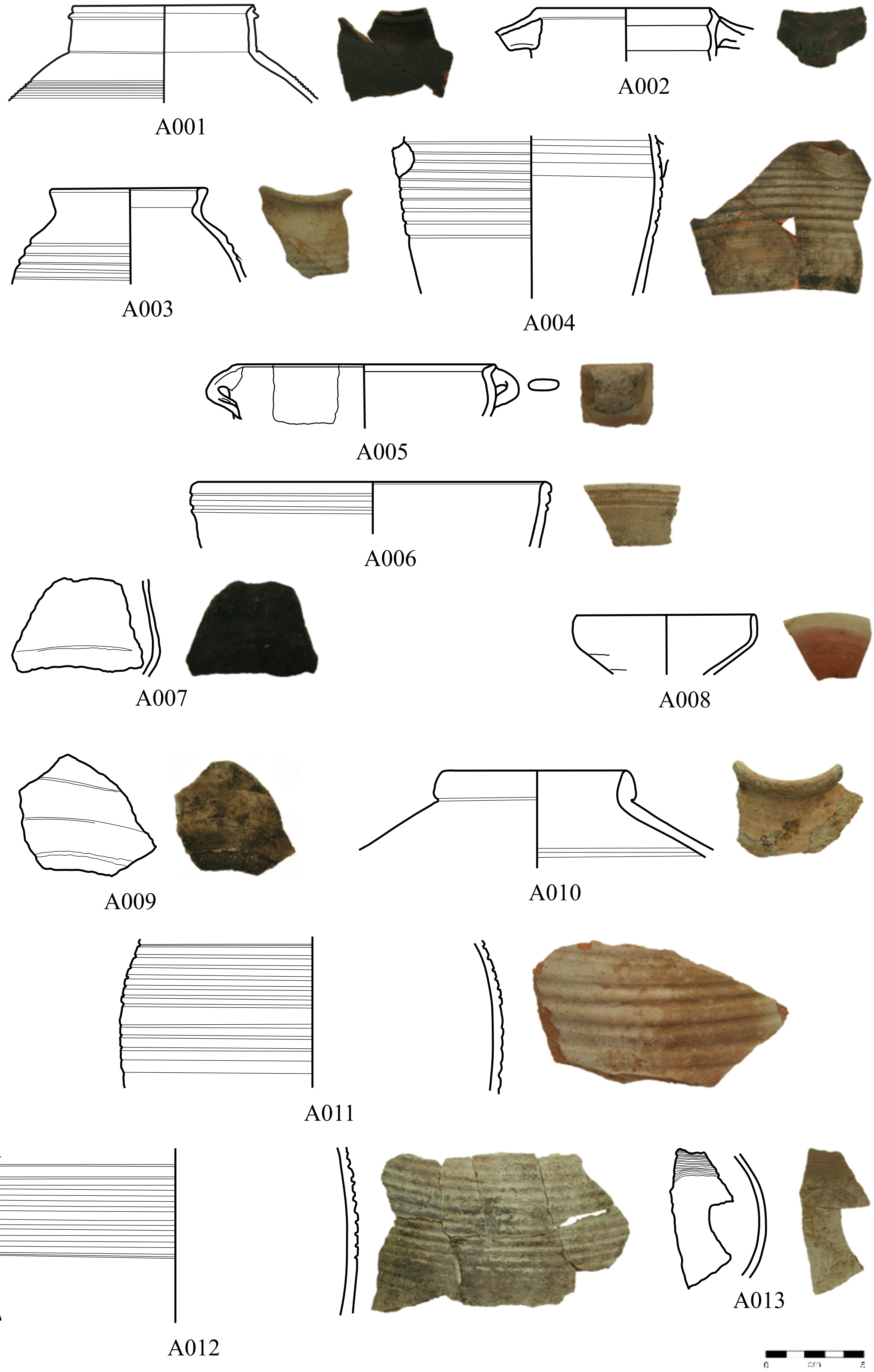
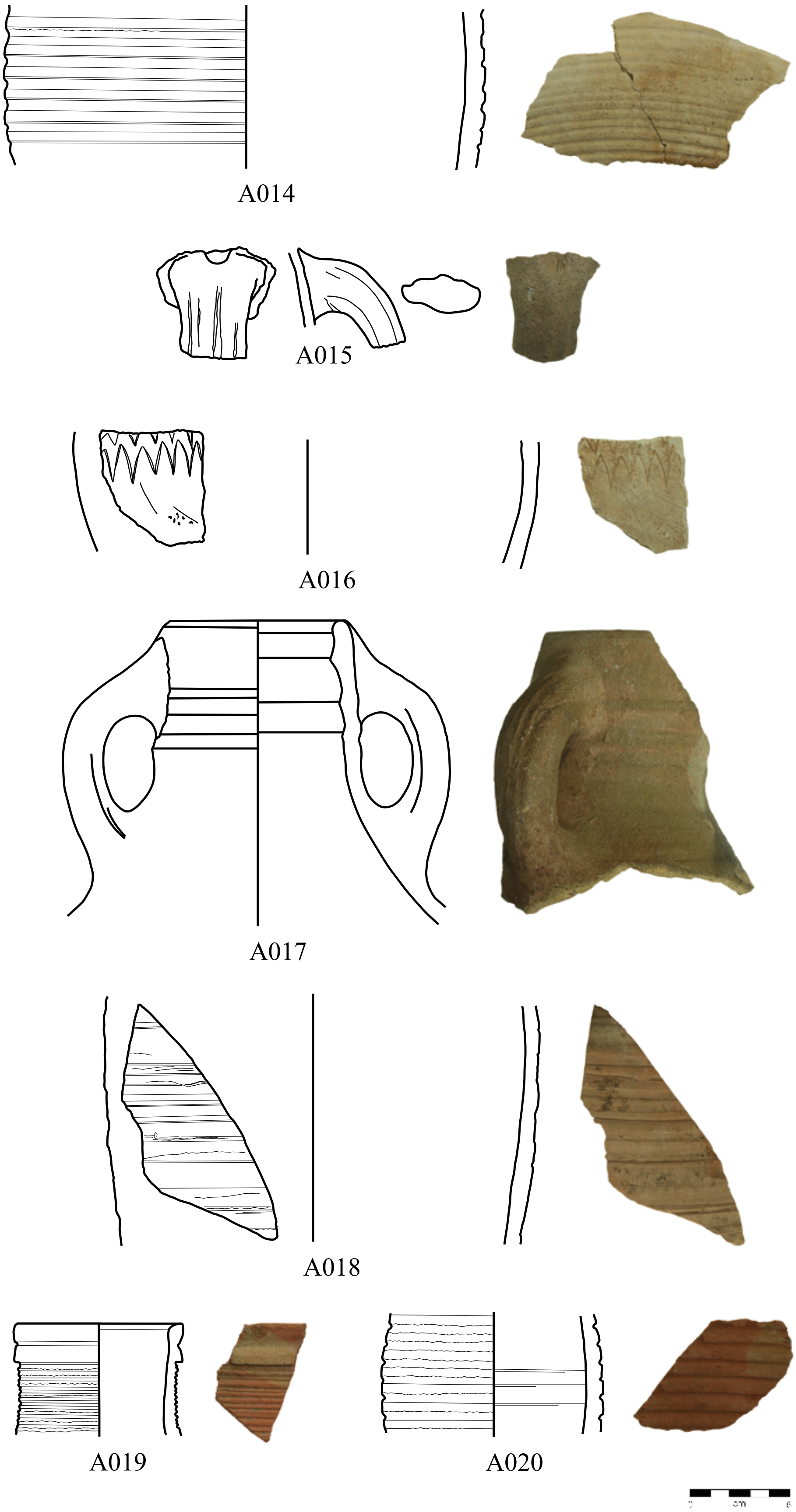


'Aqaba ceramics (samples A001–A013).

Appendix I



'Aqaba ceramics (samples A014–A020).

Appendix II

Table of samples prepared for ED-XRF and SEM-EDS analyses

Jabal Harûn			Aqaba			Khirbet edh-Dharih			Elusa			Abu Matar		
	XRF	SEM		XRF	SEM		XRF	SEM		XRF	SEM		XRF	SEM
Total	34	21	Total	20	6	Total	43	10	Total	20	9	Total	19	8
JH001	X	X	A001	X	X	DH001	X	X	E001	X	X	AM001	X	X
JH002	X		A002	X	X	DH002	X		E002	X		AM002	X	
JH003	X	X	A003	X		DH003	X		E003	X		AM003	X	
JH004	X		A004	X		DH004	X		E004	X		AM004	X	
JH005		X	A005	X		DH005	X		E005	X	X	AM005	X	
JH006	X		A006	X		DH006	X		E006	X	X	AM006	X	X
JH007	X	X	A007	X	X	DH007	X		E007	X		AM007	X	
JH008	X	X	A008	X	X	DH008	X		E008	X	X	AM008	X	
JH009	X		A009	X		DH009	X		E009	X		AM009	X	
JH010	X		A010	X		DH010	X		E010	X	X	AM010	X	X
JH011	X		A011	X		DH011	X	X	E011	X		AM011	X	
JH012	X		A012	X		DH012	X		E012	X		AM012	X	
JH013	X	X	A013	X		DH013	X		E013	X	X	AM013	X	X
JH014	X		A014	X		DH014	X		E014	X	X	AM014	X	X
JH015	X		A015	X		DH015	X		E015	X	X	AM015	X	
JH016	X	X	A016	X		DH016	X		E016	X		AM016	X	X
JH017	X		A017	X		DH017	X		E017	X		AM017	X	
JH018	X		A018	X	X	DH018	X		E018	X	X	AM018	X	
JH019	X	X	A019	X		DH019	X		E019	X		AM019	X	X
JH020	X	X	A020	X	X	DH020	X	X	E020	X		AM020		X
JH021	X	X				DH021	X							
JH022	X	X				DH022	X							
JH023	X	X				DH023	X							
JH024		X				DH024	X							
JH025		X				DH025	X	X						
JH026	X					DH026	X	X						
JH027	X					DH027	X							
JH028	X	X				DH028	X	X						
JH029	X	X				DH029	X	X						
JH030	X					DH030	X	X						
JH031	X					DH031	X							
JH032	X					DH032	X	X						
JH033	X	X				DH033	X							
JH034		X				DH034	X							
JH035	X	X				DH035	X							
JH036	X	X				DH036	X							
JH037	X	X				DH037	X							
JH038	X					DH038	X							
						DH039	X							
						DH040	X							
						DH041	X	X						
						DH042	X							
						DH043	X							

Appendix III

Table of precision tests

Arithmetic means (μ), sample standard deviations (σ) and coefficients of variation (CV, in %) for each compound after three consecutive runs of each standard on nine different days. Only measured trace elements above 20 ppm are shown. Certified values for each standard are given as reference.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	BaO	La_2O_3	CeO_2	PbO
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
ECRM 776 1																												
Certified	0.49	0.48	29.29	62.77	0.06			2.92	0.31	1.62		0.02		1.43											1220			
μ (n=27)	0.44	0.41	28.88	53.65	0.06	0.02		2.28	0.25	1.21	0.04	0.02	0.01	1.52	28	35	33	81	74	189	189	46	250	25	1105	28	69	99
σ	0.36	0.06	0.60	1.18		0.01		0.03	0.01	0.02				0.01	8	3	2	2	1	1	1	1	7	2	14	3	4	2
CV (%)	81.1	15.1	2.1	2.2	5.2	35.7	17.3	1.4	2.2	1.3	4.8	5.5	7.6	0.5	27.3	9.8	7.4	2.0	1.5	0.8	0.6	1.9	3.0	9.5	1.3	9.7	6.4	1.7
NIST 76a																												
Certified	0.07	0.52	38.70	54.90	0.12			1.33	0.22	2.03				1.60							370							
μ (n=27)	0.44	0.57	36.86	45.34	0.11	0.02		1.07	0.17	1.47	0.04	0.04	0.01	1.68	28	84	34	43	87	45	369	65	519	33	149	48	84	48
σ	0.11	0.03	0.79	0.98		0.01		0.02		0.02				0.01	7	3	2	1	2	1	2	1	9	3	5	3	5	1
CV (%)	24.1	5.2	2.2	2.2	3.0	41.7	17.6	1.7	2.1	1.4	4.1	4.3	18.1	0.7	24.4	3.7	6.8	3.2	2.1	1.6	0.5	1.2	1.8	8.5	3.4	6.7	6.1	2.4
SARM 69																												
Certified	0.79	1.85	14.40	66.60	0.28			1.96	2.37	0.78	0.03	0.03	0.13	7.18		67	58	85			129				578			15
μ (n=27)	0.43	1.46	16.41	58.29	0.26	0.02	0.01	1.66	1.87	0.56	0.02	0.03	0.13	7.41	108	56	65	85		71	131	38	234		511		38	
σ	0.23	0.05	0.18	0.74	0.01	0.01		0.02	0.02	0.01				0.05	22	3	3	2		1	1	1	9		10		7	
CV (%)	53.7	3.7	1.1	1.3	1.9	45.9	17.8	1.2	1.1	1.5	5.7	7.1	1.8	0.7	20.6	5.8	5.1	2.4		1.2	0.8	2.4	3.9		1.9		18.7	

Appendix IV

Table of accuracy tests

XRF results compared to certified values for each standard. The XRF results are represented by the arithmetic mean (μ) of three consecutive runs on nine different days (except for USGS BHVO-2). The differences are given as both absolute (δ abs) and relative (δ rel, in %) errors. Only measured trace elements above 20 ppm are shown.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	BaO	La_2O_3	CeO_2	HfO_2	PbO	ThO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
ECRM 776 1																														
Certified	0.49	0.48	29.29	62.77	0.06			2.92	0.31	1.62		0.02		1.43											1220					
μ (n=27)	0.44	0.41	28.88	53.65	0.06	0.02		2.28	0.25	1.21	0.04	0.02	0.01	1.52	28	35	33	81	44	189	189	46	250	25	1105	28	69		99	
δ abs	-0.04	-0.07	-0.40	-9.12	-0.01			-0.64	-0.06	-0.41				0.09											-115					
δ rel (%)	-9.0	-14.6	-1.4	-14.5	-8.5			-21.9	-20.2	-25.2		3.8		6.1											-9.4					
NIST 76a																														
Certified	0.07	0.52	38.70	54.90	0.12			1.33	0.22	2.03				1.60							370									
μ (n=27)	0.44	0.57	36.86	45.34	0.11	0.02		1.07	0.17	1.47	0.04	0.04	0.01	1.68	28	84	34	43	87	45	369	65	519	33	149	48	84	24	48	37
δ abs	0.37	0.05	-1.84	-9.56	-0.01			-0.26	-0.05	-0.56				0.08							-1									
δ rel (%)	523.2	9.3	-4.7	-17.4	-11.2			-19.6	-24.8	-27.5				4.8							-0.3									
SARM 69																														
Certified	0.79	1.85	14.40	66.60	0.28			1.96	2.37	0.78	0.03	0.03	0.13	7.18		67	58	85			129				578				15	
μ (n=27)	0.43	1.46	16.41	58.29	0.26	0.02	0.01	1.66	1.87	0.56	0.02	0.03	0.13	7.41	108	56	65	85		71	131	38	234		511		38			
δ abs	-0.36	-0.39	2.01	-8.31	-0.02			-0.31	-0.50	-0.22				0.23		-12	8	0			2				-67					
δ rel (%)	-45.5	-21.1	13.9	-12.5	-5.4			-15.6	-21.1	-28.0	-12.0	-9.5	0.7	3.2		-17.6	13.2	0.2			1.3				-11.7					
USGS BHVO-2																														
Certified	2.22	7.23	13.50	49.90	0.27			0.52	11.40	2.73	0.06	0.04	0.13	12.30		151					460				145					
μ (n=3)	2.26	4.33	14.74	43.74	0.17	0.01		0.42	9.30	1.92	0.05	0.03	0.17	12.55	180	131	170	128	35		458	32	131		121					
δ abs	0.04	-2.91	1.24	-6.16	-0.10			-0.10	-2.10	-0.81	-0.01	-0.01	0.04	0.25		-21					-1				-25					
δ rel (%)	1.7	-40.2	9.2	-12.3	-35.7			-19.7	-18.4	-29.7	-18.5	-15.5	33.0	2.0		-13.6					-0.3				-16.9					

Appendix V

Table of compositional groups

The order of samples follows the cluster groupings of the ED-XRF data.

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 1a	μ (n=14)	0.20	2.22	22.15	61.56	0.17	0.02	0.06	2.24	3.05	0.76	0.02	0.02	0.05	7.38	90	57	47	75	46			79	191	35	152				150	16	42	5
	σ	0.11	0.61	1.47	2.47	0.08	0.02	0.07	0.27	1.62	0.07			0.01	0.57	11	6	7	11	4			12	78	9	34				79	11	7	10
	min	0.03	1.16	19.07	57.00	0.10			1.87	1.05	0.65	0.02	0.02	0.03	6.36	73	48	38	64	36			56	112	22	116				98		32	
	max	0.44	3.29	24.55	66.39	0.40	0.05	0.21	2.69	7.11	0.88	0.03	0.03	0.08	8.48	109	67	59	104	51			93	415	60	211				399	28	58	24
	A001	0.18	1.16	21.66	64.89	0.12	0.05	0.02	1.91	1.05	0.78	0.03	0.02	0.06	7.98	91	48	42	104	47			61	208	33	134				128	21	48	
	JH009	0.14	1.99	23.50	60.74	0.10	0.05	0.21	2.14	2.29	0.74	0.02	0.03	0.03	7.91	88	55	45	88	45			72	128	28	128				105	21	39	
	JH036	0.11	2.15	19.07	66.39	0.13	0.02	0.03	1.87	1.87	0.70	0.02	0.02	0.05	7.49	95	54	42	64	41			70	115	31	139				105	23	40	
	JH037	0.09	2.17	22.01	63.24	0.16	0.05	0.02	2.08	1.36	0.74	0.02	0.02	0.05	7.91	101	58	43	66	45			73	112	34	146				98		33	23
	DH035	0.29	1.16	19.93	63.15	0.17	0.01		1.93	5.52	0.66	0.03	0.02	0.03	6.97	73	48	38	86	36			56	415	22	126				399		32	
	DH002	0.25	2.16	22.77	61.30	0.14	0.03	0.09	2.28	2.75	0.80	0.02	0.02	0.04	7.24	97	61	47	65	47			82	178	43	210				111	26	46	
	DH043	0.14	2.48	22.22	61.88	0.20	0.03	0.19	2.34	2.89	0.73	0.02	0.02	0.04	6.72	83	51	44	71	46			83	182	36	185				187	21	48	
	DH028	0.31	1.93	23.93	61.26	0.11		0.04	1.95	2.51	0.88	0.02	0.02	0.05	6.88	90	56	40	79	51			75	185	40	196				128	23	51	24
	DH017	0.03	2.15	20.97	62.92	0.40		0.02	2.19	3.85	0.86	0.03	0.02	0.08	6.36	80	51	38	70	44			81	229	60	211				162	28	58	21
	DH004	0.25	2.41	24.55	58.72	0.13	0.03	0.01	2.54	1.90	0.77	0.03	0.02	0.04	8.48	109	67	53	76	51			93	151	34	116				157	22	42	
	DH022	0.24	3.29	21.78	57.00	0.13			2.49	7.11	0.65	0.02	0.02	0.05	7.10	91	59	53	78	46			87	273	28	117				199		38	
	DH024	0.44	3.28	22.68	59.15	0.13		0.06	2.37	3.73	0.71	0.03	0.02	0.04	7.26	101	59	59	72	49			93	149	31	119				107		35	
	DH020	0.18	2.40	22.69	60.08	0.20	0.02	0.08	2.69	3.04	0.80	0.02	0.02	0.05	7.63	82	63	59	67	47			90	173	36	153				109	22	38	
	DH021	0.11	2.31	22.36	61.10	0.20		0.05	2.58	2.88	0.78	0.02	0.02	0.05	7.43	74	60	50	67	47			88	172	37	151				102	22	44	

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 1b	μ (n=7)	0.49	2.19	22.52	59.04	0.25	0.42	0.05	2.69	2.67	0.84	0.03	0.02	0.05	8.60	101	56	48	120	47			86	314	33	155	4			243	13	45	10
	σ	0.30	0.43	1.65	2.35	0.11	0.92	0.07	0.55	1.56	0.15			0.02	0.87	22	16	8	49	4			13	89	7	39	11			164	12	6	13
	min		1.66	20.85	56.69	0.15			2.14	1.25	0.74	0.02	0.02	0.02	7.41	77	30	38	76	44			60	158	23	116				118		35	
	max	0.81	2.82	25.74	63.45	0.46	2.51	0.15	3.84	5.98	1.16	0.03	0.02	0.08	9.59	136	72	62	207	54			100	453	44	230	29			516	25	49	30
	DH005	0.37	2.12	22.74	59.16	0.18	0.01		2.68	2.17	0.75	0.03	0.02	0.05	9.59	112	67	49	207	45			95	280	31	124				198		35	
	DH006	0.81	2.82	21.71	56.96	0.19		0.01	2.33	5.98	0.74	0.03	0.02	0.06	8.19	82	59	38	107	44			78	322	34	149				516		40	
	DH026		1.83	20.85	63.45	0.32	0.10	0.02	2.44	2.62	0.75	0.02	0.02	0.05	7.41	77	60	49	142	44			89	300	35	152				118	23	45	
	DH027	0.72	2.69	22.61	58.65	0.30	0.22	0.14	2.66	2.98	0.76	0.03	0.02	0.08	8.01	99	66	54	147	45			93	324	44	136				123	23	49	21
	DH007	0.27	1.66	22.97	60.52	0.15	0.08		2.14	1.78	0.90	0.03	0.02	0.05	9.28	119	39	39	77	48			60	453	29	176				434		47	30
	DH040	0.49	2.26	25.74	56.69	0.16	0.02	0.04	2.76	1.25	0.82	0.03	0.02	0.03	9.57	136	72	47	83	54			100	158	38	116				118	25	49	
	DH039	0.76	1.97	21.02	57.82	0.46	2.51	0.15	3.84	1.95	1.16	0.03	0.02	0.02	8.15	83	30	62	76	50			85	359	23	230	29			190	21	49	20
Gr 1c	μ (n=15)	0.51	3.78	18.04	55.95	0.33	0.24	0.16	2.89	9.85	0.73	0.02	0.02	0.07	7.26	84	46	50	84	37			80	411	34	178	3			200	15	42	8
	σ	0.22	1.61	2.94	3.65	0.12	0.52	0.08	0.53	3.09	0.09			0.02	0.51	10	7	15	18	5			9	142	10	57	8			104	11	7	13
	min	0.19	1.70	12.03	50.12	0.13		0.03	2.06	5.12	0.57	0.02	0.01	0.04	6.49	67	30	25	62	26			66	215	23	109				79		30	
	max	0.85	8.34	22.66	62.71	0.57	1.54	0.30	3.98	15.53	0.90	0.02	0.02	0.10	8.13	100	58	86	114	44			98	696	59	302	23			456	24	49	30
	AM017	0.42	1.70	18.94	54.66	0.20		0.06	3.98	12.23	0.82	0.02	0.02	0.09	6.70	67	45	47	95	36			76	471	38	257				229	22	42	
	DH018	0.38	2.19	16.69	59.26	0.42	0.05	0.07	3.35	8.99	0.90	0.02	0.01	0.04	7.47	90	30	27	66	37			81	633	44	302	23			237	24	49	
	DH011	0.74	2.37	18.55	55.03	0.34	0.01	0.17	3.16	11.14	0.83	0.02	0.01	0.09	7.42	95	48	59	86	40			85	320	30	160	23			116	24	49	30
	JH014	0.72	3.61	19.38	56.41	0.35	0.02	0.30	2.87	7.90	0.73	0.02	0.02	0.06	7.49	86	45	64	106	39			92	215	45	193				137	23	48	22
	DH025	0.48	3.04	17.20	54.18	0.40	0.01	0.25	2.65	13.94	0.71	0.02	0.02	0.06	6.94	95	51	62	66	37			73	414	26	109				79	21	31	
	DH042	0.63	3.62	14.58	62.71	0.57	0.08	0.13	3.47	5.59	0.85	0.02	0.01	0.06	7.51	97	51	86	85	34			94	376	36	218				330	23	49	
	DH003	0.77	3.07	18.55	61.82	0.45	0.07	0.10	2.36	5.12	0.67	0.02	0.02	0.08	6.78	80	58	45	114	37			79	283	59	207				158	21	49	
	DH023	0.24	2.87	20.47	58.85	0.22	0.05	0.21	2.54	7.11	0.62	0.02	0.02	0.05	6.62	68	50	49	94	39			77	287	31	111				114		37	
	DH010	0.19	3.68	19.99	55.51	0.36	0.01	0.16	2.06	10.49	0.79	0.02	0.02	0.08	6.49	74	42	52	68	39			73	451	43	225				177	22	45	
	DH015	0.33	3.93	20.86	54.88	0.24	0.08	0.16	2.20	8.85	0.67	0.02	0.02	0.07	7.57	85	46	43	81	44			74	334	30	176				130	22	45	22
	DH016	0.47	3.72	20.93	54.99	0.20	0.01	0.09	2.37	8.69	0.69	0.02	0.02	0.07	7.62	82	50	44	84	44			75	351	31	171				124	20	30	
	JH033	0.77	4.00	22.66	50.12	0.13	1.54	0.26	3.03	8.47	0.70	0.02	0.02	0.04	8.13	80	54	25	114	42			66	267	24	112				147		35	26
	DH009	0.85	8.34	12.03	51.56	0.40	1.52	0.26	3.20	14.33	0.57	0.02	0.01	0.10	6.67	75	39	49	67	26			75	487	23	129				238		42	27
	DH014	0.38	4.84	15.11	57.99	0.29	0.02	0.15	3.16	9.43	0.74	0.02	0.01	0.07	7.61	100	47	46	67	33			98	587	27	165				324		43	
	DH036	0.28	5.67	14.72	51.28	0.40	0.19	0.03	2.95	15.53	0.72	0.02	0.01	0.10	7.91	91	41	48	62	34			86	696	27	132				456		36	

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 2	μ (n=1)	0.69	0.96	28.59	57.58	0.12	0.05	0.03	5.41	0.99	0.29	0.02		0.03	5.06	62		81	68	84			196	192	23	269				644	25	69	34
	A007	0.69	0.96	28.59	57.58	0.12	0.05	0.03	5.41	0.99	0.29	0.02		0.03	5.06	62		81	68	84			196	192	23	269				644	25	69	34
Gr 3a	μ (n=7)	0.39	1.62	21.93	65.61	0.13	0.15	0.18	1.91	1.12	0.82	0.02	0.02	0.02	5.96	67	41	51	74	41			63	127	37	253				137	14	46	22
	σ	0.31	0.32	2.44	2.60	0.04	0.12	0.13	0.28	0.54	0.09			0.01	0.47	5	7	11	29	4			7	51	7	44				22	13	9	10
	min		1.29	18.38	62.29	0.09	0.03	0.01	1.60	0.38	0.66	0.02	0.02	0.01	5.48	62	28	32	50	35			57	76	30	190				104		33	
	max	0.98	2.24	24.59	68.64	0.20	0.32	0.32	2.30	1.93	0.93	0.02	0.02	0.03	6.75	76	49	66	136	49			76	211	51	320				161	26	56	31
	A002	0.61	1.42	18.38	68.64	0.20	0.25	0.32	1.70	1.93	0.66	0.02	0.02	0.03	5.71	76	40	46	136	35			66	182	35	219				123		42	
	DH013		1.38	20.15	67.42	0.09	0.03	0.01	1.72	1.48	0.79	0.02	0.02	0.03	6.75	65	42	32	61	39			64	125	33	233				116	21	44	22
	DH029	0.27	1.29	19.95	68.37	0.12	0.03	0.01	2.30	1.19	0.81	0.02	0.02	0.01	5.48	63	28	49	50	42			76	211	37	290				161	23	55	21
	JH010	0.29	2.24	23.55	63.04	0.11	0.32	0.22	2.08	1.26	0.90	0.02	0.02	0.03	5.80	68	37	46	54	41			58	91	42	320				156	26	53	26
	JH013	0.28	1.79	22.55	65.62	0.11	0.05	0.15	1.76	1.15	0.84	0.02	0.02	0.02	5.52	71	43	62	67	39			58	109	33	245				143		38	23
	JH019	0.29	1.60	24.34	63.90	0.10	0.25	0.26	1.60	0.48	0.93	0.02	0.02	0.02	6.08	62	49	56	72	49			61	92	51	275				153	26	56	29
	JH020	0.98	1.64	24.59	62.29	0.15	0.10	0.30	2.21	0.38	0.83	0.02	0.02	0.01	6.39	66	49	66	75	43			57	76	30	190				104		33	31
Gr 3b	μ (n=10)	0.49	1.82	23.22	62.81	0.12	0.13	0.21	1.86	1.31	0.87	0.02	0.02	0.03	6.97	89	44	46	76	43			62	112	42	247				124	21	49	23
	σ	0.24	0.35	1.47	1.72	0.04	0.11	0.12	0.20	0.73	0.06			0.01	0.41	9	4	7	14	3			7	24	9	38				10	8	7	14
	min	0.04	1.37	20.31	60.13	0.08	0.03	0.05	1.58	0.49	0.77	0.02	0.01	0.02	6.01	78	39	33	63	39			52	83	34	185				108		35	
	max	0.79	2.37	25.50	64.87	0.20	0.39	0.42	2.13	2.80	0.94	0.02	0.02	0.04	7.59	102	51	58	101	48			73	158	59	302				138	26	60	41
	A004	0.67	1.88	20.31	64.14	0.19	0.20	0.27	1.59	2.80	0.77	0.02	0.02	0.04	6.99	89	51	50	101	40			53	143	34	200				126		43	
	JH016	0.04	1.37	24.14	63.51	0.12	0.04	0.13	1.68	0.98	0.92	0.02	0.02	0.03	6.89	95	44	58	98	48			65	109	44	229				120	23	60	41
	JH022	0.24	1.54	22.97	64.49	0.09	0.07	0.11	1.70	0.66	0.82	0.02	0.02	0.03	7.13	102	47	41	75	47			68	95	35	185				116	26	54	24
	DH001	0.50	1.67	22.56	63.53	0.14	0.13	0.17	2.13	1.21	0.83	0.02	0.02	0.03	6.95	95	45	43	63	43			73	158	38	253				137	23	52	23
	JH021	0.55	1.42	23.60	64.87	0.10	0.07	0.22	1.58	0.49	0.92	0.02	0.02	0.02	6.01	99	43	45	73	44			60	91	56	302				138	25	53	39
	DH008	0.25	1.74	22.33	63.81	0.12	0.03	0.05	1.96	1.09	0.86	0.02	0.01	0.04	7.59	78	49	42	68	42			72	117	36	229				123	22	44	22
	JH001	0.63	2.37	23.65	61.05	0.11	0.06	0.26	1.98	1.50	0.87	0.02	0.02	0.04	7.33	78	44	45	85	44			65	110	40	242				122	23	49	32
	JH008	0.79	1.80	24.81	60.69	0.08	0.39	0.38	2.01	0.93	0.92	0.02	0.02	0.04	7.03	87	41	50	66	45			58	92	36	264				121	22	35	22
	JH018	0.54	2.09	25.50	60.13	0.10	0.11	0.42	2.04	1.11	0.94	0.02	0.02	0.04	6.83	78	39	33	70	41			52	83	59	273				108	23	54	23
	JH017	0.72	2.33	22.32	61.87	0.20	0.20	0.13	1.90	2.37	0.85	0.02	0.02	0.04	6.93	87	40	49	65	39			59	127	43	298				135	22	45	

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 3c	μ (n=9)	0.53	2.75	21.12	60.88	0.20	0.15	0.25	2.14	3.94	0.81	0.02	0.02	0.05	7.04	86	42	63	73	39	4		64	181	40	249				142	22	46	18
	σ	0.21	0.51	1.13	1.33	0.06	0.09	0.07	0.19	1.65	0.04			0.01	0.32	9	3	19	11	3	11		7	64	4	18				18	2	7	10
	min	0.23	2.15	19.59	58.68	0.13	0.03	0.12	1.88	1.71	0.76	0.02	0.01	0.04	6.51	72	36	41	63	35			55	127	35	226				124	20	35	
	max	0.89	3.47	22.85	63.33	0.32	0.34	0.38	2.48	6.34	0.89	0.02	0.02	0.06	7.69	98	46	98	88	44	33		79	331	45	278				173	24	58	28
	JH002	0.23	2.17	21.41	63.33	0.15	0.07	0.24	1.88	2.60	0.83	0.02	0.02	0.04	6.91	92	41	85	63	41			62	136	38	226				137	20	48	22
	JH023	0.49	2.77	22.85	60.82	0.13	0.13	0.38	1.93	1.71	0.89	0.02	0.02	0.06	7.69	78	44	98	64	44			66	127	39	230				127	23	35	23
	JH003	0.26	2.43	19.70	62.12	0.24	0.18	0.16	2.13	4.80	0.76	0.02	0.02	0.04	7.03	89	41	41	67	35			61	169	39	238				140	22	41	
	JH006	0.66	2.78	20.75	58.68	0.32	0.11	0.25	2.15	6.20	0.78	0.02	0.02	0.06	7.11	91	43	42	88	37			66	207	45	255				170	24	54	22
	JH032	0.44	2.15	20.23	60.07	0.24	0.03	0.22	2.02	6.34	0.79	0.02	0.01	0.06	7.27	98	46	52	87	38			66	208	45	241				173	24	58	21
	JH004	0.46	3.46	19.59	60.61	0.24	0.06	0.28	2.48	4.76	0.81	0.02	0.02	0.05	7.03	84	36	72	88	36			79	172	45	278				149	22	48	28
	JH007	0.71	2.38	22.00	61.41	0.16	0.20	0.28	2.11	3.28	0.79	0.02	0.02	0.04	6.51	72	37	55	67	38	33		56	147	35	274				124	21	38	23
	JH011	0.66	3.13	21.55	60.82	0.14	0.19	0.12	2.25	3.12	0.87	0.02	0.02	0.04	6.93	79	43	53	69	41			64	331	37	242				129	21	49	23
	JH012	0.89	3.47	22.03	60.08	0.15	0.34	0.28	2.32	2.65	0.79	0.02	0.02	0.04	6.84	93	45	67	67	39			55	130	36	255				127	21	42	
Gr 4	μ (n=2)	0.77	1.10	21.12	66.05	0.15	0.05	0.04	2.35	2.06	1.32	0.03	0.02	0.04	4.75	58	30	46	64	45			74	310	65	503	45			242	30	64	15
	σ	0.08	0.13	0.36	0.58		0.04	0.05	0.69	2.10	0.13			0.02	2.51	20	13		13	11			15	226	17	41	25			38	8	17	21
	min	0.71	1.00	20.86	65.64	0.15	0.02	0.01	1.86	0.58	1.23	0.03	0.01	0.02	2.97	44	21	45	54	37			63	151	53	474	27			215	24	53	
	max	0.83	1.19	21.38	66.46	0.15	0.08	0.07	2.84	3.54	1.41	0.03	0.02	0.06	6.53	72	39	46	73	52			84	470	77	532	62			269	36	76	29
	DH012	0.71	1.00	20.86	65.64	0.15	0.02	0.01	2.84	0.58	1.41	0.03	0.01	0.06	6.53	72	39	46	73	52			84	151	77	474	62			215	36	76	
	DH030	0.83	1.19	21.38	66.46	0.15	0.08	0.07	1.86	3.54	1.23	0.03	0.02	0.02	2.97	44	21	45	54	37			63	470	53	532	27			269	24	53	29
Gr 5	μ (n=1)	0.59	0.76	31.02	58.07	0.06	0.11	0.16	1.13	0.48	1.48	0.03	0.02	0.03	5.73	77	51	114	71	40			54	259	54	220	21			213	36	85	1722
	JH035	0.59	0.76	31.02	58.07	0.06	0.11	0.16	1.13	0.48	1.48	0.03	0.02	0.03	5.73	77	51	114	71	40			54	259	54	220	21			213	36	85	1722

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 6a	μ (n=8)	0.78	1.44	17.26	67.22	0.12	0.06	0.11	1.41	0.89	1.09	0.03	0.02	0.15	9.24	144	70	69	139	38			68	212	56	260	21			480	23	59	
	σ	0.31	0.10	0.76	1.36	0.03	0.03	0.12	0.06	0.10	0.05			0.01	0.50	20	5	7	9	3			5	25	3	15	9			113	3	4	
	min	0.49	1.23	16.01	65.91	0.08	0.04	0.01	1.28	0.71	1.03	0.03	0.02	0.14	8.63	103	63	61	126	33			59	166	52	239				378	21	52	
	max	1.42	1.56	18.17	69.31	0.17	0.13	0.37	1.49	1.02	1.16	0.03	0.02	0.17	9.86	165	80	81	151	43			76	252	61	281	28			707	29	65	
	AM001	0.50	1.48	18.17	66.05	0.17	0.05	0.01	1.44	0.88	1.14	0.03	0.02	0.17	9.71	165	71	65	151	40			76	202	60	239	28			445	29	65	
	E004	0.68	1.56	17.60	66.47	0.11	0.13	0.09	1.45	0.71	1.13	0.03	0.02	0.14	9.73	164	70	69	144	42			70	227	56	246	25			418	23	60	
	AM006	0.49	1.44	17.42	67.23	0.10	0.06	0.03	1.36	0.94	1.13	0.03	0.02	0.16	9.38	156	68	75	139	38			70	202	58	273	21			707	22	58	
	E001	1.42	1.51	17.70	65.91	0.08	0.05	0.37	1.39	0.95	1.06	0.03	0.02	0.14	9.21	149	74	67	135	39			67	203	56	261	23			378	22	57	
	E005	0.69	1.44	17.46	66.24	0.10	0.04	0.21	1.43	0.98	1.16	0.03	0.02	0.16	9.86	137	80	64	151	43			74	252	61	275	23			570	24	64	
	AM003	0.85	1.40	16.01	69.31	0.09	0.05	0.03	1.28	0.83	1.03	0.03	0.02	0.14	8.78	134	67	66	126	37			66	166	53	248				414	24	57	
	AM004	1.00	1.45	17.57	67.31	0.13	0.06	0.12	1.49	0.82	1.04	0.03	0.02	0.14	8.66	140	63	61	134	34			59	216	53	255	22			388	22	52	
	AM005	0.63	1.23	16.16	69.22	0.16	0.05	0.05	1.42	1.02	1.05	0.03	0.02	0.15	8.63	103	68	81	131	33			66	229	52	281	25			522	21	60	
Gr 6b	μ (n=4)	0.77	1.84	14.63	69.13	0.11	0.03	0.08	1.26	3.01	0.97	0.03	0.02	0.12	7.84	102	59	57	109	33			56	274	46	284	16			387	5	45	
	σ	0.15	0.63	0.93	2.64	0.03	0.04	0.05	0.10	2.57	0.04			0.03	0.32	7	1	7	7	1			3	121	2	33	10			57	11	5	
	min	0.62	1.26	13.58	66.65	0.08		0.01	1.15	0.80	0.93	0.02	0.02	0.08	7.46	95	58	47	99	32			52	178	43	256				329	0	38	
	max	0.97	2.57	15.84	71.84	0.13	0.09	0.13	1.38	5.88	1.02	0.03	0.02	0.13	8.24	111	61	64	117	35			59	431	47	324	21			439	22	51	
	AM002	0.62	1.38	15.84	70.95	0.08	0.04	0.10	1.15	0.80	0.93	0.02	0.02	0.08	7.84	95	59	47	107	33			52	178	46	256	21			329		47	
	E002	0.80	1.26	14.58	71.84	0.09	0.09	0.13	1.22	0.88	0.95	0.03	0.02	0.13	7.84	111	60	57	117	35			58	179	47	256				347	22	51	
	AM009	0.69	2.57	13.58	67.09	0.13		0.01	1.27	5.88	0.97	0.03	0.02	0.13	7.46	101	58	64	99	32			56	431	43	324	21			434		38	
	E003	0.97	2.16	14.51	66.65	0.13		0.09	1.38	4.50	1.02	0.03	0.02	0.13	8.24	100	61	61	112	33			59	309	47	298	21			439		45	
Gr 6c	μ (n=2)	1.01	2.74	16.75	60.56	0.38	0.07	0.07	2.08	6.47	1.04	0.03	0.02	0.12	8.44	96	66	85	135	36			70	442	46	353	21	14		678	12	49	18
	σ	0.80	0.22	1.59	0.55	0.29	0.07	0.05	0.66	0.09	0.18			0.02	0.70	2	14	18	30				18	221	3	36	1	19		285	16	4	26
	min	0.44	2.58	15.62	60.18	0.17	0.02	0.03	1.61	6.41	0.92	0.03	0.02	0.11	7.94	95	56	72	114	36			57	286	44	328	20			476		46	
	max	1.57	2.90	17.87	60.95	0.58	0.12	0.11	2.55	6.53	1.16	0.03	0.02	0.14	8.94	98	76	98	156	36			83	598	48	379	22	27		880	23	52	36
	AM012	0.44	2.58	17.87	60.18	0.58	0.02	0.03	2.55	6.53	0.92	0.03	0.02	0.11	7.94	95	56	72	156	36			83	286	48	379	22	27		476	23	52	36
	E010	1.57	2.90	15.62	60.95	0.17	0.12	0.11	1.61	6.41	1.16	0.03	0.02	0.14	8.94	98	76	98	114	36			57	598	44	328	20			880		46	

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 7	µ (n=1)	0.66	1.06	28.59	49.19	0.55		0.03	1.56	6.63	1.53	0.04	0.03	0.06	9.87	107	116	58	211	63			78	468	66	299	38			301	45	85	31
	AM014	0.66	1.06	28.59	49.19	0.55		0.03	1.56	6.63	1.53	0.04	0.03	0.06	9.87	107	116	58	211	63			78	468	66	299	38			301	45	85	31
Gr 8a	µ (n=9)	2.28	2.86	18.60	51.99	0.36	0.48	0.51	1.87	13.97	0.65	0.02	0.01	0.09	6.11	76	45	45	129	37	78	9	61	623	36	154			3	450	23	61	18
	σ	1.23	0.88	1.03	1.51	0.10	1.16	0.62	0.24	1.60	0.06			0.02	0.45	9	4	11	9	2	234	19	9	151	3	18			8	51	9	10	19
	min	0.03	2.07	17.02	50.10	0.27		0.08	1.56	12.23	0.56	0.01	0.01	0.05	5.32	65	40	28	119	34			46	506	31	124				352		42	
	max	4.74	4.71	20.45	54.14	0.59	3.53	2.07	2.14	16.21	0.79	0.02	0.02	0.12	6.65	86	51	57	140	39	702	56	72	1009	40	178			25	513	30	72	52
	A003	2.86	2.07	17.79	50.10	0.27	3.53	0.61	1.94	14.03	0.64	0.01	0.01	0.07	5.85	67	40	57	130	34			62	1009	32	158				352	25	58	29
	A008	2.66	2.11	18.83	50.54	0.35		0.55	2.09	16.06	0.63	0.01	0.01	0.10	5.86	81	47	57	120	38		21	72	573	36	124				422	27	62	52
	DH019	0.03	2.10	20.45	51.96	0.30		0.08	2.14	15.45	0.79	0.02	0.02	0.05	6.37	65	51	36	133	37	702		68	529	34	174			25	449		42	
	A009	4.74	3.49	17.02	50.25	0.59		2.07	1.56	13.62	0.59	0.02	0.01	0.11	5.75	70	47	28	120	34		56	46	592	35	135				420	22	57	
	A010	2.39	2.24	18.57	52.20	0.41		0.25	1.57	16.21	0.56	0.02	0.02	0.09	5.32	66	44	37	140	35			52	506	31	144				465	23	52	
	A011	2.19	3.18	19.05	51.67	0.31	0.19	0.51	2.04	13.54	0.67	0.02	0.01	0.08	6.33	85	40	48	134	39			68	648	38	166				495	29	72	22
	JH026	1.66	2.67	19.49	54.14	0.39	0.01	0.19	2.03	12.29	0.66	0.02	0.01	0.09	6.17	85	41	52	119	39			70	554	36	151				431	30	72	22
	A012	1.96	3.20	18.56	53.49	0.33	0.56	0.13	1.83	12.29	0.67	0.02	0.01	0.11	6.65	86	47	33	124	39			59	622	40	158				513	26	62	
	A017	2.03	4.71	17.65	53.60	0.30	0.05	0.18	1.59	12.23	0.66	0.02	0.02	0.12	6.65	82	51	55	140	39			56	576	39	178				506	29	69	36
Gr 8b	µ (n=1)	0.49	1.37	20.69	55.82	1.00	0.01	0.12	1.47	12.39	0.83	0.03	0.02	0.04	5.58	71	65	48	171	38			60	351	44	272				215	24	53	29
	JH015	0.49	1.37	20.69	55.82	1.00	0.01	0.12	1.47	12.39	0.83	0.03	0.02	0.04	5.58	71	65	48	171	38			60	351	44	272				215	24	53	29
Gr 8c	µ (n=4)	1.71	3.99	16.81	57.51	0.24	0.16	0.37	1.78	11.54	0.59	0.01	0.02	0.06	5.04	64	38	55	111	34		17	54	571	32	182				360	16	50	28
	σ	1.17	1.05	0.84	1.56	0.05	0.13	0.43	0.32	1.45	0.07		0.01	0.02	0.18	9	6	13	14	3		22	14	134	2	35				125	11	4	22
	min	0.29	2.48	15.71	55.73	0.17	0.05	0.09	1.43	9.39	0.49	0.01	0.01	0.04	4.82	55	33	36	90	31			40	381	29	144				179		45	
	max	2.75	4.75	17.77	59.18	0.30	0.28	1.01	2.11	12.56	0.63	0.02	0.02	0.09	5.20	77	47	65	120	37		46	67	680	35	223				463	22	55	53
	A006	2.75	4.66	17.77	55.73	0.22	0.28	1.01	2.11	9.39	0.62	0.01	0.02	0.05	5.20	77	33	57	114	37		46	67	647	31	162				410	21	49	35
	A013	1.21	2.48	16.86	58.40	0.26	0.06	0.09	1.98	12.56	0.63	0.01	0.01	0.09	5.18	65	34	65	120	33			65	680	33	197				388	22	55	25
	A015	2.57	4.75	15.71	56.74	0.30	0.27	0.28	1.58	12.19	0.49	0.01	0.02	0.08	4.82	55	47	64	118	37		21	43	575	29	144				463	20	51	
	JH038	0.29	4.07	16.89	59.18	0.17	0.05	0.12	1.43	12.00	0.63	0.02	0.01	0.04	4.96	61	38	36	90	31			40	381	35	223				179		45	53

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 8d	μ (n=1)	2.11	3.70	13.03	48.70	0.14	0.01	0.26	2.38	22.27	0.51	0.02	0.08	0.09	6.47	83	234	62	109	27	22		89	881	27	123				305		42	29
	E013	2.11	3.70	13.03	48.70	0.14	0.01	0.26	2.38	22.27	0.51	0.02	0.08	0.09	6.47	83	234	62	109	27	22		89	881	27	123				305		42	29
Gr 8e	μ (n=1)	1.56	1.94	20.19	56.40	0.28	0.71	0.33	3.01	9.79	0.50	0.02	0.01	0.07	5.00	61	28	36	91	51		21	117	404	30	221				597	29	63	24
	A005	1.56	1.94	20.19	56.40	0.28	0.71	0.33	3.01	9.79	0.50	0.02	0.01	0.07	5.00	61	28	36	91	51		21	117	404	30	221				597	29	63	24
Gr 8f	μ (n=15)	1.61	3.36	17.76	56.06	0.36	0.05	0.13	2.30	10.89	0.66	0.02	0.01	0.11	6.46	78	45	53	129	38			85	648	40	191				559	27	63	37
	σ	0.35	0.68	0.99	1.92	0.05	0.09	0.11	0.26	1.08	0.02			0.01	0.30	8	5	9	9	2			5	117	2	26				134	4	6	16
	min	1.06	1.85	16.41	52.03	0.32		0.02	1.96	8.81	0.59	0.01	0.01	0.09	5.74	67	32	39	106	36			77	493	35	128				413	20	57	20
	max	2.35	4.80	20.14	59.86	0.52	0.32	0.41	2.86	13.52	0.69	0.03	0.02	0.13	6.86	92	51	72	141	41			93	953	42	237				1021	34	76	72
	A014	1.25	3.31	19.31	53.49	0.32	0.16	0.08	2.32	12.12	0.68	0.02	0.01	0.10	6.61	92	46	48	132	38			89	793	41	173				502	32	65	41
	A020	1.49	3.57	18.21	52.03	0.39	0.32	0.12	2.70	13.52	0.67	0.02	0.01	0.12	6.60	78	46	45	135	36			81	792	40	182				515	25	60	44
	A019	1.45	1.85	20.14	55.03	0.38	0.02	0.19	2.86	11.12	0.64	0.02	0.01	0.09	5.98	68	47	58	126	40			90	953	36	128				413	25	57	71
	A016	2.35	2.89	18.30	56.48	0.37		0.27	1.96	10.72	0.59	0.02	0.02	0.11	5.74	71	32	39	106	38			77	493	35	171				503	34	68	27
	DH031	1.55	3.64	16.82	57.54	0.38	0.01	0.04	2.01	10.51	0.67	0.02	0.01	0.11	6.46	78	45	48	141	39			80	597	41	219				583	28	67	29
	DH032	1.56	3.82	17.06	56.87	0.34	0.01	0.02	2.06	10.78	0.68	0.02	0.01	0.11	6.46	75	48	53	128	37			80	611	40	220				534	29	68	24
	DH034	1.15	3.30	16.72	58.10	0.33		0.03	2.07	10.96	0.67	0.01	0.01	0.11	6.33	79	44	45	120	38			79	635	39	214				519	24	58	20
	JH028	1.75	4.24	17.51	54.47	0.35	0.12	0.16	2.30	11.72	0.64	0.02	0.01	0.12	6.39	85	49	51	122	37			78	572	39	188				558	25	62	24
	JH030	1.82	3.66	18.45	54.45	0.35	0.01	0.23	2.08	11.28	0.66	0.02	0.01	0.12	6.68	83	44	50	130	40			88	575	40	198				556	28	62	30
	JH027	1.84	3.44	17.64	56.41	0.52		0.21	2.37	9.68	0.66	0.01	0.01	0.13	6.86	77	38	48	139	41			93	637	41	189				565	33	76	41
	DH033	2.02	2.92	16.41	59.86	0.33	0.01	0.03	2.38	8.81	0.68	0.02	0.01	0.12	6.21	67	43	63	117	36			88	578	40	237				536	28	62	22
	DH037	1.58	2.80	17.52	56.54	0.33	0.01	0.07	2.53	10.98	0.65	0.02	0.01	0.11	6.63	67	51	72	131	37			89	655	41	184				537	27	69	32
	E014	1.92	3.00	17.45	56.73	0.34		0.41	2.18	10.13	0.69	0.02	0.01	0.12	6.77	72	43	53	129	36			86	677	42	195				514	28	60	37
	DH038	1.36	3.17	17.62	56.35	0.37		0.08	2.53	10.82	0.66	0.02	0.01	0.12	6.68	87	50	69	141	38			91	587	39	184				532	24	57	72
	JH031	1.06	4.80	17.22	56.57	0.35	0.02	0.03	2.22	10.18	0.67	0.03	0.01	0.12	6.49	85	50	54	130	38			87	559	40	183				1021	20	58	36

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 9	μ (n=3)	0.96	1.93	12.84	50.63	1.12	0.01	0.10	1.33	24.17	0.71	0.03	0.03	0.09	5.77	75	105	103	191	25	7		33	983	53	367				877		35	7
	σ	0.16	0.68	0.37	5.02	0.47	0.01	0.05	0.41	4.89	0.05		0.01		0.32	9	11	19	20	1	12		9	120	9	55				353		1	12
	min	0.83	1.45	12.44	47.07	0.60		0.05	1.00	18.53	0.65	0.03	0.03	0.09	5.41	64	96	92	168	25			24	893	43	308				473		34	
	max	1.14	2.71	13.16	56.37	1.51	0.01	0.14	1.79	27.05	0.74	0.03	0.04	0.09	6.02	81	117	126	204	26	20		42	1120	59	417				1121		36	21
	AM007	0.83	1.45	12.93	48.44	1.51	0.01	0.14	1.19	26.93	0.65	0.03	0.04	0.09	5.41	64	117	126	202	26	20		34	1120	59	417				1121		36	21
	AM019	0.90	1.62	13.16	56.37	1.26		0.09	1.00	18.53	0.73	0.03	0.04	0.09	5.87	79	101	93	204	25			24	893	57	375				1038		36	
	AM016	1.14	2.71	12.44	47.07	0.60	0.01	0.05	1.79	27.05	0.74	0.03	0.03	0.09	6.02	81	96	92	168	25			42	935	43	308				473		34	
Gr 10a	μ (n=9)	2.08	3.16	12.37	53.09	0.32	0.17	0.40	1.95	19.38	0.72	0.02	0.02	0.11	5.98	76	55	66	105	26			49	903	39	296				698	5	39	8
	σ	0.81	0.35	0.70	2.93	0.08	0.15	0.33	0.59	1.76	0.05			0.01	0.30	11	9	18	8	2			5	261	6	24				307	9	5	13
	min	1.31	2.64	11.37	49.05	0.22	0.01	0.04	1.32	16.55	0.63	0.01	0.01	0.09	5.57	54	45	47	93	24			41	687	32	259				499		33	
	max	3.91	3.79	13.27	56.83	0.47	0.37	1.12	3.35	21.34	0.78	0.03	0.02	0.14	6.37	87	77	104	119	28			56	1551	51	335				1470	22	47	28
	AM008	1.41	2.91	13.16	53.61	0.37	0.03	0.04	1.91	19.04	0.75	0.03	0.02	0.14	6.26	83	77	70	119	28			53	861	51	286				1470		34	
	AM015	1.78	3.05	11.71	54.20	0.28	0.16	0.19	1.32	20.36	0.70	0.02	0.02	0.09	5.79	85	48	51	99	24			46	1551	37	274				827		36	
	E006	1.31	3.15	13.09	55.78	0.30	0.01	0.29	2.00	16.55	0.78	0.02	0.02	0.11	6.37	87	51	67	107	28			56	687	40	307				634	20	47	
	E017	1.60	2.64	11.37	56.83	0.22	0.28	0.10	1.44	18.37	0.77	0.02	0.02	0.11	6.04	83	56	63	106	28			45	789	38	306				499		40	
	JH029	1.77	3.22	13.27	50.48	0.40	0.01	0.35	1.68	21.34	0.76	0.02	0.02	0.12	6.34	82	57	82	109	25			46	788	44	335				543	22	41	28
	E009	2.46	3.39	12.59	50.50	0.24	0.25	0.64	2.09	20.86	0.67	0.02	0.02	0.10	5.93	78	52	47	108	25			55	886	35	259				685		37	24
	E011	2.54	3.42	12.30	50.89	0.31	0.09	0.50	1.73	21.19	0.70	0.02	0.02	0.11	5.97	69	56	54	105	26			51	779	36	283				519		47	
	E007	1.95	2.85	12.07	56.45	0.26	0.36	0.33	1.99	17.10	0.69	0.02	0.02	0.10	5.58	54	52	104	93	26			52	757	35	324				560		36	
	E008	3.91	3.79	11.73	49.05	0.47	0.37	1.12	3.35	19.64	0.63	0.01	0.01	0.10	5.57	64	45	59	95	24			41	1027	32	291				545		33	23

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3	Co_3O_4	NiO	CuO	ZnO	Ga_2O_3	As_2O_3	Br	Rb_2O	SrO	Y_2O_3	ZrO_2	Nb_2O_5	SnO_2	Sb_2O_3	BaO	La_2O_3	CeO_2	PbO
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Gr 10b	μ (n=8)	1.23	3.02	12.52	60.51	0.23	0.01	0.09	1.58	13.15	0.82	0.02	0.02	0.11	6.47	80	55	60	104	29			50	629	38	330				571	3	41	5
	σ	0.35	0.32	1.01	1.89	0.10	0.03	0.07	0.09	1.57	0.08			0.01	0.48	13	3	11	7	2			3	82	2	43				112	7	4	14
	min	0.52	2.46	11.53	57.93	0.16		0.01	1.47	10.45	0.73	0.02	0.02	0.10	5.80	67	51	46	91	25			45	535	36	262				444		37	
	max	1.76	3.55	14.18	62.98	0.48	0.08	0.20	1.73	15.29	0.93	0.03	0.02	0.13	7.23	98	60	75	109	31			55	789	42	376				814	21	48	40
	AM010	1.08	2.92	12.55	61.90	0.18	0.01	0.05	1.73	11.96	0.84	0.02	0.02	0.12	6.42	67	53	51	91	28			49	602	38	376				444	21	45	
	E015	1.17	3.17	11.53	62.61	0.19		0.10	1.53	12.83	0.75	0.02	0.02	0.10	5.80	69	51	46	109	25			48	539	36	333				486		38	
	E016	1.30	2.76	11.90	60.73	0.19	0.01	0.01	1.54	14.25	0.80	0.02	0.02	0.11	6.15	78	54	65	102	28			53	535	38	315				601		40	
	E020	1.30	2.46	11.65	60.30	0.21	0.01	0.03	1.47	15.29	0.73	0.02	0.02	0.11	6.19	70	53	57	109	28			45	627	37	276				539		39	
	E019	1.76	3.55	11.85	58.80	0.19		0.20	1.56	14.74	0.75	0.02	0.02	0.10	6.26	72	55	49	109	29			49	684	36	262				515		37	
	AM011	1.31	3.08	13.88	58.84	0.20	0.01	0.11	1.49	12.73	0.92	0.02	0.02	0.11	7.06	89	60	75	95	31			51	621	39	374				592		48	
	E018	1.39	3.05	14.18	57.93	0.16	0.01	0.17	1.61	12.96	0.93	0.03	0.02	0.12	7.23	98	60	63	109	31			53	638	42	361				580		42	
	E012	0.52	3.17	12.64	62.98	0.48	0.08	0.05	1.68	10.45	0.86	0.03	0.02	0.13	6.67	97	52	71	107	28			55	789	39	340				814		40	40
Gr 11	μ (n=2)	1.45	2.88	13.57	50.84	0.47	0.16	0.11	1.95	20.88	0.68	0.01	0.02	0.10	6.33	85	87	74	127	29			52	1131	66	267				3134		27	25
	σ	0.11	0.05	1.53	4.45		0.11	0.13	0.01	6.89	0.02		0.01	0.01	0.54	25	6	4	8	2			10	17	2	9				125		1	36
	min	1.37	2.84	12.49	47.70	0.46	0.08	0.02	1.94	16.01	0.67	0.01	0.02	0.10	5.95	67	83	71	122	28			45	1119	65	261				3045		27	
	max	1.53	2.92	14.65	53.99	0.47	0.24	0.20	1.96	25.76	0.70	0.01	0.03	0.11	6.71	103	92	77	133	31			59	1143	68	274				3223		28	50
	AM013	1.53	2.84	14.65	53.99	0.47	0.24	0.20	1.96	16.01	0.70	0.01	0.03	0.11	6.71	103	92	71	133	31			59	1143	65	261				3223		28	50
	AM018	1.37	2.92	12.49	47.70	0.46	0.08	0.02	1.94	25.76	0.67	0.01	0.02	0.10	5.95	67	83	77	122	28			45	1119	68	274				3045		27	
Gr 12	μ (n=1)	2.35	5.18	14.73	53.52	0.16		0.16	1.73	13.17	0.59	0.02	0.04	0.13	7.97	117	263	356	100	29			52	612	29	115				372		35	33
	DH041	2.35	5.18	14.73	53.52	0.16		0.16	1.73	13.17	0.59	0.02	0.04	0.13	7.97	117	263	356	100	29			52	612	29	115				372		35	33
Gr 13	μ (n=1)	0.80	15.32	10.04	50.45	0.34	0.34	0.13	1.59	11.18	0.41	0.02	0.15	0.13	8.85	145	1059	97	161	22		34	56	596	21	78				208		24	24
	A018	0.80	15.32	10.04	50.45	0.34	0.34	0.13	1.59	11.18	0.41	0.02	0.15	0.13	8.85	145	1059	97	161	22		34	56	596	21	78				208		24	24

Appendix VI

Table of mineralogical inclusions

Mineral identifications based on SEM-EDS analysis, samples organised according to compositional groups (Gr 1–15).

		Apatite	Augite	Ba-rich pellet	Barite	Biotite mica	Calcite	Chromite	Clay pellet	Garnet	Garnet (Almandine)	Garnet (Andradite)	Garnet (Grossular)	Hornblende	Ilmenite	Iron oxide	K-feldspar	Magnetite	Mg-rich pellet	Mn hydroxide	Mn-rich pellet	Perowskite	Plagioclase feldspar	Quartz	Rock fragment 1 [1]	Rock fragment 2 [2]	Rock fragment 3 [3]	Rutile	Sandstone	Spinel	Titanite	Titanomagnetite	Ulvite	Zircon
Gr 1	JH033								x															x										
	JH036	x							x						x									x										x
	JH037	x							x							x		x						x				x						
	A001								x							x								x										
	DH020	x							x						x	x								x										x
	DH025	x							x							x								x										
	DH026	x							x						x	x								x										
	DH028								x							x								x				x						
	DHO11	x							x						x	x								x		x		x						
Gr 2	A007	x	x			x			x														x	x							x			x
Gr 3	JH001								x						x	x								x				x						
	JH003	x							x							x								x										x
	JH005	x							x							x								x										
	JH007								x							x								x				x						x
	JH008	x							x						x	x								x										
	JH013								x							x								x				x						
	JH016								x						x	x								x										
	JH019	x							x						x	x								x				x						
	JH020								x							x								x				x						
	JH021								x							x								x				x						
	JH022								x							x								x				x						
	JH023	x							x							x								x										
	JH024								x															x				x			x			
	JH025								x						x	x	x							x										
	A002	x							x						x	x								x				x						x
	DH001	x							x						x									x				x						
	DH029								x							x	x							x				x						x
Gr 4	DH030								x															x				x						x
Gr 5	JH035		x	x					x						x	x					x		x	x					x		x			x
Gr 6	E001								x						x		x			x				x										
	E005										x				x		x				x			x										x
	E010		x					x	x	x					x	x	x							x		x		x			x	x		
	AM001	x													x	x	x				x			x								x		x
	AM006												x		x		x				x			x										x
Gr 7	AM014								x						x	x	x							x				x						x
Gr 8	JH028		x			x			x	x					x	x	x		x				x	x										
	A008		x			x									x	x							x	x				x			x	x		x
	A020		x			x										x	x						x	x								x		
	DH032		x			x				x					x		x	x						x				x			x			
	E013		x				x	x	x						x	x								x										
	E014	x	x			x			x	x					x	x	x						x	x				x						
Gr 9	AM016	x					x		x			x	x		x	x								x				x				x	x	x
	AM019	x	x										x		x		x					x	x	x							x	x		x

		Apatite	Augite	Ba-rich pellet	Barite	Biotite mica	Calcite	Chromite	Clay pellet	Garnet	Garnet (Almandine)	Garnet (Andradite)	Garnet (Grossular)	Hornblende	Ilmenite	Iron oxide	K-feldspar	Magnetite	Mg-rich pellet	Mn hydroxide	Mn-rich pellet	Perowskite	Plagioclase feldspar	Quartz	Rock fragment 1 [1]	Rock fragment 2 [2]	Rock fragment 3 [3]	Rutile	Sandstone	Spinel	Titanite	Titanomagnetite	Ulvite	Zircon
Gr 10	JH029	x					x		x	x					x	x	x							x				x			x			
	E006									x				x	x	x								x				x						x
	E008		x		x		x		x	x					x	x	x					x		x				x						
	E015	x	x				x								x									x				x			x			x
	E018		x							x					x	x	x							x				x			x			
	AM010						x			x		x			x									x										x
Gr 11	AM013	x			x	x			x	x					x	x	x	x						x									x	
Gr 12	DH041	x	x			x		x	x	x				x	x	x							x	x		x	x			x				
Gr 13	A018		x			x		x			x											x		x							x			
Gr 14	JH034						x		x	x				x	x									x				x			x			x
Gr 15	AM020		x			x			x	x				x	x	x	x							x	x						x			

[1] Rock fragment 1 aluminium silicate-iron oxide; [2] Rock fragment 2 basalt (olivine-plagioclase);

[3] Rock fragment 3 albite, melted

Appendix VII

Table of representative SEM-EDS analysis of selected minerals

Results given as weight-% (normalised to 100%, oxygen by stoichiometry) and number of ions.

	Magnetite	Biotite	Apatite	Rutile	Titanite	Almandine	Ilmenite	Zircon	Augite	Plagioclase	Calcite	Andradite	Grossular	Ulvite	Titanomagnetite	Barite	Chromite	Perowskite	Hornblende	K-feldspar
	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 6	Gr 7	Gr 8	Gr 8	Gr 9	Gr 9	Gr 9	Gr 9	Gr 10	Gr 11	Gr 12	Gr 13	Gr 14	Gr 15
	JH037	A007	A002	DH030	JH035	E005	E010	AM014	A020	A020	AM016	AM016	AM016	AM016	AM010	AM013	DH041	A018	JH034	AM020
Na2O									1.2	9.5			0.4						1.2	0.8
MgO	1.5	10.3	0.5			3.7			15.5			1.0	3.2		1.4		13.5	3.2	13.2	
Al2O3	0.7	17.3		0.6		19.2			5.1	20.8		10.2	13.8	1.1	1.9		24.6	2.5	11.6	17.4
SiO2	2.9	39.7		0.5	32.6	36.6		32.5	55.6	66.2		34.1	39.7					6.8	49.2	65.8
P2O5			42.3										0.5							
SO3			1.4													33.2				
K2O		8.7							0.5	0.3		0.4	3.7					0.3	3.0	15.9
CaO	1.0	0.5	55.9	0.2	27.6	1.5			10.6	3.2	100.0	26.0	26.2	0.7	0.7		0.5	33.9	7.5	
TiO2		3.9		96.0	39.8		43.8		0.8			23.4	1.1	27.5	23.7			49.1	1.1	
Cr2O3												0.4					45.4			
MnO		0.6				2.8	7.5							1.5	0.5		0.9			
FeO	93.9	19.2		2.7		36.2	48.7	0.6	10.7			4.5	11.4	69.2	71.9		14.4	4.2	13.3	
CuO																	0.7			
SrO																3.8				
ZrO2								66.9												
BaO																63.0				

	Magnetite	Biotite	Apatite	Rutile	Titanite	Almandine	Ilmenite	Zircon	Augite	Plagioclase	Calcite	Andradite	Grossular	Ulvite	Titanomagnetite	Barite	Chromite	Perowskite	Hornblende	K-feldspar
	Gr 1	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 6	Gr 7	Gr 8	Gr 8	Gr 9	Gr 9	Gr 9	Gr 9	Gr 10	Gr 11	Gr 12	Gr 13	Gr 14	Gr 15
	JH037	A007	A002	DH030	JH035	E005	E010	AM014	A020	A020	AM016	AM016	AM016	AM016	AM010	AM013	DH041	A018	JH034	AM020
Na									0.1	0.8									0.1	0.1
Mg	0.2	0.8				0.3			1.1			0.1	0.3		0.2		1.2	0.3	1.0	
Al	0.1	1.1				1.2			0.3	1.1		0.6	0.9	0.1	0.2		1.8	0.2	0.7	1.0
Si	0.3	2.1			1.7	2.0		2.0	2.7	2.9		1.8	2.1					0.4	2.4	3.0
P			1.9																	
S			0.1													2.0				
K		0.6											0.3						0.2	0.9
Ca	0.1		3.1		1.5	0.1			0.6	0.2	8.0	1.4	1.5	0.1	0.1			2.1	0.4	
Ti		0.2		3.9	1.6		2.3					0.9		1.6	1.4			2.2		
Cr																	2.2			
Mn						0.1	0.5							0.1			0.1			
Fe	7.1	0.8		0.1		1.7	2.9		0.4			0.2	0.5	4.5	4.7		0.7	0.2	0.6	
Cu																				
Sr																0.2				
Zr								2.0												
Ba																1.9				

Appendix VIII

Table of SEM-EDS microchemical analysis of the ceramic matrices

Arithmetic means (μ; n=4), sample standard deviations (σ), and maximum and minimum values.
Results are normalised to 100%.

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO
		%	%	%	%	%	%	%	%	%	%
JH001	μ	0.6	2.2	20.9	65.1	0.2	0.2	2.4	1.9	1.0	5.5
	σ	0.1	0.2	0.8	1.5	0.2	0.1	0.1	0.3	0.1	0.3
	max	0.6	2.4	21.9	66.8	0.6	0.3	2.5	2.3	1.1	5.9
	min	0.4	2.1	20.0	63.9			2.3	1.8	0.9	5.1
JH003	μ	0.4	2.2	19.5	59.5	0.5	0.3	2.9	6.8	1.1	6.9
	σ	0.1	0.4	0.2	1.1	0.1	0.2	0.2	1.1	0.1	0.4
	max	0.5	2.7	19.8	61.1	0.6	0.4	3.2	8.1	1.2	7.3
	min	0.4	1.8	19.3	58.3	0.4	0.1	2.7	5.4	1.0	6.3
JH005	μ	0.5	2.7	22.4	60.0	0.2	0.7	3.1	2.2	1.1	7.1
	σ	0.1	0.2	0.6	1.7	0.2	0.4	0.2	0.2	0.1	0.3
	max	0.6	3.0	23.0	62.4	0.4	1.1	3.3	2.4	1.2	7.4
	min	0.3	2.6	21.6	58.6	0.1	0.2	2.8	2.0	1.0	6.7
JH007	μ	0.6	2.3	20.0	58.6	0.2	0.4	3.3	5.4	1.2	8.0
	σ	0.1	0.1	1.6	3.2	0.1		0.3	1.3	0.1	0.5
	max	0.7	2.4	21.7	62.0	0.2	0.5	3.7	7.3	1.3	8.6
	min	0.5	2.1	17.9	55.8	0.1	0.4	3.0	4.3	1.1	7.4
JH008	μ	1.4	2.1	22.9	59.9	0.2	1.4	2.7	2.5	1.1	6.0
	σ	0.4	0.1	0.8	1.4	0.2	0.9	0.1	0.4	0.1	0.3
	max	1.8	2.2	23.5	61.1	0.5	2.1	2.8	2.9	1.2	6.2
	min	1.0	1.9	21.7	57.8		0.5	2.5	2.1	1.0	5.7
JH013	μ	0.4	1.7	20.1	68.3	0.4		2.0	1.6	0.9	4.6
	σ	0.1	0.1	1.1	1.4	0.2	0.1	0.2	0.4	0.1	0.1
	max	0.6	1.7	21.3	70.1	0.6	0.1	2.2	2.0	1.0	4.7
	min	0.3	1.6	19.1	67.1	0.2		1.8	1.3	0.8	4.4
JH016	μ	0.3	1.6	23.5	62.4	0.2	0.1	2.5	1.6	1.3	6.6
	σ	0.1	0.1	0.4	0.7	0.1	0.1	0.3	0.3	0.1	0.4
	max	0.4	1.8	24.1	63.3	0.3	0.2	2.8	1.8	1.4	6.9
	min	0.2	1.5	23.2	61.9	0.2		2.2	1.2	1.2	6.2
JH019	μ	0.4	1.6	22.8	65.6	0.2	0.1	2.1	0.7	1.2	5.2
	σ	0.1	0.3	1.5	2.4	0.2	0.1	0.2	0.2	0.1	0.7
	max	0.6	1.9	24.1	68.6	0.4	0.3	2.3	1.0	1.2	6.3
	min	0.3	1.2	20.7	62.7			1.8	0.5	1.1	4.7
JH020	μ	0.7	1.6	23.0	62.2	0.5	0.1	3.1	0.8	1.1	6.9
	σ	0.1		0.7	0.8	0.2		0.1	0.1	0.1	0.3
	max	0.8	1.7	23.5	63.3	0.6	0.2	3.3	0.9	1.3	7.1
	min	0.7	1.6	22.0	61.4	0.3	0.1	3.0	0.8	1.0	6.6
JH021	μ	1.0	1.3	22.2	65.5	0.2	0.2	2.1	0.6	1.4	5.7
	σ	1.7	0.1	0.7	2.5	0.1	0.2	0.2	0.3	0.4	0.5
	max	3.5	1.4	23.3	67.7	0.2	0.5	2.3	1.0	1.9	6.4
	min	0.1	1.2	21.7	62.7	0.1		2.0	0.4	1.1	5.3

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO
		%	%	%	%	%	%	%	%	%	%
JH022	μ	0.3	1.6	23.4	64.3	0.3	0.1	2.4	0.8	1.2	5.7
	σ	0.1	0.1	1.2	2.0	0.1	0.1	0.1	0.1	0.3	0.8
	max	0.4	1.7	24.8	67.2	0.5	0.2	2.5	0.9	1.5	6.8
	min	0.2	1.4	22.0	62.9	0.2		2.3	0.7	0.9	5.0
JH023	μ	1.2	2.6	20.8	63.2	0.3	0.2	2.5	2.0	1.0	6.2
	σ	0.5	0.2	0.8	1.8		0.1	0.1	0.2	0.2	0.5
	max	1.9	2.8	21.5	65.8	0.3	0.3	2.7	2.2	1.2	6.7
	min	0.6	2.5	19.7	61.6	0.2	0.1	2.4	1.8	0.8	5.6
JH024	μ	0.7	2.1	19.4	63.1	0.3	0.1	3.0	4.2	1.1	6.1
	σ	0.3	0.2	1.8	3.0	0.1	0.1	0.7	0.9	0.1	1.0
	max	1.1	2.4	21.0	67.6	0.4	0.2	4.1	5.6	1.2	6.8
	min	0.4	1.9	17.7	61.5	0.2		2.5	3.4	0.9	4.6
JH025	μ	0.5	3.2	21.6	61.5	0.1	0.2	3.3	1.7	1.0	6.8
	σ	0.1	0.2	0.3	0.5	0.1	0.2	0.2	0.4	0.1	0.4
	max	0.7	3.5	21.9	62.1	0.3	0.4	3.5	2.2	1.1	7.3
	min	0.4	3.1	21.4	61.1	0.1	0.1	3.1	1.4	0.9	6.3
JH028	μ	1.5	4.3	15.2	50.0	0.5	0.5	2.6	17.3	0.9	7.3
	σ	0.1	0.7	0.6	1.1	0.2	0.2	0.1	0.8	0.1	0.2
	max	1.7	5.1	15.8	50.8	0.7	0.7	2.6	17.9	1.1	7.6
	min	1.4	3.6	14.4	48.5	0.2	0.2	2.5	16.1	0.8	7.1
JH029	μ	0.9	2.9	10.8	48.9	0.2	0.3	1.7	26.4	1.1	6.8
	σ	0.3	0.3	1.0	2.4	0.1	0.1	0.2	0.7	0.2	0.4
	max	1.3	3.2	11.6	52.4	0.3	0.4	2.0	27.0	1.3	7.3
	min	0.7	2.6	9.4	47.0	0.2	0.3	1.5	25.6	0.9	6.4
JH033	μ	0.6	3.0	20.9	54.9	0.2	0.4	3.0	9.8	0.9	6.4
	σ	0.2	0.4	1.3	1.1	0.1	0.1	0.2	1.8	0.2	0.1
	max	0.8	3.3	22.3	56.0	0.3	0.5	3.3	11.4	1.1	6.5
	min	0.4	2.5	19.1	53.5		0.2	3.0	8.1	0.6	6.2
JH034	μ	1.1	3.0	10.4	67.2	0.2	0.2	1.6	10.9	0.7	4.7
	σ	0.3	0.6	1.3	2.4	0.1	0.2	0.2	1.0	0.1	0.3
	max	1.5	3.8	12.3	69.7	0.4	0.4	1.8	12.3	0.8	5.2
	min	0.8	2.6	9.4	64.2	0.1		1.3	10.0	0.7	4.5
JH035	μ	0.7	0.8	26.7	62.4	0.1	0.1	1.4	1.2	2.1	4.7
	σ	0.3	0.2	1.6	0.3	0.1	0.1	0.2	0.6	0.2	0.8
	max	0.9	1.0	27.7	62.7	0.3	0.3	1.6	2.0	2.3	5.9
	min	0.4	0.5	24.2	62.1			1.1	0.7	1.9	4.1
JH036	μ	0.3	2.4	22.1	61.4	0.1	0.1	2.9	2.0	1.0	7.8
	σ		0.1	0.7	1.1	0.1	0.1	0.1	0.8	0.2	0.4
	max	0.3	2.4	22.8	62.8	0.2	0.3	3.0	2.9	1.2	8.5
	min	0.2	2.2	21.3	60.1			2.7	1.3	0.8	7.5
JH037	μ	0.3	2.2	21.0	62.0	0.4	0.2	2.9	2.3	1.2	7.5
	σ	0.1	0.3	1.7	2.5	0.2	0.2	0.3	0.3	0.1	0.3
	max	0.5	2.5	22.5	65.2	0.7	0.4	3.3	2.7	1.2	7.9
	min	0.2	1.9	18.6	59.0	0.2		2.6	1.8	1.0	7.2

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO
		%	%	%	%	%	%	%	%	%	%
A001	μ	0.3	1.3	22.2	60.6	0.2	0.1	3.2	2.2	1.4	8.7
	σ	0.1	0.1	0.8	0.6	0.1	0.1	0.1	0.3	0.1	0.5
	max	0.4	1.5	23.3	61.0	0.3	0.2	3.2	2.6	1.4	9.3
	min	0.3	1.2	21.3	60.1	0.1		3.1	1.9	1.3	8.1
A002	μ	0.8	1.7	19.3	63.9	0.5	0.1	2.4	3.0	1.0	7.3
	σ	0.3	0.1	0.9	2.1	0.1	0.1	0.2	0.5	0.2	0.7
	max	1.2	1.8	20.5	66.4	0.6	0.1	2.6	3.4	1.3	7.8
	min	0.5	1.5	18.3	61.3	0.4		2.3	2.3	0.9	6.3
A007	μ	0.5	0.9	28.3	54.5	0.4		8.6	1.7	0.2	5.0
	σ	0.3	0.1	1.4	1.3	0.3		0.5	0.9	0.1	0.3
	max	0.9	1.1	29.6	56.3	0.7	0.1	9.0	3.1	0.3	5.4
	min	0.1	0.8	26.7	53.5	0.1		7.8	1.0	0.1	4.7
A008	μ	1.3	2.9	15.5	51.4	0.6	0.6	2.8	17.8	0.8	6.3
	σ	0.2	0.2	1.4	1.7	0.2	0.2	0.5	1.2	0.4	0.4
	max	1.6	3.1	17.2	52.6	0.8	0.9	3.5	19.4	1.4	6.6
	min	1.2	2.7	13.8	48.8	0.3	0.5	2.4	16.5	0.5	5.8
A018	μ	0.5	13.7	8.4	53.3	0.4	0.5	1.7	13.3	0.6	7.8
	σ	0.1	0.4	0.2	1.0	0.1	0.1	0.2	1.2	0.1	0.2
	max	0.6	14.2	8.5	54.2	0.5	0.6	1.9	14.6	0.7	8.0
	min	0.4	13.3	8.1	52.0	0.3	0.3	1.5	12.0	0.5	7.5
A020	μ	1.7	3.4	15.6	49.0	0.6	1.3	3.0	18.6	0.9	5.8
	σ	0.4	0.2	0.6	0.8	0.2	0.2	0.2	0.5	0.1	0.3
	max	2.2	3.6	16.4	49.8	0.8	1.5	3.2	19.1	0.9	6.3
	min	1.4	3.1	15.1	48.0	0.5	1.0	2.7	17.9	0.8	5.5
DH001	μ	0.3	1.7	22.0	60.6	0.2	0.1	3.1	2.3	1.6	8.3
	σ	0.1	0.1	0.9	1.5	0.1	0.1	0.3	0.4	0.4	0.3
	max	0.4	1.9	22.5	62.4	0.3	0.3	3.3	2.7	2.0	8.6
	min	0.2	1.6	20.6	59.1	0.1		2.8	1.8	1.1	7.9
DH011	μ	0.8	2.1	16.8	49.4	0.3	0.3	4.5	15.3	1.5	9.2
	σ	0.5	0.1	0.1	0.4	0.1	0.2	0.2	0.9	0.2	0.1
	max	1.5	2.2	17.0	49.7	0.4	0.5	4.7	16.2	1.7	9.3
	min	0.4	2.0	16.7	48.8	0.2	0.1	4.3	14.0	1.3	9.0
DH020	μ	0.4	3.1	20.5	58.9	0.2	0.1	3.5	4.6	1.1	7.6
	σ	0.1	0.4	1.0	1.5	0.1	0.1	0.2	0.3	0.1	0.6
	max	0.5	3.5	21.9	59.9	0.3	0.2	3.7	4.9	1.3	8.4
	min	0.3	2.5	19.7	56.6	0.1		3.3	4.2	1.0	7.1
DH025	μ	2.6	3.0	15.1	49.6	0.1	0.3	3.1	17.9	1.2	7.2
	σ	1.8	0.2	0.6	0.8	0.1	0.1	0.1	0.4	0.1	0.3
	max	4.9	3.2	15.6	50.9	0.2	0.4	3.1	18.3	1.3	7.4
	min	0.6	2.8	14.3	49.1		0.1	3.0	17.4	1.0	6.8
DH026	μ	0.4	1.7	20.6	61.5	0.6	0.1	4.1	2.5	1.2	7.3
	σ	0.1	0.2	1.7	3.3	0.2	0.1	0.3	0.3	0.1	0.6
	max	0.5	1.9	21.7	66.3	0.9	0.2	4.3	2.9	1.3	7.8
	min	0.3	1.5	18.0	59.0	0.4	0.1	3.6	2.1	1.1	6.5

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO
		%	%	%	%	%	%	%	%	%	%
DH028	μ	0.3	1.5	22.6	58.7	0.1	0.8	3.1	4.2	1.4	7.5
	σ	0.2	0.1	0.2	0.9		0.5	0.2	0.4	0.1	0.5
	max	0.5	1.6	22.9	59.9	0.1	1.1	3.3	4.4	1.5	8.1
	min		1.4	22.4	57.8		0.1	2.8	3.6	1.3	7.0
DH029	μ	0.2	1.4	20.9	63.9	0.2		3.9	1.8	1.7	6.0
	σ	0.1	0.1	1.4	2.2	0.1		0.2	0.5	0.9	0.5
	max	0.3	1.4	22.0	66.0	0.4	0.1	4.2	2.5	3.0	6.7
	min	0.2	1.3	19.0	60.9	0.1		3.7	1.5	1.0	5.5
DH030	μ	0.5	1.0	18.0	66.0	0.3	0.6	2.9	4.9	1.9	3.9
	σ	0.1	0.1	1.5	2.2	0.1	0.5	0.2	0.6	0.3	0.4
	max	0.6	1.1	20.1	67.6	0.4	1.1	3.1	5.5	2.4	4.3
	min	0.4	0.9	16.8	62.8	0.2	0.1	2.6	4.2	1.7	3.5
DH032	μ	0.9	3.5	14.4	50.9	0.5	0.2	2.1	18.0	1.2	8.3
	σ	0.1	0.2	0.7	1.9	0.1		0.3	0.9	0.2	0.4
	max	1.0	3.7	15.2	52.3	0.6	0.3	2.4	19.3	1.5	8.8
	min	0.8	3.3	13.8	48.2	0.4	0.2	1.9	17.5	1.0	8.0
DH041	μ	1.5	4.8	11.9	50.3	0.3		1.9	19.5	0.9	9.0
	σ	0.2	0.3	0.4	0.8	0.2		0.1	0.4	0.1	0.6
	max	1.8	5.2	12.2	50.9	0.4	0.1	2.1	20.0	1.0	9.9
	min	1.2	4.4	11.4	49.2			1.8	19.0	0.8	8.5
E001	μ	1.2	1.7	18.4	62.6	0.2	0.2	2.0	1.6	1.5	10.7
	σ	0.1	0.2	0.7	1.4	0.2	0.2	0.1	0.2	0.2	0.5
	max	1.3	1.9	19.0	64.6	0.4	0.4	2.1	1.8	1.7	11.3
	min	1.0	1.5	17.4	61.7			1.8	1.3	1.3	10.2
E005	μ	1.1	1.9	18.7	61.8	0.3		2.0	1.5	1.8	11.1
	σ	0.3	0.1	0.4	0.8	0.1		0.1	0.2	0.3	0.4
	max	1.4	1.9	19.1	62.6	0.4	0.1	2.1	1.7	2.1	11.6
	min	0.8	1.7	18.2	60.7	0.2		1.8	1.3	1.6	10.8
E006	μ	1.5	2.5	11.0	50.5	0.5	0.7	2.6	23.7	0.9	6.3
	σ	0.3	0.3	1.1	2.4	0.2	0.2	0.6	2.9	0.1	0.1
	max	2.0	2.9	12.5	53.6	0.6	0.9	3.6	27.1	1.0	6.4
	min	1.2	2.1	10.2	47.7	0.2	0.4	2.2	21.3	0.7	6.1
E008	μ	2.8	3.5	9.6	48.8	0.3	2.3	4.6	21.3	0.7	6.3
	σ	0.3	0.1	0.5	1.1	0.2	1.1	0.2	2.4	0.2	0.5
	max	3.1	3.6	10.0	50.2	0.4	3.5	4.7	24.4	1.0	6.6
	min	2.5	3.4	8.9	47.6	0.1	0.8	4.3	18.9	0.5	5.7
E010	μ	1.5	2.6	13.0	61.2	0.1	0.2	2.0	8.2	1.5	9.7
	σ	0.2	0.1	0.7	2.4	0.1	0.1	0.3	1.2	0.1	0.5
	max	1.7	2.8	13.5	63.4	0.2	0.3	2.2	9.5	1.6	10.3
	min	1.3	2.5	12.2	58.8		0.2	1.7	7.1	1.4	9.2
E013	μ	1.5	3.1	11.9	51.0	0.1	0.2	3.4	20.5	0.9	7.5
	σ	0.1	0.2	0.5	0.9	0.1	0.1	0.1	1.3	0.1	0.5
	max	1.7	3.4	12.4	52.3	0.2	0.4	3.4	22.4	1.0	8.0
	min	1.5	2.9	11.5	50.2		0.1	3.3	19.6	0.8	6.9

		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO
		%	%	%	%	%	%	%	%	%	%
E014	µ	1.4	2.8	15.1	52.2	0.4	0.4	2.4	16.4	1.1	7.9
	σ	0.5	0.3	0.4	2.1	0.2	0.5	0.1	1.1	0.3	
	max	1.9	3.1	15.5	55.2	0.6	1.2	2.5	17.2	1.5	7.9
	min	0.9	2.3	14.7	50.5	0.1		2.4	14.8	0.8	7.9
E015	µ	1.0	2.9	10.8	56.0	0.1	0.1	1.4	20.0	1.1	6.7
	σ	0.1	0.3	0.7	4.8	0.1	0.1	0.5	3.6	0.4	0.7
	max	1.1	3.3	11.2	62.8	0.2	0.2	2.1	24.0	1.6	7.2
	min	0.8	2.6	9.7	51.7	0.1		1.0	15.2	0.6	5.6
E018	µ	1.3	3.1	11.2	53.0	0.2	0.9	1.4	18.3	1.3	9.5
	σ	0.2	0.3	0.6	0.7	0.1	0.8	0.2	0.7	0.2	0.4
	max	1.6	3.4	12.0	53.8	0.4	2.0	1.6	18.9	1.5	9.8
	min	1.1	2.8	10.6	52.2		0.3	1.1	17.4	1.1	8.9
AM001	µ	0.7	1.5	17.2	64.2	0.3	0.1	2.0	0.9	2.0	11.0
	σ	0.1	0.1	1.3	2.3	0.2	0.1	0.1	0.1	0.2	0.7
	max	0.9	1.6	18.9	65.8	0.5	0.2	2.2	1.1	2.2	12.0
	min	0.6	1.4	15.7	60.9	0.1		1.9	0.9	1.7	10.5
AM006	µ	0.9	1.8	18.4	62.7	0.3	0.2	1.9	1.1	1.8	10.9
	σ	0.2	0.1	1.0	2.0	0.1	0.1	0.2	0.1	0.3	0.5
	max	1.1	1.9	19.4	65.4	0.5	0.3	2.2	1.2	2.2	11.6
	min	0.8	1.7	17.0	60.7	0.2	0.1	1.7	0.9	1.4	10.4
AM010	µ	0.9	3.0	10.4	59.4	0.3	0.2	2.0	15.2	1.1	7.5
	σ	0.2	0.2	0.9	3.3	0.1	0.1	0.3	1.5	0.2	0.7
	max	1.1	3.3	11.2	62.2	0.3	0.2	2.4	16.6	1.4	8.2
	min	0.6	2.7	9.2	55.7	0.2	0.1	1.7	13.7	1.0	6.5
AM013	µ	1.2	2.9	12.7	51.4	0.6	0.3	2.8	19.2	1.1	7.8
	σ	0.1	0.3	0.3	2.0	0.2	0.1	0.5	1.9	0.2	0.4
	max	1.3	3.4	13.1	54.0	0.8	0.4	3.6	21.8	1.3	8.3
	min	1.1	2.7	12.4	49.4	0.4	0.2	2.4	17.3	1.0	7.4
AM014	µ	0.3	0.9	25.5	52.9	0.6	0.1	2.0	7.1	2.1	8.5
	σ	0.1	0.1	0.2	1.6	0.1	0.1	0.2	1.2	0.1	0.1
	max	0.4	0.9	25.8	55.3	0.7	0.2	2.3	8.0	2.2	8.6
	min	0.2	0.8	25.3	51.8	0.5		1.8	5.3	2.0	8.4
AM016	µ	1.3	2.4	9.9	47.0	0.7	0.4	1.9	30.3	0.8	5.4
	σ	0.1	0.2	0.4	3.9	0.1	0.1	0.5	3.2	0.4	0.6
	max	1.5	2.7	10.5	50.0	0.8	0.5	2.6	34.5	1.3	5.9
	min	1.1	2.2	9.5	41.2	0.6	0.2	1.5	27.0	0.5	4.7
AM019	µ	0.6	1.4	10.8	50.3	1.6	0.2	0.9	26.2	1.1	6.9
	σ	0.2	0.2	0.6	3.6	0.1	0.1	0.3	2.6	0.4	0.7
	max	0.8	1.5	11.3	55.6	1.7	0.3	1.1	29.4	1.6	7.9
	min	0.4	1.2	10.0	47.5	1.5	0.1	0.6	23.2	0.8	6.2
AM020	µ	0.3	0.6	27.7	61.8	0.2	0.1	1.5	0.6	2.2	5.1
	σ	0.1	0.1	0.4	0.5	0.1	0.1	0.1	0.2	0.1	0.3
	max	0.4	0.7	28.2	62.4	0.3	0.2	1.6	0.8	2.3	5.4
	min	0.3	0.5	27.3	61.1	0.1		1.4	0.4	2.0	4.8

This book focuses on the utilitarian ceramic traditions during the socio-political transition from the late Byzantine into the early Islamic Umayyad and ‘Abbasid periods, c. 6th–9th centuries CE in southern Transjordan and the Negev. These regions belonged to the Byzantine province of Palaestina Tertia, before Islamic administrative reorganisation in the mid-7th century. Cooking ware and ceramic containers were investigated from five archaeological sites representing different socio-economic contexts, the Jabal Harûn monastery, the village of Khirbet edh-Dharih, the port city of ‘Aqaba/Aila, the town of Elusa in the Negev, and the suburban farmstead of Abu Matar. The ceramics were typo-chronologically categorised and subjected to geochemical and micro-structural characterisation via X-ray fluorescence spectrometry (ED-XRF) and scanning electron microscopy (SEM-EDS) to geochemically ‘fingerprint’ the sampled ceramics and to identify production clusters, manufacturing techniques, ceramic distribution patterns, and material links between rural-urban communities as well as religious-secular communities. The ceramic data demonstrate economic wealth continuing into the early Islamic periods in the southern regions, ceramic exchange systems, specialized manufacture and inter-regional, long-distance ceramic transport. The potters who operated in the southern areas in the formative stages of the Islamic period reformulated their craft to follow new influences diffusing from the Islamic centres in the north.

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