

**Technological transfer in production of Majiayao-style pottery
between Neolithic communities in northwest China**



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PREFACE

This DPhil project is a collaboration between the University of Oxford and the British Museum within the Collaborative Doctoral Partnership scheme funded by the Arts and Humanities Research Council (AHRC). The final two years of this project including fieldwork were funded by the Gerda-Henkel-Foundation.

The research proposal to the AHRC was jointly written by Dr Anke Hein (University of Oxford) and Dr Michela Spataro (the British Museum). The aim of this project was to address the gap in research on pottery production technology of Neolithic northwest China. The investigation started with the examination of the pottery material held in the Early China Collection at the British Museum and extended to include the pottery held in Museum of Far Eastern Antiquities in Stockholm, and at the Ashmolean Museum. The close collaboration with the Museum of Far Eastern Antiquities provided most of the research material for this project. The samples were obtained under the umbrella of the Andersson Prehistoric Pottery Analysis (APPA) project led by Dr Anke Hein and Dr Ole Stilborg as a collaboration between the Museum of Far Eastern Antiquities, University of Oxford and Stockholm University.

The project further included information and material collected during fieldwork within the Tao River Archaeological Project led by Prof. Rowan Flad at Harvard University.

This project is a contribution to the growing body of research on Neolithic and Bronze Age pottery technology in northwest China. It is hoped that the results of this study will be useful to researchers studying the Neolithic and Bronze Age pottery of northwest China as well as to researchers investigating knowledge transfer and connectivity of people in prehistory.

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ABSTRACT

This study investigates the transfer of technological knowledge in production of the Neolithic Majiayao-style pottery (5300-4000 cal yr BP) on the territories of the modern Chinese provinces Gansu and Qinghai. The Majiayao-style pottery includes fine painted ware and coarse cord-impressed ware. Both wares of the Majiayao style were widely distributed across different river valleys located hundreds of kilometres away from each other. This study investigates whether there are similarities in production technology of the Majiayao-style beyond the shape and decoration and addresses communication and connectivity of prehistoric people living in the Tao River, Huangshui River, and the Yellow River valleys.

The methods of macroscopic examination, ceramic petrography and experimental firing of raw materials were used to reconstruct the *chaîne opératoire* of the Majiayao-style pottery from sites in three river valleys. The results of this study revealed similarities in raw materials and techniques for making this pottery in different locations indicating common technological knowledge that could have been disseminated among potters. The combination of macroscopic and microscopic analyses has shown that there are patterns in connection between coarse and fine clay pastes with specific decoration and firing atmospheres. The observations suggest that beside the technological knowledge, the production of Majiayao-style pottery also required specific social knowledge to connect outer appearance of the Majiayao style with the production materials and techniques.

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1 Introduction

This study investigates the production technology of the Neolithic Majiayao-style pottery and the possibility of technological knowledge transfer over long distances. There are two main pottery ware types that form the Majiayao style: fine painted ware and coarse ware with impressed decoration. Majiayao-style pottery was found on the territories of modern Chinese provinces Gansu, Qinghai, Ningxia and northwest Sichuan (An 1987:137; Hung 2011:39). Based on radiocarbon dating the time period when this pottery was produced and used falls between 5300-4000 cal yr BP (Dong et al. 2013).

The Majiayao-style painted ware is one of the earliest painted pottery styles in northwest China and one of the many painted pottery styles identified in that region (Andersson 1925, Xia 1949, Zhang 1990, Ren 2016). Since the first excavations and typological study of the painted ware from northwest China by Johann Gunnar Andersson (Andersson 1925; Fiskesjö and Chen 2004:56) it has been considered in a global context together with early painted pottery ware from Neolithic Europe, Central Asia and Mesopotamia (Andersson 1925; Chen and Hiebert 1995; Lhuillier 2007; Kozhin 2013). Suggestions and studies have been made to link the distribution of the pottery types from these regions in order to search for a global origin of prehistoric painted pottery (Andersson 1923; Chen and Hiebert 1995; Lhuillier 2007, 2011; Han 2013; Kozhin 2013). The painted pottery from Northwest China was specifically linked to the Cucuteni-Tripillia painted pottery from Europe, but besides similar designs no tangible proof exists that the production of these styles is in some way connected or has a common origin (Andersson 1923, 1925). Nevertheless, the search for the origin and research on the distribution of the prehistoric painted pottery in northwest China

and Central Asia is ongoing, but many studies focus on the Bronze Age pottery from Xinjiang province (Chen and Hiebert 1995:264, 267; Debaine-Francfort 2001; Francfort 2001; Lhuiller 2007, 2011). Xinjiang province is located between the modern territories comprising Central Asia and the Gansu-Qinghai area in China. Therefore, it has been hypothesised that the painted pottery from Xinjiang may have had its origins in the Bronze Age painted pottery styles in Gansu-Qinghai region (Chen and Hiebert 1995:264, 267; Debaine-Francfort 2001:61). The Bronze Age painted pottery styles are regarded as having developed from the Majiayao style (Andersson 1925; Zhang 1990; Ren 2016).

The technological perspective on the Majiayao-style production technology offered in this study is different from the stylistic approach to the painted ware dominating the previous research. Adopting the technological perspective to investigate the earliest painted pottery in the Gansu-Qinghai region could help approach the question of the painted pottery spread in Xinjiang and Central Asia.

It is generally accepted that the Majiayao-style pottery is one branch of multiple pottery styles which originated from the Yangshao-style pottery found on sites on the central Loess Plateau in Shaanxi and Henan (Ding 2010:85f; Wang 2012:213, 215-16; Han 2013). In Chinese archaeology, Neolithic pottery is mostly studied using a culture-historical approach (Chen and Fiskesjö 2014; Hein 2019). Therefore, in archaeological research the issue of Majiayao-style pottery production and distribution is referred to as the emergence, spread and decline of a “Majiayao culture” (Xia 1949; Yang 1962; Yan 1978). There is debate in the scholarly literature where exactly the Majiayao culture originated (Zhang 1990:52; Wang 2012:215-216). It is argued that the Majiayao culture could have developed and separated from the Shilingxia culture or the Miaodigou culture, which are

distinguished by painted pottery typology and are westward branches of the Yangshao-style pottery or the Yangshao culture (Wang 2012:216; Ding 2010:38; Wei and Chang 2020). The Yangshao-style pottery also includes the fine painted ware and the coarse cord-impressed ware (Ren 2016). The main concentration area of the Majiayao culture is in the area between western Gansu and eastern Qinghai (Guojia Wenwuju 1996:15-16; 2011a:70-71; Wang 2012:217; Dong et al. 2013). Further west in Qinghai province, following the Yellow River further upstream, the Majiayao culture sites overlap with the contemporaneous Zongri culture (Wang 2012:220). The contact between the two archaeological cultures is mainly reflected in the Majiayao and Zongri painted pottery types found in graves (Hung 2011; Hou et al. 2016; Ren et al. 2020). It is not known whether all people who produced and used Majiayao-style pottery perceived themselves as one community. Therefore, the present study uses the term “Majiayao-style pottery” instead of “Majiayao culture” to avoid presupposition and to focus on the technology of the potters independent from their ethnic or cultural affiliation.

The people living between 5300-4000 BP in the Gansu and Qinghai area settled mostly along the rivers Tao 洮河, Huangshui 湟水河 and the Yellow River 黄河 (Guojia Wenwuju 2011a:70-71; Hou et al. 2012; Dong et al. 2013). High site density in these areas suggests population growth and a settled way of life (Hou et al. 2012; Li et al. 2015). The subsistence strategies of the prehistoric people in the valleys consisted of agriculture, animal husbandry and hunting (Zhang and Li 2012; Dong et al. 2016). The architecture of the settlements consisted of semi-subterranean houses made of wattle and daub with floors made of white plaster and a hearth in the middle (Womack et al. 2019a:2; Ding 2010:61). Grave fields were located outside the settlements. According to Hou et al. (2012:117), the

average shortest distance between the sites was 5853 m. For Hou et al. (2012:118) this implied more social interaction and bonding between the communities, possibly resulting in division of labour between sites/communities. If this assumption is correct, division of labour may suggest specialised pottery production.

Painted pottery seems to have been a preferred funerary good (not counting potential unrecoverable organic materials) because it was deposited in graves in large quantities, more than 70 pieces in some (Allard 2001:17; Hung 2011). The burial customs appear to be similar in each geographical area of Majiayao-style pottery distribution (Hung 2011). The high quantity of the painted vessels in some graves is striking, Therefore the fine painted ware has been interpreted as a symbol of wealth (Allard 2001; Hung 2011). However, it is not known if the vessels themselves were regarded as a symbol of wealth or the content which they were holding. The fine painted pottery looks aesthetically pleasing to the modern viewer and is regarded as a work of high craftsmanship by collectors, however, the perspective of the prehistoric viewer is unknown.

Very little is known about the organisation of pottery production and the location of production centres. Based on the pottery appearing in both graves and settlements in considerable numbers (Andersson 1925, 1943, 1945; Bylin-Althin 1946), it can be assumed that the demand was there for the pottery to be used in everyday life and as a grave good. It is not known if all the pots deposited in graves initially belonged to and were used by the deceased or if some were added by the people associated with the deceased, but some showed traces of use-wear, suggesting that they had not been made especially for burial (Womack 2017:177; Womack and Wang 2020). There is archaeological evidence for sites with multiple

kiln clusters such as at Dadiwan 大地湾遗址 and Baidaogouping 白道沟坪遗址 where also tools for producing paint were found (Gansusheng Bowuguan 1957:5; 1960:16; 1983:21; Li and Huang 1993:74; Womack et al. 2019b:3). There is also evidence for kilns being located among the houses at habitation sites such as Linjia 林家 (Womack et al. 2019a:2), suggesting household production.

Most research on production technology of the Majiayao-style pottery has focused on the fine painted ware (Wu 1938; Li 1984; Ma and Li 1991; Li and Huang 1993; Ma 2000; Hung 2011), but some research on coarse ware has been included in both early (Palmgren 1934; Bylin-Althin 1946) and in most recent studies (Yu et al. 2017; Womack 2017, et al. 2019a-b; Hein and Stilborg 2019), and they are also considered together in the current study. It is possible that by creating two very different types of coarse and fine wares there was some kind of human expression in attention to textures (Evans 2003) and colours which can only be approached by studying technological choices from the beginning to the end of the production process. A study of technological transfer as conducted in the present thesis can help investigate whether the same attention was paid to textures and colours in different regions of the Gansu-Qinghai area where the Majiayao-style pottery was found.

By using scientific analysis and experimental archaeology, this study aims to reconstruct the technological sequence – *chaîne opératoire* – of the production process from the raw material selection to the firing process (Lemonnier 1976, 2002; Sillar and Tite 2000). The *chaîne opératoire* consists of technological choices which are made at each step in the manufacturing process (Sillar and Tite 2000; Tite 1999). This study investigates these choices by analysing pottery fabric composition, vessel structure and presence of tool marks, surface finish, as well as

indicators of firing process. The information gathered about the technological choices is regarded as technological knowledge which can be shared by a potter to an apprentice or by a potter to another potter (Schiffer and Skibo 1987; Crown 2001; 2014; Wright 2001; Roux 2013, 2015). This study investigates the possibility of a technological knowledge transfer between the Tao River, Huangshui River and the Yellow River Valleys. Investigation of technological transfer of pottery production has been conducted in archaeological research around the world (e. g. Badre et al. 2005; Kiriati 2010; Roux 2013, 2015; Gauß et al. 2015). Studying prehistory from this perspective can shed new light at the connection between communities, social structure, settlement patterns, travel and exchange routes (Roux and Courty 2019:312). The perspective of technological knowledge transfer across space has not been adopted in the research on Majiayao-style pottery yet. This approach will not only contribute to the study of connectivity between producers and users of this pottery, but also hopes to contribute to the understanding of the technology of other contemporaneous pottery styles from other regions which show similarities in shapes and decoration to the Majiayao style, such as the Zongri style (Chen et al. 1998; Hung 2011).

This thesis consists of eight chapters. Chapter 2 introduces the previous research conducted on the Majiayao-style pottery from the typology studies by Andersson (1925) and Xia (1949) to the scientific analyses of mineral and elemental pottery composition by Hung (2011) and Womack (2017).

The research questions of this thesis are discussed in Chapter 3. Chapter 3 first outlines the concept of the *chaîne opératoire* and technological choices (Lemmonier 1976; Gosselain 1998; Schiffer and Skibo 1987; Sillar and Tite 2000) as the main tools for investigating the production technology from the raw

material procurement to firing. It then defines and discusses technological knowledge and technological transfer. The chapter concludes with the discussion of transmission strategies and highlights the potential of studying technological transfer in Neolithic China.

Chapter 4 presents research material and research methods. The research material for this study includes complete Majiayao-style vessels from the collections in the British Museum, the Museum of Far Eastern Antiquities (MFEA) and the Ashmolean, pottery sherds from the MFEA and geological samples of clay, rocks and sand from the Tao River Valley collected by the author. The analytical methods include macroscopic examination, thin-section petrography, and experimental firing of collected clay samples. This chapter further outlines the geological setting in the study area and describes the field sampling methods. The firing experiment is described at the end of this chapter.

Chapter 5 discusses the data and findings from macroscopic analyses of vessels and sherds as well as results of a petrographic study of pottery sherds from the MFEA. The sections discussing the macroscopic study focus on the reconstruction of the *chaîne opératoire* from forming to firing. Furthermore, Chapter 5 highlights the interconnection of the pottery fabrics, decoration and firing patterns which can be regarded as the one of the significant technological characteristics of the Majiayao style. The discussion of petrographic data is structured by site, highlighting different aspects of matrix, inclusions and porosity of coarse and fine fabrics. The data from each site is presented together in a comparative study in the last section of the chapter.

Chapter 6 discusses the results of the macroscopic and petrographic studies of the geological samples. The macroscopic study of the sediment samples includes a

discussion of the collected clay in raw state and after firing. The petrographic study was conducted on specifically selected fired clay samples and rocks from the total sample amount.

The first part of Chapter 7 reconstructs the *chaîne opératoire* for the Majiayao-style pottery technology from the raw material selection to the finished product based on the insights from pottery analysis and the study of the geological samples. The reconstruction of the *chaîne opératoire* is described by the technological choices made at each step. The second part of this chapter discusses the indicators and extent of technological knowledge transfer in the study area. It looks at the evidence from previous research and at the insights inferred from this analysis and argues that the dissemination of technological knowledge probably happened through potter networks in the study area.

Chapter 8 concludes this thesis by summarising the main insights into Majiayao-style pottery technology and outlining potential avenues for future research. The study resulted in many new questions regarding the technological choices, organisation of production and the routes of knowledge disseminations. Many aspects of the identified technological choices in this study can be further investigated with different scientific techniques and sampling strategies to address the complexity of Majiayao-style pottery production.

Information on provenance and current location of the complete vessels analysed in this study is presented in Annex 1. The detailed descriptive data from the macroscopic study of vessels and sherds is presented in Annexes 2 and 3. The description of petrographic fabrics identified in pottery and geological clay samples is included in Catalogues 1 and 2. Full macroscopic and microscopic descriptions of each individual prehistoric pottery sherd are presented in

Catalogue 3. Full macroscopic and microscopic descriptions of individual geological sediment and rock samples are presented in Catalogue 4.

2 Previous research on Majiayao-style pottery

2.1 First studies by scholars in Europe

Majiayao-style pottery was first excavated and documented by the Swedish geologist and archaeologist Johann G. Andersson and his team in the 1920s on the territory of modern Gansu and Qinghai Provinces (Andersson 1925, 1929; 1939; 1943; 1973:264; 1945; Bylin-Althin 1946; Xia 1949; Sommarström 1956; Chen 1997; Fiskesjö and Chen 2004). Andersson's work in Gansu and Qinghai was motivated by his previous excavations of prehistoric sites in Henan Province, which yielded the first finds of Neolithic painted pottery in China (Fiskesjö and Chen 2004:36). These sites are now seen as comprising the core of the Yangshao archaeological culture which is largely defined based on characteristic painted pottery. Assuming that the painted pottery found in Henan might be linked to the known painted pottery from prehistoric sites in Central Asia, Andersson and his team decided to extend their archaeological expeditions to the northwest of China (Andersson 1925:3; Fiskesjö and Chen 2004:56). They surveyed areas in the Tao, Huangshui and Yellow River (Guide County) Valleys deeming these places as most suitable for prehistoric occupation (Andersson 1925:7).

The locals living in the Tao River Valley noticed Andersson's interest in the pottery and looted many sites to sell complete painted vessels to him (Andersson 1943:107). Andersson bought many vessels but soon realised that by doing so the artefacts were reduced in their scientific value because there was no record of the archaeological context (Andersson 1943:132). While the provenance record of the acquired complete vessels may be uncertain, pottery sherds provide a more reliable material for research because they were collected during a survey or an excavation. The excavated and bought pottery together with bone and stone

artefacts was brought to Sweden by Andersson for analysis and cataloguing (Fiskesjö and Chen 2004:62). Part of it was later returned to China and the other part formed the core collection of the Museum of Far Eastern Antiquities (Fiskesjö and Chen 2004:64). First studies of this pottery were conducted by Andersson himself. He distinguished six different pottery types based on the vessel shape and decoration (Andersson 1925). He distinguished the types Majiayao and Banshan according to their respective find places – habitation site and burial ground by colour and function: Majiayao pottery he defined as predominantly monochrome black and Banshan bichrome red and black, which led him to the conclusion that bichrome vessels were used solely in a funerary context (Andersson 1929:69; 1943:139). Andersson described Machang pottery type as related to Banshan, because of the bichrome decoration, though at a “more advanced stage”, and placed it later in the chronological sequence (Andersson 1943:159).

Combining his pottery typologies with stratigraphic analysis, Andersson (1925:23) established relative chronologies for the occupation of the sites from the Neolithic to the Early Bronze Age in the study area. He followed the method of relative archaeological dating published by Swedish archaeologist Oscar Montelius (Montelius 1903; Chen and Fiskesjö 2014:6). Andersson linked each pottery type to a different cultural stage or period. Andersson’s identification of archaeological cultural periods was based on pottery types and on the types and presence/absence of copper artefacts (Andersson 1925:19, 36). The “archaeological culture” approach belonged to the trend of culture-historical theory in archaeology at the beginning of the twentieth century in Europe. It is a theory which links archaeological material evidence to an ethnic group that lived in the past and formed an archaeological culture (Trigger 2006:237). Andersson

did not provide a definition of archaeological culture in his publications but wrote that he directly links pottery types to ethnically different communities (Andersson 1925:22-23). This is reflected in his comparisons of painted pottery from China and from the Near East. Based on these comparisons along with chronologies of the prehistoric Scandinavia and Crete, he estimated the duration of each cultural stage lasting 300 years (Andersson 1925:24-27). These comparisons were also Andersson's attempt to provide absolute dates for the archaeological cultures. He suggested that the material evidence of what he called the Yangshao culture in Henan, can be approximately dated to 3000 BC. The Majiayao-style pottery was also classified as belonging to the Yangshao culture by Andersson. The terms "Majiayao pottery" or "Majiayao culture" as they are used today were coined later by the Chinese archaeologist Xia Nai 夏鼐 (Xia 1948, 1949) and will be discussed further below.

In his typological study, Andersson primarily focused on painted pottery, on which he also based his relative chronologies. The subsequent studies by the Swedish art historian Palmgren (1934), Chinese archaeologist Wu (1938), and Swedish archaeologists Bylin-Althin (1946) and Sommarström (1956) included the pottery with impressed and appliqué decoration, addressing issues of pottery technology. Palmgren (1934) studied the pottery brought to MFEA by Andersson and focused on the vessels from the Banshan burial area and Machang site, which were later established as names for the painted pottery sub-types of the Majiayao-style (Li 1998). He discussed production technology and design of the Banshan and Machang types. Palmgren (1934:36-45) separately discussed the production technology and design of the vessels with impression and appliqué decoration classifying them as Banshan type. Palmgren's analysis of pottery has a strong

technical focus without going into detailed discussions on the usage of the pottery or the life of the people who made and used them. He provided first macroscopic descriptions of fabric composition, firing patterns, and suggested coiling as the primary construction technique. Furthermore, Palmgren (1934:174, ft-note 2) published the first results on the chemical composition of the black paint consisting of manganese and iron oxides from the analysis in the Swedish State Testing Laboratories.¹ Additionally, Palmgren published a comprehensive catalogue of the vessels held in MFEA in the appendix of his study. The catalogue includes photos of the vessels which are now on permanent display and inaccessible for another study. Some of the photos show vessels before complete reconstruction, allowing an examination of the vessels' interior. Palmgren's insights on technology are integrated into the discussion of the technological sequence for pottery production in Chapter 5 and compared with the data of the present study.

Published shortly after, the doctoral thesis by Wu (1938) built upon Palmgren's study on pottery. Wu was a Chinese archaeologist conducting a PhD study at University College London on prehistoric pottery types from several different Chinese provinces in the Northwest, the Northeast and Central Plains. Wu's work on pottery from the sites in Gansu and Qinghai consists of a detailed macroscopic assessment of fabrics, shapes, decoration and firing methods. Part III of Wu's thesis (1938:125-145) is a comparative study of the pottery technology from the different regions in his study area which is a useful overview of the pottery making techniques of prehistoric China. Wu's most important insights for this study were the identification of beating as a secondary construction technique on the one hand,

¹ The method of analysis is not mentioned.

and turntable usage on the other hand, thereby disproving some of Palmgren's claims regarding construction techniques (Wu 1938:91-92; here section 5.1.1). The macroscopic analyses in works by Palmgren and Wu were recorded in great detail and are still relevant as most of their observations were confirmed in the present study which included using additional equipment besides a loupe and high-resolution photography.

Bylin-Althin's (1946) analysis and discussion of material excavated at Luohantang was especially useful for this study because Andersson did not publish all his work on this site. Bylin-Althin conducted macroscopic analysis on the painted and impressed sherds and discussed making and firing techniques. The results of her analysis are also integrated and discussed in Chapter 5. Bylin-Althin (1946:443-444) was the first to point out and describe sherds with the coarse-fine-combination fabric from Luohantang. She provided comprehensive descriptions and clear photographs of each sherd she analysed which facilitated the sherd sample selection for this study. Furthermore, Bylin-Althin (1946:450-451, 462) noted the similarities between the pottery, bone and stone artefacts found at Luohantang, Zhujiashai and Majiayao regarding their design. Her observation of similarities in the material from these sites provided one of the reasons to focus this study on these sites.

Sommarström (1956) reviewed the material from the Majiayao site in the collection and added unpublished information about every site Andersson had worked on. Sommarström completed a meticulous description of pottery, bone, and stone artefacts from the Majiayao site in the MFEA collection. His macroscopic description of sherds included ceramic paste, shape, surface finish, as well as a comprehensive list of painted motifs. Sommarström (1956:87-88) identified the

sherds with coarse-fine-combination fabric collected at the Majiayao site and pointed out that similar sherds were found at Luohantang as published by Bylin-Althin (1946). Furthermore, Sommarström (1956:80-81) published descriptions of pictures of rounded and rectangular sherds, identifying the latter as knives or scrapers. These sherds are discussed in section 5.1.1 as potential tools for pottery making.

The early research by scholars in Europe following Andersson's publications deal predominantly with the pottery from the MFEA collection. Their content is mostly descriptive but includes analyses and discussions of the pottery production technology. Although these works do not engage in extensive discussions of social structure or similar topics about life in prehistory, they provide a solid basis for the present study of pottery technology and are a valuable resource for sample selection strategy.

2.2 Research on Majiayao-style pottery in China

During the 20th century many Neolithic sites in Gansu and Qinghai were surveyed and excavated, improving the understanding of the spatial distribution of the Majiayao-style pottery (Fang 1991; Ding 2010; Wang 2012; here Figs 2.1-2).

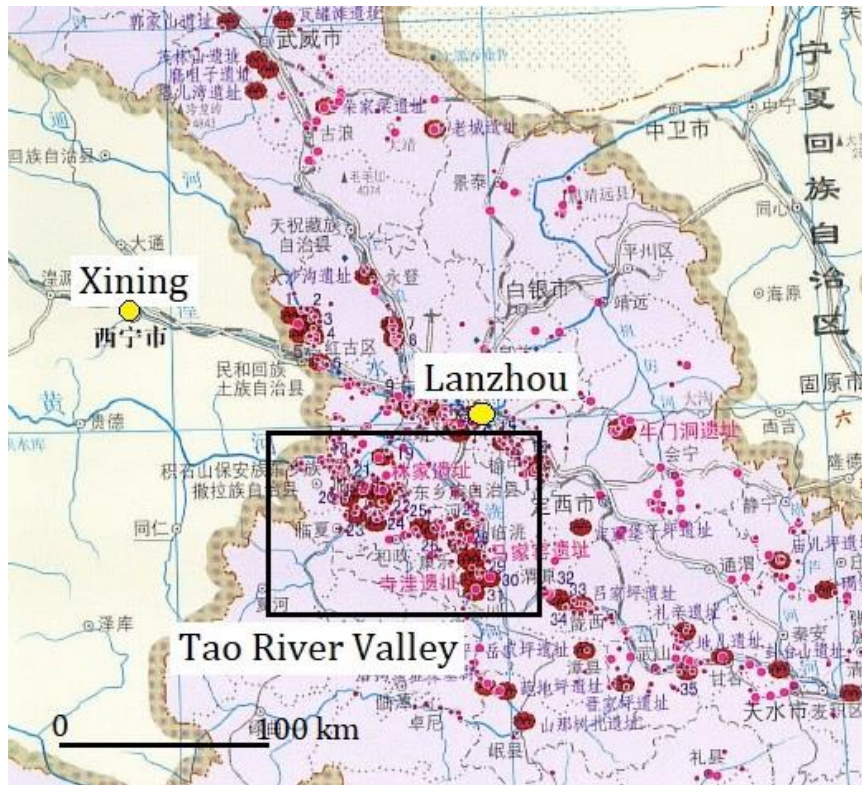


Fig. 2.1. Distribution of the Neolithic sites in Gansu Province where Majiayao-style pottery was found (red and purple dots), from the Atlas of Chinese Cultural Relics: Gansu Province (Guojia Wenwuju 2011a:70-71) Full map and legend see Annex 3, Fig.1; English captions by the author.

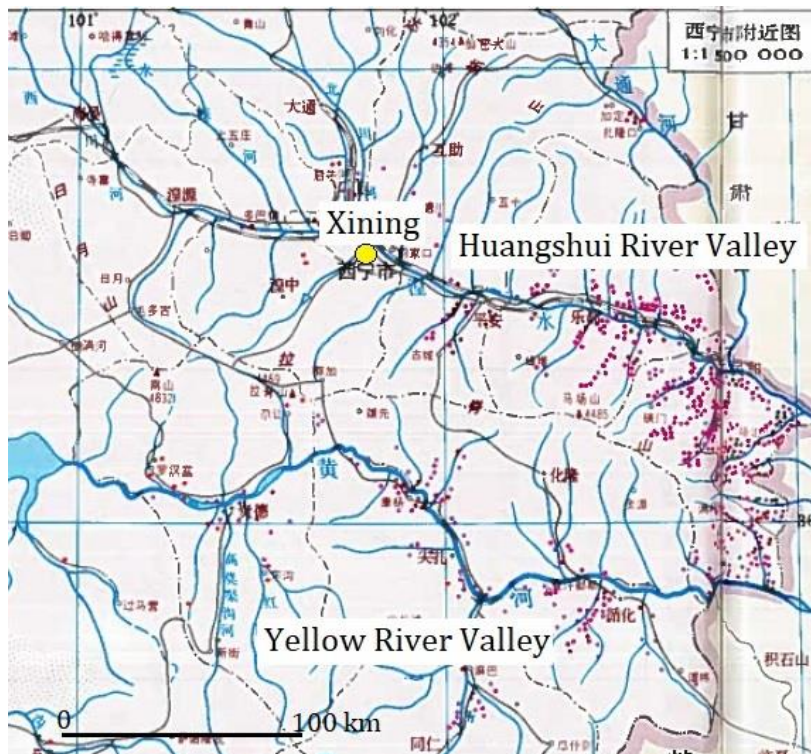


Fig. 2.2. Distribution of the Neolithic sites in Qinghai Province where Majiayao-style pottery was found (red and purple dots), from the Atlas of Chinese Cultural Relics: Qinghai Province (Guojia Wenwuju 1996:15-16) Full map and legend see Annex 3, Fig. 2; English captions by the author.

The relative chronologies established by Andersson were revised by Xia Nai who conducted further excavations in the Tao River Valley and separated Majiayao-style from Yangshao-style, coining the term “Majiayao culture” (Xia 1948, 1949; Fiskesjö and Chen 2004:112; Ding 2010:42). The culture-historical approach to prehistoric archaeology prevailed as an academic tradition in Chinese archaeology and remained largely unchanged (von Falkenhausen 1993; Hein 2016:34; Chen and Fiskesjö 2014; Ehrich 2017:47-48; Hein 2019:45). The theoretical approaches in Chinese archaeology are deeply rooted in history and entwined with politics. Archaeological finds are used to justify and legitimise political agenda (von Falkenhausen 1993:844-847; Trigger 2006:267; Hein 2016:26; Ehrich 2017:78; Hein 2019:46-47). The idea of equating archaeological remains with ancient ethnic groups was not unanimously accepted and was scrutinised by some Chinese scholars (cf. references in Ehrich 2017:67 and in Hein 2019:50-52). However, this approach is still applied for the analysis and interpretation of the prehistoric pottery in the study area (Chen and Fiskesjö 2014:1).

Due to its material robustness, a large quantity of pottery has survived and now this particular style of painted pottery described and set apart by Xia (1949) is used to define the Majiayao culture. However, it is unclear how important the pottery was to the prehistoric people living in the region at that time. It is impossible to say whether by using the same pottery style the people in different valleys also felt a sense of community. Potters who made the Majiayao-style pottery in different river valleys might not have belonged to the same group of people who perceived themselves as one community or an ethnic group (Dietler and Herbich 1994:461). The present study argues that it is possible that the prehistoric potters in the study area kept in contact with each other, regardless of

social affiliation. The culture-historical approach complicates the investigation of prehistoric life from the perspective of a potter. If deemed as style specific, the technological sequence of the Majiayao-style could then be perceived as a cultural trait within the established culture-historical theoretical framework. Subsequently, there is a risk to view similarities and changes in pottery technology or typology in a larger geographical area through the lens of inter-cultural contact and influence on a large scale. The pottery technology would then also characterise the consumers of this pottery who are not potters. This study aims to investigate the issues of technological choices and knowledge transfer in pottery production (Chapter 3) without the distorting lens of the culture-historical framework and to focus on the people who left unambiguous evidence of their activity – potters.

Nevertheless, the typological classification of the pottery within this long-established framework provides a foundation for the investigation of a style-specific technological sequence. After his works having been translated into Chinese, the method of typological classification after Montelius (1903) became the main tool for pottery analysis in Chinese archaeology (Chen and Fiskesjö 2014). Typological studies of the Majiayao-style pottery focus on the change of vessel shapes and decorative design. Different scholars argue for different sub-types and further sub-division (Ding 2010). However, the main sub-types Majiayao, Banshan and Machang prevail because this order was established by combining typology, stratigraphy and radiocarbon dating (Yang 1962:74, 77; Xia 1977; Yan 1978:66).

Major typological studies by Chinese archaeologists Zhang (1990) and Li (1998) only consider the painted pottery. Due to this limitation, the typology of the Majiayao-style seems to be incomplete considering that the painted and non-painted pottery appears to be excavated in relatively equal amounts in the study

area.² The PhD study by Ren (2016) includes unpainted pottery and other stone tools in the discussion of relative chronologies of Neolithic and Bronze Age painted pottery in northwest China. His work is strictly typological and provides little new information about the technology or usage of the vessels. However, it is a comprehensive source of reference on the pottery in the study area, showing both painted and non-painted pottery considered as Majiayao-style.

2.3 Studies on pottery technology and regional contact in northwest China

Scientific studies on the Majiayao-style pottery technology have been conducted since the 1980s, though the Majiayao-style samples were mostly considered together with pottery samples of different later or earlier prehistoric pottery styles in the entire northwest China. Besides macroscopic examination, the new included analytical techniques were X-ray-radiography, petrographic and chemical analysis. There are three scientific studies conducted by Vandiver (1988), Ma and Li (1991) and Ma (2000) which complemented the insights from the first macroscopic analyses discussed above and which contributed to the basis of the present project. Vandiver (1988) studied primary and secondary building techniques on xero-radiographs of five complete painted Majiayao-style vessels from the Peabody Museum, Harvard University. She was able to confirm Palmgren's (1934) and Wu's (1938) macroscopic observations that vessels were first coiled and then further shaped by percussion treatment. In addition to the radiographs, Vandiver conducted scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) on three polished sections from these vessels. This analysis was aimed to provide insight into the chemical composition and

² Personal observation in the MFEA collection and excavated pottery from the Tao River Valley in China during research stay.

microstructure of fired clay. Vandiver (1988:163, Table 1) compared the results to the chemical composition of a loess sample from the Xi'an area in Shaanxi province. The data for pottery clay and loess largely corresponded and Vandiver (1988:163) concluded that this type of sediment was used as raw material in pottery construction. The provenance of the Majiayao-style vessels is unknown, but it is likely that they have become part of the Peabody Museum collection through private collectors/looters shortly after Andersson's reports. If these vessels indeed come from Andersson's exploration area, then a comparison with a geological sample collected in a geographically distant area in Shaanxi might not be entirely appropriate and appears rather random for addressing the issue of pottery raw material. However, since loess is one of the most abundant sediment types also in the study area, Vandiver's data gave a first impression of how the chemical composition of the pottery clay relates to the unprocessed geological material and indicated potential difficulties in provenance studies using only chemical analysis and a limited number of samples.

Ma and Li (1991) conducted a study on 25 samples from twelve pottery types of eight different cultural periods from the Neolithic to Bronze Age including Majiayao in northwest China. They analysed the chemical composition of the pottery clay and six Malan loess³ samples using X-ray diffraction and ran analyses of physical properties such as hardness, water absorption, porosity and firing temperature (Ma and Li 1991: Tables 1 and 2). They investigated issues of pottery making in prehistory and conducted ethnographic research into modern pottery production to help interpret the results of their analysis.

³ Malan loess 马兰土 is the youngest layer of loess on the Chinese Loess Plateau (Fan and Du 1999:34; Liu 1988:15; Derbyshire et al. 2000:48-49).

Ma and Li (1991:263, Fig.1) concluded that prehistoric potters deliberately chose a particular type of raw material. This conclusion was based on their chemical sample distribution map where most of the samples of various types are concentrated in one area (Ma and Li 1991:263, Fig. 1). The Malan loess samples collected from various places in Gansu were not included in that area of concentration; therefore, Ma and Li (1991:265) concluded that this type of sediment was not used as raw material in pottery production. Further, by using a high temperature dilatometer they were able to determine the average firing temperature: 900° to 1050° C (Ma and Li 1991:268). The prehistoric kilns would have been down- or updraft kilns fired in an oxidising atmosphere, since most of the pottery appears to be red in body colour (Ma and Li 1991:268). It is not clear whether Ma and Li came to this conclusion because they had only sampled painted sherds, which would have been predominantly fired in an oxidising atmosphere as the present study argues (see section 5.1.2).

Ma (2000) continued with a similar approach to pottery analysis in his PhD study. The first part of his thesis presents the same data on the same samples from Ma and Li's study (1991). The provenience of the pottery samples in Ma's study varied. There was a focus on 44 pottery samples of different types and periods found at the Dadiwan site 大地湾遗址 in one chapter, but he also included additional analysis on 13 Majiayao-style pottery samples from different locations in Gansu. The aim of Ma's study, similar to Ma and Li (1991), was to provide insight into the technological sequence of the prehistoric pottery production. By using X-ray diffraction and X-ray fluorescence he put an emphasis on pigment analysis, identifying magnetite and hematite as pigments on the Majiayao-style pottery besides the already known manganese and iron oxides (Ma 2000:58). In sum, Ma

came to similar conclusions as Ma and Li (1991) in terms of kiln structure, firing temperature and raw material for paste and paint. Ma's analysis (2000:46-47) of the CaO content on the fine fabrics from Dadiwan showed different amounts for each sample; therefore, Ma suggested that the clay might have been purified. However, as the experimental firing of the geological samples conducted in the present study shows, local clays can naturally have different CaO content (sections 4.4.3 and 5.2.1).

Studies by Ma and Li (1991) and Ma (2000) reconstruct pottery technology in the study area by combining data obtained from samples from different periods which are dated hundreds of years apart. It is possible that the pottery technology did not undergo significant changes throughout the Neolithic and Bronze Age. There are studies on prehistoric pottery from other places in the world that show long consistency in pottery technology (e. g. D'Ercole et al. 2017). However, Bronze Age pottery styles in the study area show changes in visible technological choices such as vessel shapes, surface treatment and painted motifs. Studies such as by Ma and Li (1991), analysing samples from different pottery styles and periods provide various data on elemental composition, firing temperature and surface treatment. It is difficult to address technological questions focusing on one type or period using such studies as a basis. Although the overall sample size might be sufficient, the number of samples of a certain pottery type within might be low. This approach contrasts with the typological studies in Chinese archaeology which tend to further separate the vessels into different sub-types, while scientific research does not differentiate and instead aims to reconstruct the technological sequence for the entire prehistoric period of Northwest China.

There are several subsequent scientific studies on a small number of samples (max. 10) using X-ray diffraction, 3D-X-ray fluorescence, SEM-EDX, Raman spectroscopy, petrography and P-ED-XRF (Ma et al. 2000; Chen et al. 2000; Zhong et al. 2013; Yan et al. 2013; Yi et al. 2016a-b; Li and Yu 2018; Hein and Stilborg 2019). These are pilot studies which provide preliminary scientific data and experiment with new methods. They touch on the issues of technology such as clay paste or paint composition or firing temperature, but the small sample size does not allow for a detailed investigation of specific archaeological issues.

Although the people who used Majiayao-style pottery are considered to belong to the same prehistoric community in Chinese archaeology, research on the technology of Majiayao style combining analysis of pottery excavated in Gansu and pottery excavated in Qinghai is scarce.⁴

The first large-scale study addressing the production of Majiayao-style pottery from several sites in Qinghai and Gansu was conducted by Hung (2011). She was a critic of the culture-historical approach in Chinese archaeology arguing that this approach is a simplistic view of the communities during the Majiayao period (Hung 2011:211). Her study focused on the connections in settlement patterns, pottery production and mortuary practices between Majiayao period sites in Gansu, northeast Qinghai (including sites in the Tao, Huangshui and Yellow River Valleys) and northwest Sichuan provinces, covering a geographical area of more than 1000 km north-east and 500 km east-west. By analysing 687 pottery samples⁵ of Majiayao-style pottery from thirty-three archaeological sites using laser ablation

⁴ It needs to be pointed out though, that the published research on pottery analysis by archaeologists working in Qinghai appears to be difficult to access outside of Qinghai. Some serials and edited volumes are published by museum staff such as by the Liuwan Museum of Painted Pottery, e. g. the pilot study on pigments by Li and Yu (2018) and sold in museum shops (pers. observation during a research trip in 2019).

⁵ 473 painted and 214 unpainted pottery samples.

inductively coupled plasma atomic emission spectroscopy (LA-ICP-AES) and principal component analysis she investigated issues of regional pottery production, inter-regional pottery exchange and social hierarchy (Hung 2011:30). Through comparison of chemical data, Hung was able to draw conclusions about inter-regional exchange and provenience of pottery (Hung 2011:70). The samples were grouped according to the amount of calcium carbonate (CaO) and magnesium oxide (MgO) and compared with each other. It appears that Hung's study was based on the geochemical data from the study of Quaternary loess and Tertiary clay from Gansu by Chen et al. (2001) and on chemical studies of prehistoric pottery from northwest China, totalling less than 20 samples of Majiayao-style pottery by Zhou et al. (1964), Ma (2000), and Sundius (1961). Based on these studies Hung (2011:70) concluded that the sediments in the Gansu and Qinghai area have a high calcium carbonate content and so do the painted Majiayao-style sherds in contrast to the prehistoric pottery from other regions in northwest China. Through principal component analysis, Hung (2011:70) determined that the Majiayao painted pottery from Gansu has a higher content of CaO and MgO than unpainted pottery from Sichuan which she assumed was produced locally (Hung 2011:71). Therefore, she suggested that the painted pottery from Sichuan with high CaO and MgO content was imported from Gansu and the imported pottery would have been made from Tertiary red clay (Hung 2011:71; 127). Hung treated the different sample groups as equivalent to separate production groups in the Gansu and Qinghai area, implying that each production group used chemically different raw material but painted the vessels in similar designs for inter-regional exchange (Hung 2011:70-71, 107, 127).

Relying on CaO and MgO as determining elements to identify and differentiate raw materials origins might be misleading. First, the data provided by Chen et al. (2001) on the CaO and MgO content from Gansu is limited to the Xifeng area 西峰区 in south-eastern Gansu and may not apply to the entire Gansu and Qinghai area. Second, geochemical data from Sichuan for comparison is not provided in Hung's study; however, the sediments in Sichuan show high variation in CaO and MgO content (Du et al. 2013:1834). Therefore, the data obtained from pottery alone might not necessarily point to the Tertiary clays in Gansu and could also be characteristic of raw material available in Sichuan.

Hung's study did not include geological samples which could have put the data gathered from archaeological material into another perspective and added to the discussion. Different chemical composition of pottery might also point to a different clay bed in the same location which is difficult to infer from large scale geological maps. This issue could be addressed by local geological sampling. Furthermore, in Hung's interpretation of data, she did not consider post-depositional alterations in pottery paste. Results of chemical analysis suggested analcime content in the pottery paste (Hung 2011:184), which she interpreted as tempering material, though noting that it was an unusual choice of temper. Studies on post-depositional alteration of ceramics (Schwedt et al. 2006:238; Zacharias et al. 2007) have shown that analcime is also a product of a chemical reaction which happens due to weathering underground. Analcime content being a product of underground weathering might explain its presence since Hung analysed pottery deposited in graves.

Although Hung included 214 unpainted coarse pottery samples in her principal component analysis, there was no sufficient consideration of it in her study. She

assumed it was produced for a local market in Sichuan as it differed from the CaO and MgO content from the painted pottery found in that area and did not further investigate its production (Hung 2011:232, 285 fig. 2.19). A closer look at the coarse unpainted vessels might have offered a different perspective on the production of the fine vessels and contributed to the understanding of their provenance.

The wide distribution of the Majiayao-style pottery highlighted in Hung's study provides further incentive to investigate technological transfer beyond the shared painted designs. Hung's approach to investigate pottery making within one archaeological period and in a geographically large study area is innovative for prehistoric archaeology in northwest China. Regardless of the production place and the export extent, Hung has shown that the fine painted pottery from distant areas is chemically similar. This chemical overlap may be a result of either similar properties of chosen raw material or it may be due to a general similar sediment composition from northeast Qinghai to northwest Sichuan. Ma and Li (1991) interpreted the overlap in chemical composition of pottery samples from different sites in Gansu as potters' knowledge of which clay to choose. Chemistry as the main method analysis of archaeological pottery has proven to produce data that includes elements formed during firing and underground deposition (Freestone 2001; Cultrone et al. 2001; Pollard and Heron 2008:116, 127-129; Schwedt et al. 2006:238; Maritan 2020). This means that this data does not reflect the actual chemical composition of the raw material, and that the comparison between pottery samples from distinct places might be inaccurate. A combination of chemical study with other analytical methods such as firing experiments or

petrographic studies could have added a different perspective to the discussion of pottery provenance.

Cui et al. (2015) analysed 28 Majiayao-style pottery sherds from the Huangshui River Valley using X-ray fluorescence measurement as a part of their study on prehistoric pottery exchange during different periods between sites in Gansu and Qinghai, which altogether analysed 118 samples dating to the Neolithic and Bronze Age. The results of the trace element analysis showed that all Majiayao sherds except one form one cluster meaning that they were made from similar clay (Cui et al. 2015:66-67); calcium was excluded from the trace element analysis because of contamination risks. Cui et al. (2015:66) additionally collected five red clay and five loess samples in the area about 100 km south from the Huangshui Valley and compared their composition to the pottery clay. Despite the large distance between the locations of pottery and clay sample collection, Cui et al. (2015:67-68) found that the chemical composition of pottery corresponds to the composition of red clay more than it does to loess. This observation is in agreement with the studies by Ma and Li (1991)⁶ who also suggested that loess was unlikely used for pottery making and is further supported by the experimental study in the present project.

Yu et al. (2017) came to the similar conclusion of red clay being the preferred raw material for pottery making instead of loess. They suggested that loess was used as tempering material for coarse pottery (Yu et al. 2017:117). Yu et al. (2017:109) investigated prehistoric pottery making, analysing the pottery dated to four different cultural periods (4100-3500 BP) including Majiayao from the site of

⁶ The unsuitability of loess for pottery making due to its low plasticity is also mentioned in the study by Zhou et al. (1964:17) which mainly focused on prehistoric pottery from Shaanxi, Henan and Shandong provinces.

Xichengyi 西城驿遗址 in northern Gansu. They applied petrographic analysis and energy dispersive X-ray fluorescence measurement to 172 coarse and fine pottery samples. Although they did not identify significant changes in the paste recipes over time, by combining the methods of mineral and chemical analysis, Yu et al. were able to identify technological steps that cannot be detected through merely chemical analysis. They observed in thin section that the groundmass (matrix and fine fraction) in some coarse samples was very fine ($<10\text{ }\mu\text{m}$) and homogeneous but contained poorly sorted coarse grains (Yu et al. 2017:115). Based on this observation, Yu et al. concluded that the clay was first purified to remove naturally present coarse particles before rock temper was added. Ma and Li (1991) suggested clay purification as a means to reduce calcium content but not with regard to coarse paste mixing. Similar to the researchers in the previously discussed studies, Yu et al. (2017:116-117) also highlight the role of calcium in determining the type of raw material selected for prehistoric pottery making. Loess and red clay deposits on the Chinese Loess Plateau have varying calcium carbonate contents; calcium carbonate appears to be one of the most abundant elements in these sediments and yet it is frequently used in provenance identification, or at least in investigations into whether Tertiary or Quaternary deposits were used for clay extraction (cf. discussion in Ma et al. 2020). The content in prehistoric pottery has proven to vary as well, and so far, this issue has mainly been analysed through chemistry and trace element analysis. Comparative studies with geological samples from the same area as pottery yielded rather general results where both sample types were grouped in broadly consistent clusters (e. g. Hong et al. 2011; Ma et al. 2020). The firing experiment in the present study (see sections 4.4.3 and 5.2.1) has shown that the calcium content in

the red clay samples collected within a radius of 1 km can vary significantly. To continue using mainly chemistry to investigate raw material selection in prehistory on the Chinese Loess Plateau would not contribute to progress on this issue, as such studies seem to be detached from the practical technological process where the physical properties of clay and its reaction to firing play a major role in selection. Further, the possible post-firing or post-depositional alteration or formation of new carbonate components is often not taken into account in the previous chemical studies on prehistoric pottery. Such a miscalculation led Hung (2011) to interpret analcime, which possibly formed due to underground weathering, as tempering material used in production. Chemical data on the environment of the burial context of the pottery analysed by Hung (2011) is required to approach this issue.

The present study suggests that to investigate the role of calcium in raw material provenance, it would be beneficial to include experimental pottery making from geological samples with further chemical comparative studies of geological clays and prehistoric pottery. Experimental firing has proven to be an effective method of preliminary assessment of calcium content in clay which would have potentially affected the technological choices in prehistory due to the degree of visible lime spalling after firing. The comparison between the experimentally fired samples and prehistoric pottery would need to happen under the consideration of the factor of post-depositional contamination, which would have potentially contributed to a higher calcium content in the sample. Such a comparison would allow one to address follow-up questions such as whether the purification of clay was possible to reduce the calcium content raised by Ma (2000:46-47). To this author's knowledge there were no previous firing experiments on clay from the

study area to specifically observe its post-firing behaviour. Li (1984) published a research paper about replicating Majiayao-style pottery. He collected raw clay next to the Yellow River riverbed (Li 1984:54) and described the making and decorating process but did not describe his firing techniques. It can be assumed though that most of his firings were successful since he published a research paper on the making process. Unfortunately, it was not possible to conduct chemical analyses on the geological samples in the present study due to the COVID-19 pandemic, but this will be considered for a future project.

Petrography as one of the main analytical techniques for investigating pottery making was applied by Womack (2017; et al. 2019). He analysed 273 thin sections of sherds from three sites in the Tao River Valley (Dibaping 地巴坪遗址, Dayatou 大崖头遗址 and Siwashan 寺洼山遗址) to assess the diversity in paste mixing of both styles and to find indicators of change or continuity in Neolithic and Bronze Age technologies within his study area. Womack (2017:79) considered the variation in paste recipes as indicators of different local production groups. He proposed a hypothesis that a production group would use similar paste recipes to produce a specific type of vessel; different pastes identified in a single vessel type would indicate different production groups making pottery in the same shape (Womack 2017:90). As result of his study, Womack identified diversity in coarse fabrics and less diverse fine fabrics. He associated the varying coarse pastes with being made by different production groups and the similar fine fabrics by one single production group (Womack 2017:214). His connection of paste diversity to the existence of multiple production groups led him to the conclusion that there was a higher demand in coarse pottery and that multiple producers were engaged in production and potentially exported pottery to other sites (Womack 2017:214-

215). Nevertheless, the coarse fabrics identified by Womack are similar in composition with constant feldspar and quartz inclusions, and vary only slightly in other predominant inclusions, as he himself explained (Womack 2017:137). Womack constructed his argument around the differences in amounts of matrix, silt and sand in the fabrics, which vary in fabrics. However, there could be several reasons, including wedging/kneading, for the different distribution of particles and homogeneity in the fabric. A thin section is but a snapshot of a vessel fabric and may not show the average amount of all its components within. Therefore, an overly detailed assessment of fabric components might be counterproductive for studying clay recipes. A general description of textures and types of large inclusions could be more helpful in this case and for addressing provenance, especially in comparison with geological samples.

Womack's study of raw materials included collecting geological clay and rock samples within a radius of 2 km in his study area. Although he concluded, based on comparison with archaeological ceramics, that the sampled clay was likely used by prehistoric potters (Womack 2017:138, 208), he compared pottery fabrics to the fabrics of unfired geological samples which could complicate the interpretation of paste preparation. Unfired clay samples contain organic material and other impurities which combust or alter during firing but could be detectable in the thin section of a raw sample. Prior to firing, the pottery clay likely underwent some processing such as crushing, purification by sedimentation or levigation, which separated coarse grains and large pieces of unwanted material (e. g. small sticks, grass etc.) from the clay material, and wedging to homogenise the paste. All these steps contribute to the change of the groundmass texture which would end up looking different from the groundmass of the unprocessed and unfired raw

material. Details of Womack's research results will be further discussed in the interpretation of petrographic data regarding the issues of tempering and clay mixing in Chapter 5 of the present study.

A potential existence of multiple production groups as proposed by Womack (2017) could be an indicator for potter networks which could then provide a basis for long-distance technological knowledge exchange. In a subsequent petrographic investigation of clay recipes within the same study area Womack et al. (2019a:11, 13) concluded that the paste preparation did not change in the transition from Majiayao style to Qijia style (4100-3600 cal yr BP), contrasting with the change in vessel shape and decoration. Womack et. al (2019a:13-14) demonstrated that the knowledge of Majiayao-style was shared between generations within a small geographical area (25 km radius), despite changes in visual features over hundreds of years.

The present study follows Hung (2011) in covering a large study area to investigate connectivity in prehistory through Majiayao-style pottery distribution and it follows Yu et al. (2017) and Womack (2017) in applying petrography together with studies of geological material to investigate the technological choices in pottery production. The following Chapter 3 focuses on the questions addressed by this combined approach and discusses the theoretical framework for investigating technological transfer in prehistory.

3 Research questions and theoretical background

3.1 Research questions

Womack (2017; Womack et al. 2019a) showed that there was a potential temporal transfer of pottery making knowledge from the Neolithic to the Bronze Age within a confined geographical area in the Tao River Valley. The present study investigates the possibility of a spatial technological knowledge transfer, i. e. from one place to another, within a large geographical area during the Neolithic focusing only on the Majiayao-style pottery. There are two questions about pottery technology which need to first be investigated in order to address the issue of technology transfer:

- 1) Are there evident similarities in the technological features of the pottery, such as paste recipe or building technique, as there are in its outer appearance, such as shape and decoration?
- 2) Is there a specific technology or technological sequence that characterises the Majiayao style?

After these questions are investigated, there are two possible ways in which the study could proceed. First, if there are similarities in pottery making technology, then the study will address the degree of communication and connectivity of the people in the study area during the Neolithic: how and by whom was the technological knowledge shared? Alternatively, if there are no similarities in the pottery from different areas beside the outer appearance, then the investigation will focus on the different ways of making pottery in Majiayao-style in different valleys: how did the potters choose the resources to produce similar results? What could be possible reasons for such a wide distribution and people's preference for the Majiayao-style pottery?

Investigation of a spatial distribution of knowledge implies that the people who shared this knowledge lived contemporaneously. There are no absolute dates for the archaeological remains from Majiayao, Waguanzui, Zhujiashai or Luohantang. However, Dong et al. (2020, supplement material) published a comprehensive table with radiocarbon dates⁷ of samples taken from sites in China including the northwest area. There are only sixteen sites dated to the Majiayao-period (5300-4000 cal yr BP) which are located within ca 100 km radius to the four sites in question (Table 3.1, Fig. 3.1).

Table 3.1. Sites with absolute 14C dates within a radius of ca 100 km of the study area (after Dong et al. 2020).

ID	Site	14C sample amount and type	cal yr BP ⁸ 68.3% probability	Laboratory
1	Andaqiha ⁹ 安达其哈遗址, Hualong, Qinghai; at the Yellow River	5; bone collagen, charcoal, charred millet seeds	earliest: 6122-5600 latest: 5053-4826	MOE KLLU ¹⁰ , BA ¹¹
2	Benbakou, Huangzhong, Qinghai	2; charcoal and charred millet seeds	earliest: 4976-4414 latest: 4832-4522	PURL ¹² , MOE KLLU
3	Buziping, Dingxi, Gansu	8; charcoal and charred millet seeds	earliest: 4971-4825 latest: 4092-3623	PURL, MOE KLLU
4	Caojiazui 曹家嘴遗址 Gaolan, Lanzhou, Gansu	1; charcoal	5325-4800	IA CASS ¹³
5	Changning 长宁遗址, Datong, Qinghai	10; bulk organic matter, charcoal, wood, barley	earliest: 6004-5657 latest: 3932-3824	MOE KLLU
6	Gaoquding, Guinan, Qinghai; at the Yellow River	2; charcoal	earliest: 4444-3680 latest: 4522-3447	PURL
7	Linjia 林家遗址, Dongxiang, Gansu	3; charcoal, charred millet seeds	earliest: 5485-4855 latest: 4873-4290	IA CASS

⁷ Acquired through conventional method and accelerated mass spectrometry (AMS).

⁸ calibrated using raw data provided by Dong et al. (2020) with OxCal by the author; <https://c14.arch.ox.ac.uk/oxcal/OxCal.html>

⁹ A Neolithic downdraft kiln structure was found on this site (Zhongguo Ciwang 2020).

¹⁰ MOE Key Laboratory of Lanzhou University.

¹¹ Beta Analytic

¹² Peking University Radiocarbon Laboratory

¹³ Institute of Archaeology, Chinese Academy of Social Sciences

8	Liuwan 柳湾墓地, Ledu, Qinghai; at the Huangshui River	8; wood	earliest: 4849-3889 latest: 4292-3338	IA CASS, PURL
9	Luowalinchang, Jianzha, Qinghai	3; charcoal	earliest: 5475-4960 latest: 4838-4291	MOE KLLU
10	Maniwan, Qinghai, Guinan	1; charcoal	4859-4149	IA CASS
11	Ping anxincun, Qinghai, Ping'an; at the Huangshui River	2; charcoal, charred millet seeds	earliest: 5049-4519 latest: 4525-4403	PURL, MOE KLLU
12	Qinggangcha, Lanzhou, Gansu	5; charcoal and charred wood	earliest: 4875-4148 latest: 4843-3618	IA CASS, PURL
13	Shangduoba 上多巴 遗址, Hualong, Qinghai; at the Yellow River	2; charcoal, charred millet seeds	earliest: 5322-4578 latest: 4734-4349	PURL, MOE KLLU
14	Shangsihesheng 上 四合省遗址, Hualong, Qinghai; at the Yellow River	1; charcoal	4830-4145	MOE KLLU
15	Shangsunjiazhai 上 孙家寨遗址, Datong, Qinghai	6; charcoal, wood	earliest: 5323-4511 latest: 2750-2310	PURL
16	Shannashuzha, Minxian, Gansu; at the Tao River	4; charcoal, bone collagen	earliest: 5319-4968 latest: 2880-2422	IA CASS, MOE KLLU

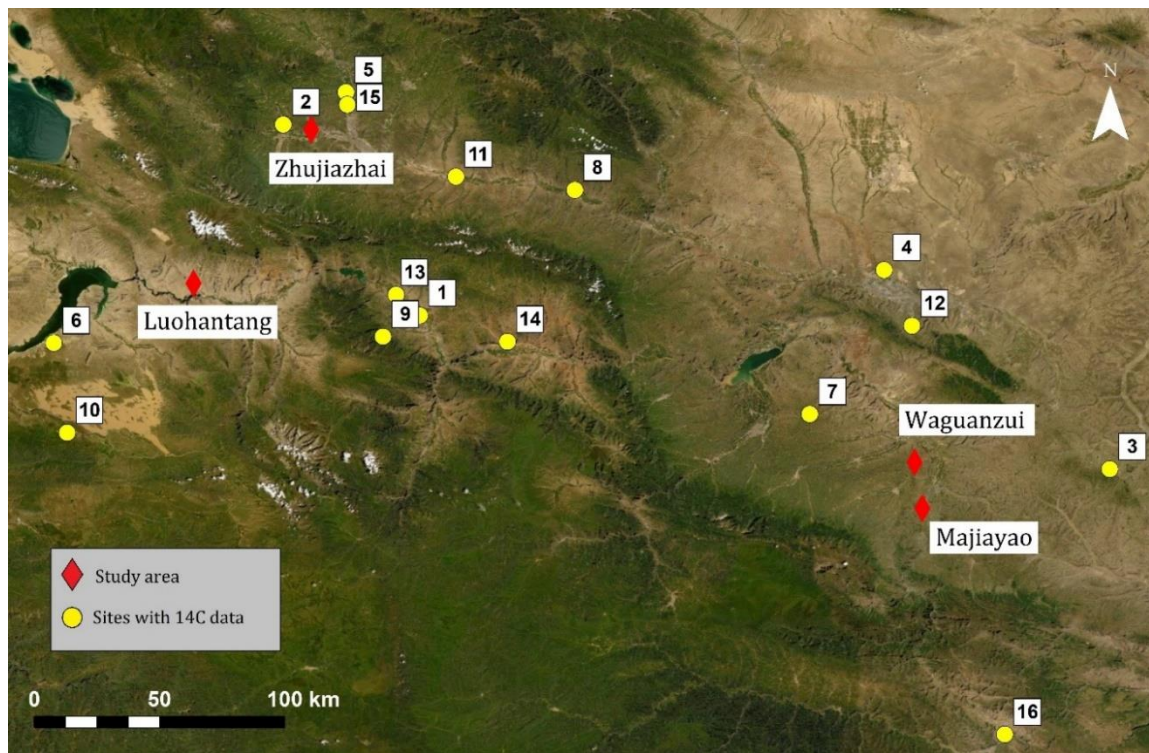


Fig. 3.1. Sites (yellow dots) with absolute 14C dates located within a radius of 100 km to the study area; for ID Number key see Table 3. 1.

There are a few sites with absolute dates attributed to the Majiayao-period in proximity of each site in the target area which might indicate their contemporaneous occupation. However, the reliability of the radiocarbon dating in northwest China is questionable due to difficulties with the dating of wood of an unidentified type (cf. old-wood problem discussed by Dong et al. 2014) and might be inaccurate in some cases. There are many more sites in the study area where Majiayao-style pottery was found (Figs 2.1-2), and the relative chronology established by stratigraphy and typological classification of pottery remains the most reliable dating information for the study area for now. In this case, the present study must rely on relative chronology and assume that people's activity using/producing Majiayao-style pottery at Majiayao, Waguangzui, Luohantang, and Zhujiashai fell approximately in the same period. Pottery making techniques tend not to change over several generations in contrast to the outer appearance of the vessels (Roux and Courty 2019:311). The reluctance to change the technology

might have been the case with the transition from Majiayao to Qijia pottery styles, which according to Womack's analysis the paste recipes did not undergo a significant change, though vessel design and decoration did change markedly.

Long-established paste recipes suggest that there might be more identifiable evidence for different established techniques such as forming, surface treatment, and firing. Together these techniques could form a technological action sequence to make pottery – *chaîne opératoire* – which could then be passed on as technological knowledge within generations or shared within a geographical area (Gosselain 1998:94). To investigate whether such action sequences to make Majiayao-style pottery existed, the present study follows the approach of *chaîne opératoire* and analyses the technological choices made by potters based on prehistoric pottery samples.

3.2 *Chaîne opératoire* and technological choices

Chaîne opératoire is a concept created by archaeologists and anthropologists to study stone tool production and was further developed by ethnographers to describe material and non-material actions in craft production (Leroi-Gourhan 1943, 1945, 1964; Mauss 1968; Cresswell 1972; Lemonnier 1976, 1986, 2002, 2010; Schiffer and Skibo 1987, 1997). In ceramic analysis this concept includes the general stages of raw material procurement, vessel forming, surface treatment, decoration, and firing, and investigates the technological choices made at each stage which can reveal a variety of different approaches to pottery making in different areas (Lemonnier 1976:106; Cresswell 2010:26; Roux 2017:103). Identifying and discussing the technological choices means to investigate the alternatives and options of materials and techniques available for making a pottery

vessel (Lemonnier 1976:109; 1983:54; 1986:153; Schiffer & Skibo 1997:31; Rice 2015:212). However, it is not possible to identify all the options available to the prehistoric potter, only those which led to creating the object which became the archaeological artefact (Rice 2015:213). The present study approaches this issue by including geological sampling and assessing the variety of clays and potential tempering material available in the study area. Analysing a high number of samples or artefacts can help uncover the extent of the repertoire of materials and techniques available to the potters in a study area (Gosselain 2011:216).

Technological choices are made at every stage of the production process: raw materials, tools, techniques, and energy invested into material procurement, performing the techniques, and the order of the steps in the operational sequence (Sillar and Tite 2000:4). The raw materials include clay, temper, water, pigments, fuel (Sillar and Tite 2000:4). The types of tools range from the potter's hands to wheels, beaters, scrapers, brushes, to kilns and workshop facilities (Sillar and Tite 2000:4). Techniques include actions from raw material procurement to the making of the final product (Sillar and Tite 2000:4). Energy sources are, for instance, animal or waterpower for grinding the raw material, solar power for drying, fuel for firing and the potter's own energy investment in the activities (Sillar and Tite 2000:4). If the choices a potter makes at every stage are the same or similar for making each vessel, then they might form a routine technological sequence (*chaîne opératoire*) which is repeated every time a new vessel is made and can be taught to an apprentice or shared with another potter.

Sillar and Tite (2000:4-9; Tite 1999:223) argued that technological choices are determined, on the one hand by the properties of the materials available to a potter, and on the other hand by societal norms of the community to which this

potter belongs. Sillar and Tite (2000:4) summarised the factors of a potter's social environment and economic situation that play a role in the manufacturing process under "cultural context" next to the practical technical considerations. These factors might be certain customs and ways of interacting with the environment which are dictated by the way of life of the community a potter lives in and not necessarily contributing to making the best technological choices from a practical perspective. Other scholars have also noted the connection between the technological process and cultural context (e. g. Sackett 1990:33, Lemonnier 1986, 1993:26; Gosselain and Livingstone Smith 1995:158; Gosselain 2011:215). However, the influence of social or economic factors cannot be easily observed in the archaeological record of the Majiayao-style pottery. Investigating the *chaîne opératoire* can help uncover potential factors which impacted the potters' work during the Majiayao-period and provide a point of departure to study other aspects of prehistoric life.

The connection between technology and social background has mainly been highlighted by ethnographic studies where the technological practices of a living community are investigated by direct observation and through conversation with potters, which is not possible in archaeology (Gosselain 1998:83). Ethnographic research includes working with groups of people who express a sense of community through the same customs, language and ethnicity, which facilitates the identification of characteristics of this community and comparison to other groups (Dietler and Herbich 1994; Gosselain 1998). It is not known whether the prehistoric people who produced and used the Majiayao-style pottery expressed a sense of community through this pottery, although it is implied in Chinese

archaeology based on the culture-historical approach (Andersson 1925:22-23, Yan Wenming 1978; Chen and Fiskesjö 2014; Hein 2019).

Archaeology integrates the insights from ethnographic studies of *chaîne opératoire* and technological choices to interpret the information about ancient technology, which is mainly investigated through material science. The application of analytical methods from material science to the study of pottery structure and composition allows for an in-depth investigation of raw materials and making techniques (Tite 1999:182). Studies of archaeological pottery focused on the materials and pottery technology include the examination of samples on a macroscopic and microscopic level (Shepard 1985; Rice 2015). Questions concerning the provenance of raw materials and firing are addressed through chemical (Pollard and Heron 2008) and petrographic analyses (Reedy 2008; Quinn 2013). Petrographic analysis can additionally provide insight into clay recipes and the choice of materials which influence the physical properties of pottery. Experimental construction and the firing of ancient pottery shapes provides a sense of the amount of materials, energy and tools involved in making a vessel (Roux 1994; Courty and Roux 1995; Roux and Courty 1998; 2019; Martineau 2000; Hammersmith 2010). Experiments can be of further help in provenance studies by focusing on testing the properties of available raw material in a study area (Gauß and Kiriatzi 2011:78-79). All these methods generate data which is then interpreted by the researcher while also taking into account the archaeological context and the initial research question. Relying on only one method of analysis may bear a risk of not addressing all points of a research issue and limiting the interpretation of data. Scientific pottery analysis works best when multiple techniques are combined to address one or a set of research questions about pottery production (Rice 2015:291). Different

methods can provide data for making inferences about various aspects of prehistoric technological knowledge.

3.3 Technological knowledge

Technological knowledge does not only consist of step-by-step instructions on how to make an object. Schiffer and Skibo (1987:597) called such instructions “recipes for action” which specify the raw materials, tools and facilities and describe the actions and rules of the technological process. According to the authors, these recipes for action are subjective reconstructions made by a researcher based on archaeological material and the technological process might have been different in prehistory (Schiffer and Skibo 1987:597). Following Schiffer and Skibo’s concept (1987:597), technological knowledge further includes techno-science and teaching frameworks. Techno-science is comprised of the experience acquired through experimentation and trials of techniques or tools until the outcome is satisfactory (Schiffer and Skibo 1987:597). By testing different raw materials, tools, and firing temperature, potters become familiar with the resources available in their environment, gaining experience in pyrotechnology along with calculating proportions for raw materials and fuel.

Strategies for transmission and preservation of the recipes for action as well as for gaining experience in techno-science can be employed within teaching frameworks. There are different ways of teaching crafts but most of them rely on practice and hands-on working with the material (Schiffer and Skibo 1987:597). By sharing their own experience and letting students learn by doing, the masters of a craft transmit the know-how which is required to successfully follow recipes for actions. Verbal communication is a part of teaching and would presumably include technical vocabulary (Bender Jørgensen 2012:93; Gosselain 2018:17). Technical

vocabulary could be an independent subject of study which would result from an investigation of knowledge transfer in order to study the development of language in a geographical area where knowledge transfer potentially took place (Arnold 1981:38-39). Teaching frameworks are further discussed in the next section as a scenario of long-term close contact essential for successful knowledge transfer.

3.3.1 Transmission of technological knowledge

Why is the transfer or transmission of technological knowledge in prehistory worth exploring? Transfer and transmission are synonyms that mean to pass something on or to carry something from one place to another.¹⁴ Transfer can imply communication if information is passed on. It can also imply physical movement if people or objects are transferred between places. In the context of a transfer of knowledge over far distances, it needs to involve both communication and movement. Pottery is sometimes the only evidence of prehistoric people's activity in an area. Identifying pottery techniques and investigating the transmission of technological knowledge is a means to shed light on the level of connectivity between sites, movement of people and social structure (Roux and Courty 2019:312). Furthermore, insights into the techno-science gained through this study contribute to understanding how the prehistoric potters engaged with their local environment. Did they have extensive geographical and geological knowledge in order to select specific materials or did they work with materials available in close proximity without apparent preference?

Technological transfer, as defined in this study, does not mean an exact copy and application of all steps in the recipes for action. It is rather an adaptation of shared techniques to work with locally available raw material (Gosselain 2000:206;

¹⁴ According to the definition provided by the Oxford dictionary (OED Online 2021).

Nikolakopoulou and Knappett 2016:109). It is different from imitation where it is possible for a potter to replicate the visible features after seeing pottery by using their own tools and technical knowledge (Gosselain 2018:12; Czekaj-Zastawny et al. 2017:90). In prehistory, imitation of visual pottery traits is not uncommon. Kohring (2011) studied Bell Beaker pottery found in the San Blas region (Spain) and which was produced in many places and widely distributed across Europe. Kohring (2011:159-160) concluded that in her study area the Bell Beaker pottery was produced using local techniques, only modifying the steps in surface treatment and decoration to copy the visual appearance. Kohring (2011:155, 157) argued that while the *chaîne opératoire* used by potters in San Blas broadly resembled the technology for making Bell Beaker pottery, steps such as clay preparation and firing were different and done according to local practice. This insight revealed that the appropriate social knowledge required for the recognition and usage of the Bell Beaker was more important than following a specific technological sequence to make this pottery (Kohring 2011:159-160).

Could specific social knowledge be the main factor in the wide distribution of Majiayao-style pottery? Hung (2011:6, 225, 236) argued that painted Majiayao pottery was used for displaying the wealth and prestige of elite social class since it was found in high quantities in graves over a large geographical area. As discussed in the previous chapter, Hung (2011:70, 107, 232) argued that painted Majiayao pottery was produced for inter-regional exchange and unpainted coarse pottery was produced locally. However, only in a few cases did Hung specify that unpainted pottery was decorated with cord-impression and appliqué, which is in accordance with Majiayao-style. The question would then be: if only painted pottery of this style was subject to inter-regional exchange, why was the unpainted

pottery of the same style produced locally in remote places which imported the painted pottery? Why would potters in different locations over a large area produce coarse pottery and decorate it in similar ways when only the painted pots were socially significant for displaying wealth? The limitations of Hung's (2011) analysis have been discussed in section 2.3. She argued that the production of fine painted Majiayao-style pottery might have never developed in her study area in Sichuan because the CaO and MgO content of painted ware from Sichuan match the CaO and MgO data of her samples from Gansu (Hung 2011:71). Investigating the transfer of making technology of pottery in both types of wares might shed some light on this issue and challenge previous assumptions on the social meaning of the Majiayao-style pottery.

The transfer of pottery making technologies has been widely studied in Aegean prehistoric archaeology (e. g. Badre et al 2005; Kiriati 2010; Kiriati and Knappett 2016). Kiriati (2010:685) studied two classes of Minoanising pottery which were produced in different regions of the Aegean and showed similarities in shapes, making techniques and paste recipes with the *chaîne opératoire* at the original production place of the Minoan pottery – Bronze Age Crete. As these pottery classes are more frequent on the coastal sites in the different regions than in inland (Kiriati 2010:686), Kiriati (2010:692) argued that the occurrence of these Minoan pottery classes together with technological knowledge is evidence for Cretan potters moving and settling elsewhere in the Aegean and continuing practising their craft and adapting to the new geological environment. Further, Kiriati (2010:693) showed that the local potters from the island of Kythera developed similar techniques for using the potters' wheel as the Cretan potters who settled there. Before the appearance of the Minoanising pottery, there was no

wheel-made pottery on Kythera, so that the production of Minoanising pottery serves as evidence for the introduction of a new forming technique and a new tool: the wheel (Dr E. Kiriati pers. comm.) This observation of shared technological knowledge in wheel usage indicates close communication between potters on Kythera and the potters on Crete, as this type of technique cannot be learned from mere visual examination of the finished product (Kiriati 2010:693).

Attention to detail in the macroscopic study of construction techniques which were known in different parts of the world in prehistory can be crucial to identifying different ways of their application characteristic for different *chaînes opératoires* (Gosselain 2018:21). In the case of Majiayao-style pottery, these techniques are coiling, beating, and using a turntable. By investigating differences in the application of these techniques on pottery from different sites could shed light on the possible existence of local specifics in construction. The observation made by Kiriati (2010) about technological transfer happening mostly on the coastal sites is interesting in the context of the settlement pattern of people during the Majiayao-period in the study area. Numerous sites, including Majiayao, Waguanzui, Zhujiazhai and Luohantang, are located along the rivers and scattered within river valleys (Figs 2.1-2). Transportation by water could have contributed to the travel of potters and dissemination of technological knowledge, similarly to the case of Cretan potters in the Aegean Bronze Age.

In her studies on the spreading of the potter's wheel in the Bronze Age northern and southern Levante, Roux (2013:325, 2015) argued that first, this technological innovation was only able to spread when pottery production became a specialised craft and a part of social structure as potters became an established social group. Second, transmission of technology did not occur through general contact (e. g.

trade, politics) between different communities or through the increasing demand for certain types of ceramic vessels (Roux 2015:83). Instead, Roux (2015:83; 2013:316) argued that the dissemination of technological knowledge happened mainly through the potters, the carriers of this knowledge, who were moving their locations and expanding their workshops. It is unlikely that two distinct communities would borrow or adopt entire technical systems from each other if they already had their own technology in the first place (Roux 2013:317-18). More probable is the integration of single techniques into an already established *chaîne opératoire* of a potter or potting community (Roux 2015:71). In contrast to Roux's hypotheses, the study by Kiriati (2010) on re-settled Cretan potters has shown that it is possible for an entire technical system of wheel production of one community to be adopted by another. However, also in this case, as it is in the case studies discussed by Roux (2013, 2015) the knowledge transfer required experienced potters to initiate the introduction of new tools and techniques.

If technological knowledge is more likely to be shared through experienced potters, what is required for a transfer to take place? The following sub-section focuses on the ways potters could have shared their craft with other potters.

3.3.2 Potter networks as a means to transmit technological knowledge

Many scholars argue that technological or practical knowledge is shared through long-term personal contact (e. g. Schiffer and Skibo 1987; Petrequin 1993; Gosselain 1998, 2000; Pollock 2013; Schier 2013; Kiriati 2010; Gauß et al. 2015; Lis et al. 2015). It is invisible knowledge that cannot be acquired just by observing the objects (Petrequin 1993:69; Lis et al. 2015:63). Gauß et al. (2015:8) and Lis et al. (2015:63) referred to Gosselain's (1998, 2000) ethnographic research in Sub-Saharan Africa and argued that certain making steps are easier to observe and

imitate within local tradition, such as the surface finish and the type of decoration. Whereas steps that do not leave traces on the surface cannot be adopted without specific knowledge. Schier (2013:6) and Lis et al. (2015:63-64) argued that knowledge transfer in the past is connected to personal contact and presupposes individual travel of the knowledge carrier or someone who wishes to acquire it, which means that the distribution of pottery alone through trade and exchange cannot ensure successful sharing of technologies.

A typical way to transmit technological or any other type of knowledge is by creating a teaching framework. Technological knowledge cannot be acquired without practice and requires long-term direct contact between the carrier and receiver (Schiffer and Skibo 1987:597; Crown 2001:456; 2014:73; Gosselain 2018:11), therefore, in pottery production craft, learning through apprenticeship is the most common teaching framework. An apprenticeship provides practical experience and intensive engagement in all stages of pottery making from raw material procurement to firing. Ethnographic studies have demonstrated that supervised long-term practice in the same place might be required for the knowledge to be absorbed, the actions to become routine and to develop an understanding for the technological process (Gosselain 1998:94; Gosselain and Livingstone Smith 2005; Livingstone Smith 2000; Pollock 2013:97). Long-term apprenticeship is an opportunity not only to learn techniques and recipes for action but also to acquire knowledge and experience in techno-science. It can take at least ten or fifteen years to achieve the master level (Crown 2014:73). The technical skills and mechanisms of potting which are learnt during a long-term apprenticeship can be difficult to change (Roux 2015:70), thus apprenticeship is also a way to long-term knowledge preservation.

Potters who regularly practiced their craft could have kept in contact with other potters in their area and exchanged information regarding techniques or materials. Similar to Roux (2013, 2015), studies on pottery technology transfer in prehistory by Wright (2001) and in modern time by Gosselain (2016) have concluded that specialised potters are the main driving force behind the spread of tools, technologies and technological knowledge. Wright (2001:134-135) argued that similarly looking pottery found in distant areas of ancient Uruk does not necessarily imply shared cultural traits but is a result of close contact between specialised potters. The widely distributed pottery types in Uruk were not made in households but in specific areas in larger settlements (Wright 2001:134) which enabled network establishment and communication. In places with specialised pottery production in modern era, potting centres are in contact with each other and contribute to the distribution of the technological knowledge and sharing of techniques (Gosselain 2016:292).

The duration of contact between specialised potters is different from that of an apprenticeship. Specialised potters from different workshops may not necessarily interact on a daily basis like master and apprentice do. Potters could use kiln sites outside of settlements as meeting points within their firing schedules or workshops inside settlements if they are established craftspeople (Crown 2007:677-679; Gosselain 2018:9). Could potter networks have existed between potters who produced Majiayao-style pottery? There is evidence of two larger kiln sites (more than 10 kilns) with tools found in the same context near the Tao River Valley (Gansusheng Bowuguan 1957:5; 1960:16; 1983:21). These are only a few considering the amount of pottery being excavated. Further, it is not known if and

how much pottery was produced at or near the sites in question in the three river valleys to discuss whether specialised potters might have practiced there.

3.4 Transmission of technological knowledge in Neolithic China

Studies of Majiayao and other Neolithic pottery styles found in China are dominated by typological analysis (Chen and Fiskesjö 2014; Hein 2016). In connection with stratigraphy, typological analysis provides helpful relative chronological frameworks for addressing further archaeological questions. Archaeological ceramic typologies present the repertoire of pottery shapes used by prehistoric people; however, the classification reflects the subjective view of the archaeologist or art historian and the vessels may not have been perceived as belonging to the same type by prehistoric people who made and used them (Rice 2015:227-228). Detailed analysis of shapes and sizes of prehistoric pottery indicates their possible usage: storage, eating, drinking, cooking, pouring, etc. In this sense, typology reveals more about people who used the pottery and where they used it (the spatial distribution) than about the people who made it.

The analysis of technology and the reconstruction of the *chaîne opératoire* provide the perspective of the people who produced the pottery, complementary to the typological analysis. It allows a glimpse into people's actions that led to the finished vessel. It is worth investigating whether the spatial distribution of Majiayao-style pottery is related to the distribution of technological knowledge on how to make. This consideration may contribute to the study of the sense of community between the potters and possibly the pottery users.

Previous technological studies on Majiayao-style pottery have shown potential for the further study of knowledge transfer and potter communication. The production of this pottery consisted of distinct fabric textures and the employment

of different construction techniques as concluded by Palmgren (1934), Wu (1938), Bylin-Althin (1946) and Vandiver (1988). The vessels were fired under relatively consistent firing temperature as investigated by Ma and Li (1991). This pottery style includes two completely different decoration techniques which require different tools and possibly different skills. Recent analyses by Hung (2011) and Womack (2017; Womack et al. 2019a) have demonstrated that there was consistency in raw material choice and paste recipes over a wide period. All these aspects indicate that potters of the Majiayao-period possessed knowledge of techno-science and employed specific techniques to create high quantities of pottery in a consistent Majiayao style.

4 Material and Methods

This chapter is divided into four parts. The first part discusses the research material which consists of complete vessels and sherds of the Majiayao style and of the geological samples including clay, sand and rocks. A description of the archaeological sites from where the analysed material was collected is provided in a sub-section within the discussion of pottery material. The second part discusses the method of macroscopic analysis conducted on pottery and geological material. The third part discusses the procedure of the petrographic study as well as the criteria for petrographic grouping. The fourth part includes the description of the geological setting in each river valley and the description of geological sampling. The firing experiment including the processing of clay is described at the end of part four.

4.1 Material

4.1.1 Pottery

The prehistoric pottery analysed in this study comes from the collections held at the Museum of Far Eastern Antiquities (MFEA) in Stockholm, the British Museum (BM) in London, and the Ashmolean Museum in Oxford. The invasive sampling of sherds for petrographic analysis was done on the pottery from the Museum of Far Eastern Antiquities within the Andersson Prehistoric Pottery Analysis project run by Dr Anke Hein from the University of Oxford and Dr Ole Stilborg from Stockholm University. It was not possible to sample pottery from the recent excavations in China as the material is still undergoing post-excavation processing. The determination of the study area (Fig. 4.1) equally depended on the availability of the material for invasive and non-invasive study, as well as on the sites' location

regarding their potential for the study of knowledge transmission over far distances.

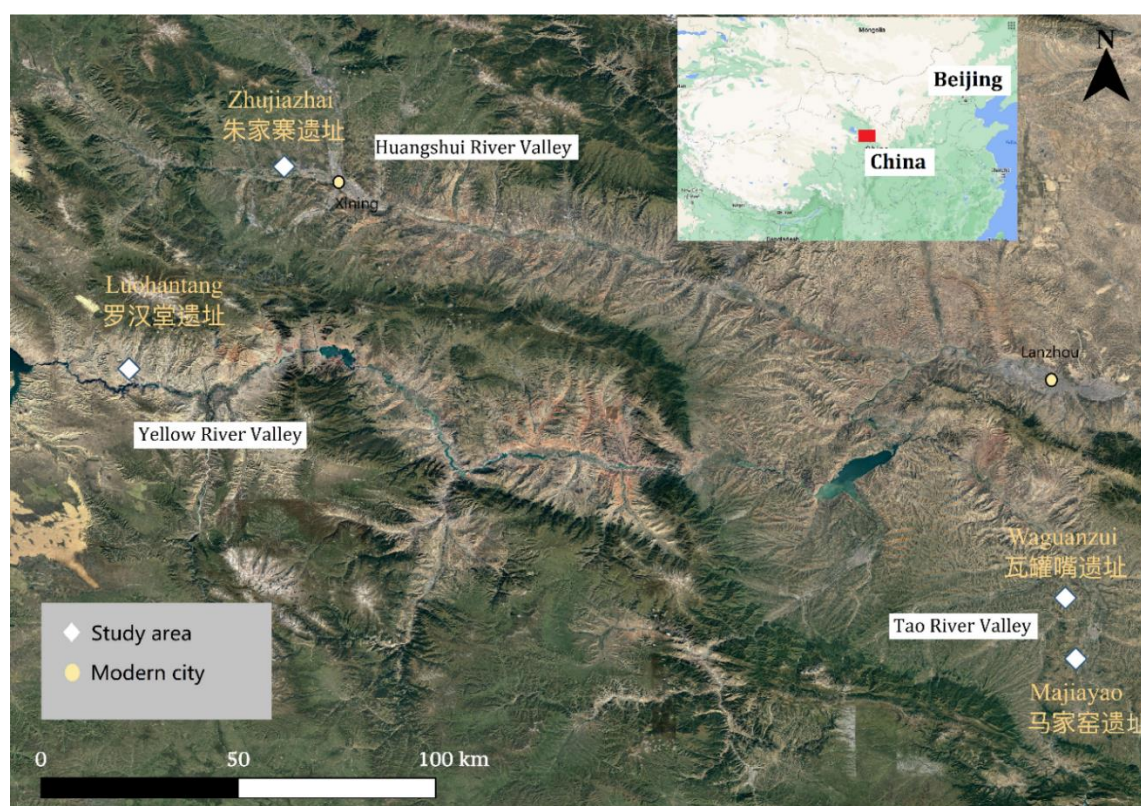


Fig. 4.1. Map of the study area (red rectangle on the map of China in the upper right corner).

4.1.1.1 Complete vessels

Fifty-two complete painted vessels and vessels with impressed decoration were macroscopically analysed for this study (Table 4.1).¹⁵ Most of the vessels kept in the collections outside China lack exact provenance to a specific archaeological context, though in some cases the broad region, river valley, or site is known. The provenance of the vessels bought by Andersson in the Tao River Valley and then traced back by him to the general excavation area can be regarded as generally correct and is the only link between the finds and the find locations. These vessels were analysed macroscopically with the purpose to identify marks from the shaping process and surface treatment. Preference was given to large globular jars

¹⁵ The full vessel list with information about their provenance and current location can be found in the Annex 1.

with wide or narrow openings because such vessels offer more surface area than smaller vessels for analysing construction techniques, and therefore a higher chance to detect tool marks.

Table 4.1. Number and provenance of the vessels analysed in the present study.

Number of complete vessels	Provenance	Painted / Impressed decoration
35	Sites in the Tao River Valley (including Majiayao and Waguanzui)	33 painted and 2 impressed
9	Zhujiashai	7 painted; 2 impressed
1	Luohantang	1 impressed
7	unknown, possibly Tao River Valley	7 painted
Total: 52		Total: 47 painted; 5 impressed

The difference in numbers between the studied painted vessels and vessels with impressed decoration (Table 4.1) is due to the fact that there were no more complete vessels with impressed decoration either existing in the collection or available for a closer macroscopic study because they were on permanent display.

4.1.1.2 Pottery sherds

The sampled pottery sherds come from both habitation and burial archaeological contexts. 187 sherds were selected for destructive sampling (Table 4.2). In the case of sherds from burials, the exact context is known. For sherds from habitation sites, only the site is known but material excavated by Andersson was not kept separate by archaeological layer. For the sherds excavated from Zhujiashai, the find context is clearly stated for only some of them. In the archaeological report by Andersson, as provided by the MFEA Online Database,¹⁶ the find context is summarised as

¹⁶ <https://collections.smvk.se/carlotta-om/web>

“sherds from graves and settlement area”. Therefore, a clear comparative study between the pottery fabrics from habitation and graves is not possible.

Each sampled sherd was given a code name CNP “Chinese Neolithic Pottery” and a number from 1 to 187. The selection strategy was to include an equal number of fine and coarse fabrics, as well as sherds with different exterior decoration and colour indicating firing in different atmospheres.

Table 4.2. Number and provenance of sherds sampled for the present study.

Site	Number of sherds
Majiayao (马家窑遗址) habitation; Tao River Valley	71
Waguanzui (瓦罐嘴遗址), burial; Tao River Valley	9
Zhujiashai (朱家寨遗址), habitation and burial; Huangshui River Valley	52
Luohantang (罗汉堂遗址), habitation; Yellow River Valley	55
	Total: 187

Only nine sherds were sampled from the material from Waguanzui because the number of collected sherds from this site was very small. Waguanzui was included in this study for three reasons. First, ten of the complete vessels analysed in this study come from this site. Second, the intent was to investigate whether burial ceramics were petrographically different from the sherds found on the Majiayao habitation site. Third, this site was described by Andersson (1943:116) as the largest burial complex on the Banshan hills and was documented in his publications. In short, in contrast to the several other burials found by Andersson on the Banshan hills, Waguanzui included both vessels and sherds which were available for analysis, as well as documentation of the site area.

A larger number of samples was taken from the Majiayao assemblage than from the other sites because Majiayao is the type-site for this pottery style and the intent was to assess a greater variety of samples from there.

Besides the study of sherds in museum collections, further macroscopic study of the Majiayao-style pottery was possible when this author took part in the post-excavation laboratory work at the Tao River Archaeological Project (TRAP) run by Prof. Rowan Flad from Harvard University in collaboration with the Gansu Provincial Institute of Archaeology and Beijing University.¹⁷ The Majiayao-style sherds excavated during TRAP campaigns come from Dayatou which is located north of the Majiayao site and Siwashan which is situated south of Majiayao. Important insights into the variety of ceramic fabrics and decoration were gained by visiting the archaeological workstation in Lintao 临洮, where the pottery from the latest excavations at Majiayao is kept. Due to the fact that the excavations were conducted very recently (2014-2018), the pottery material has not been published yet and the study was limited to only visual assessment. The visual assessment showed that the selected fabrics of the pottery material kept at MFEA largely correspond to the fabrics of excavated material by coarseness degrees, inclusion types as well as firing atmospheres. Nevertheless, these observations have yet to be further investigated and scientifically tested by future research.

During a visit to the Liuwan Museum of Painted Pottery located in the Huangshui River Valley in 2019, this author was able to view and record information about prehistoric coarse pottery sherds found on the Liuwan burial site 柳湾墓地 (see section 5.1.2). This burial ground includes graves dating to the Neolithic as well as to the Bronze Age.

¹⁷ <https://projects.iq.harvard.edu/flad/projects>

4.1.1.3 Description and location of the sites in the study area

This section includes the background information about the four sites from where the pottery material analysed in this study was retrieved. Each description includes the first information reported by Andersson combined with available information on subsequent archaeological research conducted on these sites.

Majiayao 马家窑遗址 in the Tao River Valley, Gansu province

Coordinates: 35°18'43.6"N 103°48'15.8"E.

Majiayao is a habitation site situated on loess terraces to the west of the Tao River (Guojia Wenwuju 2011a:268; 2011b:641) (Fig. 4.2).

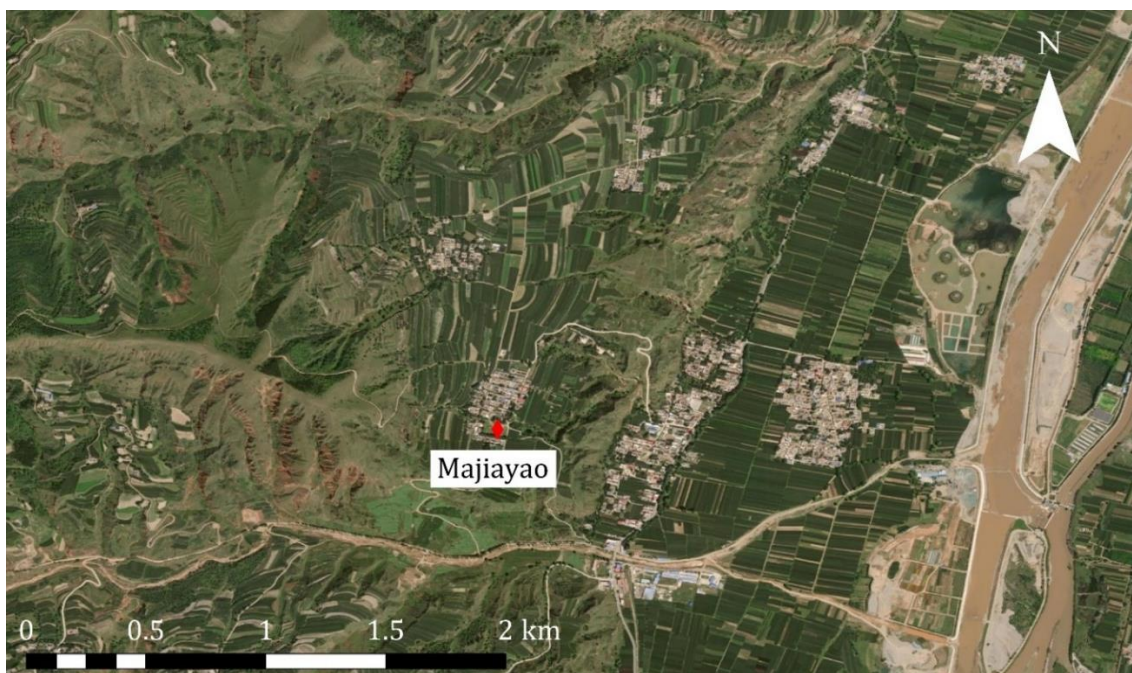


Fig. 4.2. Location of the Majiayao site.

The site was discovered and excavated in 1924 by Andersson's assistant Mr Chen, a fossil conservator (Andersson 1973:264; Fiskesjö and Chen 2004:58). He recorded an area with cultural deposit stretching over ca 350 m in EW direction (Andersson 1943:88-89). The list of objects retrieved by Chen was first published in the *Bulletin of Far Eastern Antiquities* 15 (Andersson 1943:89-97). Apart from

pottery sherds, it also includes stone tools, pendants, beads, rings, clay rings and bone artefacts.

In 1988, this site occupying area of 98.000 m² was taken under Cultural Heritage protection (Wang and Gao 2018:30). In 2012 the Gansu Provincial Institute of Cultural Relics and Archaeology carried out a large-scale survey of the site. After the survey the estimated extent of the site was over 300,000 m² (Hu 2014). First systematic excavations on the site were carried out by the Archaeological Institute of the Chinese Academy of Social Sciences Gansu Provincial Institute of Cultural Relics and Archaeology in 2014-2018. The official excavation reports have not been published yet. According to the information shared in the latest preliminary reports and newspaper articles, more than 400,000 objects including pottery vessels and sherds, stone objects, bone objects, 13 house remains (largest extended over 50 m²), 72 ash pits and seven spots covered in ash soil (Song and Lu 2015; China News 2019). No information about kiln structures has been shared so far. A few tombs with human remains have also been unearthed at this site (Li 2016), but it is not stated to which period these tombs belong to.

Waguanzui 瓦罐嘴遗址 in the Tao River Valley, Gansu province

Coordinates: 35°28'37.6"N 103°46'36.7"E (approximate location).

Waguanzui is a burial site and a part of a large Neolithic burial complex called Banshan 半山遗址 which lies west from the Tao River (Guojia Wenwuju 2011b:763, see the entry for 半山遗址). This burial complex is situated on loessal hills and Waguanzui is located on one of the hill tops (Fig. 4.3).

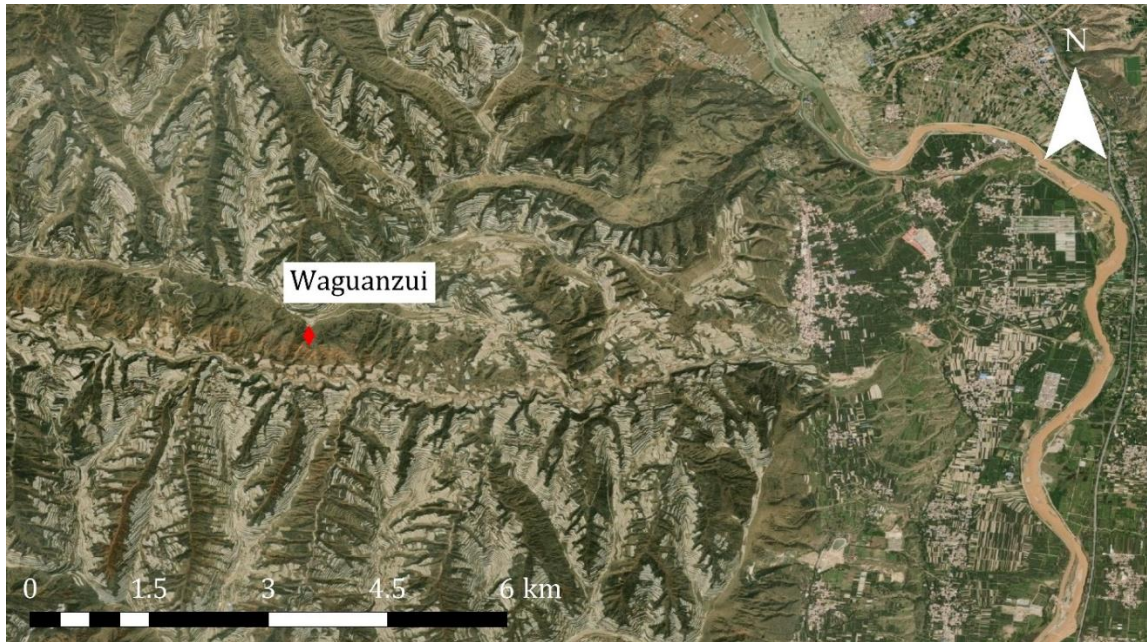


Fig. 4.3. Location of the Waguanzui site.

The hills slope towards a small river Bayanghe 八洋河 and form the ravine Bayanggou 八羊沟. In the summer of 1924, Andersson and his team excavated grave fields on the hill tops which were called Banshan 半山, Bianjiagou 边家沟, Wangjiagou 王家沟 and Waguanzui 瓦罐嘴 extending further down the slope (Andersson 1925:9-10). Andersson described Waguanzui as the largest grave field out of the four (Andersson 1943:116). Many large intact vessels from this site are kept at the MFEA today. Apart from the pottery, the graves at the Banshan complex also contained stone objects such as axes, jade rings and chisels, turquoise pendants and amazonite crystals. Andersson published a full list of Waguanzui finds (1943:119-128) but only two stone axes (K-01616, K-01619) were found in situ in the graves. Most of the identified graves were plundered. It was possible to properly excavate three skeletons but even these graves were already disturbed as noted by Andersson in retrospect (Andersson 1943:120). The majority of artefacts from Waguanzui was bought from local people. Although Andersson was quite

certain they all came from that grave field, their position and distribution in the burials is unknown (Andersson 1943:118-119).

Andersson and his team could not identify any habitation sites around Waguanzui. The artefacts retrieved from the burials indicated that the graves belong into the same period as the Neolithic settlements in the valley (Andersson 1943:132). Therefore, Andersson suggested that the Banshan burial grounds were used by the people inhabiting the sites by the Tao River, such as Majiayao. He calculated that in this case the prehistoric people would have carried their deceased for ca 22 km (aerial distance) and climbed up the hills (Andersson 1925:10; 1943:132).

Surveys in 2003 conducted by the Gansu Provincial Institute for Cultural Relics and Archaeology around the burial complex revealed four Neolithic sites in the east: Shanggeda 上疙瘩遗址, Sanjiaogeda 三角疙瘩遗址, Majingwan 马井湾遗址 and Shangbianjia 上边家遗址 (Guojia Wenwuju 2011a:298). According to the entries in the Atlas of Chinese Cultural Relics, the pottery found there belongs to the Majiayao style (Guojia Wenwuju 2011b). No burials were mentioned in the description of these sites in the Atlas of Chinese Cultural Relics (Guojia Wenwuju 2011b) and these sites could potentially form the habitation area that Andersson was looking for. However, there are no published excavation reports for these sites, and it is unknown whether they contain graves or not.

Zhujiashai 朱家寨遗址 in the Huangshui River Valley, Qinghai province

Coordinates: 36°40'13.8"N 101°36'36.0"E

This site is located at the village of Zhujiashai 朱家寨 which is now a part of Xining City 西宁市. This site includes a habitation area in the north and a burial area in the south (Andersson 1943:153; 1945:25-26; Sommarström 1956:58; Guojia

Wenwuju 1996:36). The site is surrounded by sloping loess hills and is located close to a narrow stream in the east which is flowing south into the Huangshui River (Fig. 4.4). The northern part of the site was already disturbed by modern construction when Andersson and his team began excavating in 1923. The estimated extent of the dwelling area was 850 m (N-S) x 470 m (Andersson 1943:153).



Fig. 4.4. Location of the Zhujiazhai site.

Because of the modern houses built over the habitation area already at the time of Andersson it was not possible to systematically excavate and study the stratigraphy. Nevertheless, a few hundred of painted and unpainted pottery pieces were collected and published in the Bulletin of Far Eastern Antiquities (Andersson 1945). More thorough excavation was conducted in the burial area, even though the graves have been disturbed, presumably by an earthquake (Anderson 1943:152, 249). Forty-seven skeletons have been excavated in a 74 m² trench in SW but the total number of burials in this area is unknown. The graves contained a large number of pottery vessels dating to the Neolithic and Bronze Age and some stone (including amazonite and turquoise) and bone objects which were also

published in the Bulletin. Further, one photograph and a simple topographic map were published by Andersson to indicate the dimensions and location of the site (Fig. 4.5)

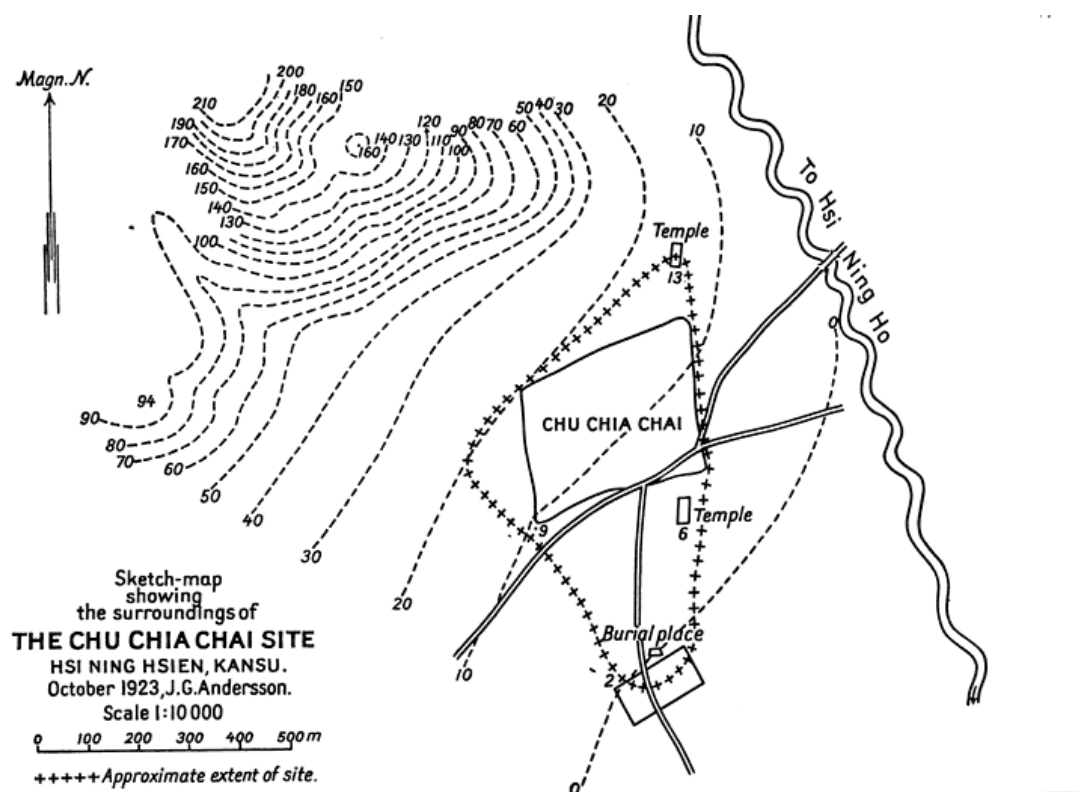


Fig. 4.5. Topographic map of the Zhujiashai site drawn by Andersson (1945: Fig. 2)

Andersson suggested that Zhujiashai had contacts to Luohantang because of the similarity in bone knives and flint flakes found on both sites; he also noted that those knives have not been found in Central Gansu at that time (1945:63). The short entry in the Atlas of Chinese Cultural Relics does not provide any additional information about a new survey or excavation conducted at this site (Guojia Wenwuju 1996).

Luohantang 罗汉堂遗址 in the Yellow River Valley (Guide Basin), Qinghai province

Coordinates: 36°7'10.223"N, 101°11'13.168"E.

The only available detailed description of the prehistoric site near Luohantang was written by Andersson (1939:35; 1943:84) who called it Luohantang West because

it was situated to the west of the village named Luohantang (Mandarin) or Gomitaju (Tibetan) (Bylin-Althin 1946:430, quote from an unpublished manuscript by Andersson; Sommarström 1956:59). Andersson added a black-and-white photograph with a view of the site from the west and a simple topographic map of the surrounding landscape to the description (Fig. 4.6). No detailed site plan or sketch of its features was published.

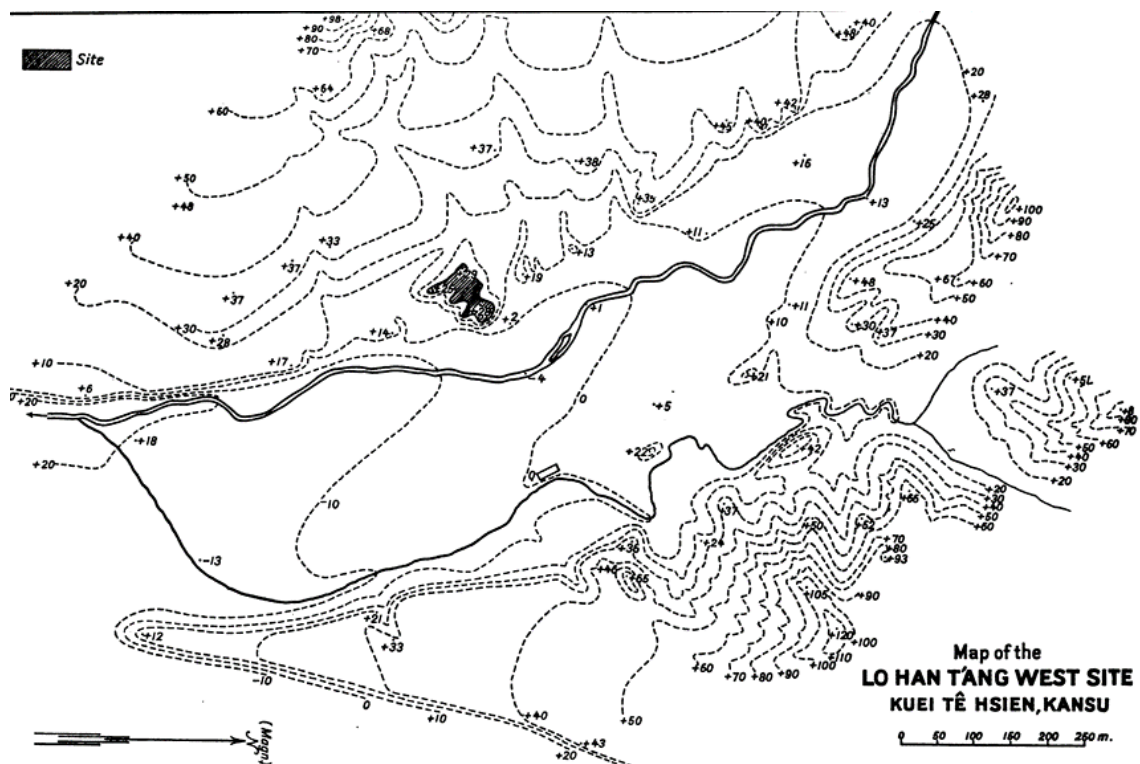


Fig. 4.6. Topographic map of the Luohantang site drawn by Andersson (1943: Fig. 22).

Since Andersson, this site has not been systematically excavated. The Atlas of Chinese Cultural Relics for the Qinghai province does not show this exact site on its maps (Guojia Wenwuju 1996). Instead, two other Neolithic sites are marked on the maps – Luohantang East 罗汉堂东遗址 and Jialong Kaya South 加龙卡亚南遗址 – which are in proximity of the village Luohantang mentioned by Andersson (Guojia Wenwuju 1996:74-75). The latter is located at what appears to be the location of Luohantang West. In the description of Jialong Kaya South given in the Atlas of

Chinese Cultural Relics (Guojia Wenwuju 1996:159) it is mentioned that the site was first excavated by Andersson. However, according to that entry only the pottery belonging to the Bronze Age Kayue culture 卡约文化 was found there. Andersson did not mention the name Jialong Kaya South in his published work. Through examination of different satellite images of this location and detailed comparison with the photograph and the topographic map published by Andersson (1943) it was possible to identify the exact location of Luohantang West (Fig. 4.7). The detected location corresponds with the description given by Andersson about where the site is situated: 20 km west of the Guide city and north of the Yellow River (Andersson 1943:84). The excavated area had the dimensions 90 m NE-SW and 55 m NW-SE (Andersson 1943:84).



Fig. 4.7. Location of the site of Luohantang.

It is situated west of the Luohantang village next to a small stream which over time slightly changed its direction and shape of the channel. On the satellite images from Google Earth or Bing Maps the site area is clearly distinguishable from the surrounding area by the lighter colour of the ground surface. The contours of the

lighter coloured area match the sketch of the site on the map drawn by Andersson. Its dimensions also match Andersson's recordings. It is possible to see the exact view captured on the photograph with the 3D view option available on Google Earth. As seen on satellite images this site is not disturbed by modern construction nor there is any modern construction in immediate proximity to the site.

The site is situated on a loess cliff and has a shallow riverbed to its east (for a detailed description of geological environment see section 4.4.1.3). Andersson noted that the topography of this area most likely stayed the same from the Neolithic period and the landscape of cliffs and riverbed served as a natural protective barrier (Andersson 1943:84). The whole area including the site and the village is part of the valley with the upper reaches of the Yellow River which is 5 km south from the site.

The site was excavated in August-September 1923 (Bylin-Althin 1946:430, quoting Andersson's unpublished manuscript). Two sections of the area were chosen for excavation on this site. There is no marking of these sections on the topographical map, but Andersson briefly described the stratigraphic profile of each section. The cultural layer of Section 1 was 0.25 m thick and at the depth of 0.36 m belonged to the uppermost part of the profile containing loess sediment (Bylin-Althin 1946:431). Apart from a large number of the artefacts this layer contained traces of fire, areas with unspecified white substance and charcoal. Below this level no other artefacts were found. The cultural layer of Section 2 was 0.72 m containing artefacts, charcoal and white spots. The layer above (uppermost, 0.66 m thick) had few artefacts and white spots. Below the main cultural layer nothing else was found.

A round feature found on the site was described as two pottery kilns (Andersson 1925:5; 1943:84; Bylin-Althin 1946:431). Only a simple sketch with the dimensions of one kiln is published (Fig. 4.8).

Fig. 4.8. Sketch of a kiln structure found at Luohantang made by Andersson (Bylin-Althin 1946: Fig. 6).

Beside this feature many artefacts were unearthed at this site: about 1500 pottery sherds and very few complete or partially complete vessels, as well as 108 stone objects (including jade) and 90 fragments of artefacts made from bones (for full description of stone and bone objects see Andersson 1943 and Bylin-Althin 1946). The retrieved pottery was identified by Andersson as belonging to the Majiayao style and to the Bronze Age Qijia style. Andersson did not record any burials from this site, however there is an entry about a Luohantang burial group 罗汉堂墓群 in the Atlas of Chinese Cultural Relics (Guojia Wenwuju 1996:162). According to this

entry, the site extends over 35,000 m² and fine pottery in Majiayao style was found there. No further details or pictures of the site were published.

As far as can be inferred from these site descriptions, no unambiguous kiln structures were found there. A structure resembling a kiln was found only at Luohantang, according to Andersson's report. However, since no re-excavating and reassessment of the site were carried out it is difficult to say if pottery production took place there.

The published archaeological reports for the sites do not include a documentation of the find context for the pottery. It is not known where exactly the pottery was found and with what other objects together. The record of the burials at Zhujiashai is an exception, and the information from the new excavations at Majiayao is awaiting publication.

4.1.2 Geological samples

Forty-seven geological samples including clay¹⁸, rocks, sand, and loess were collected at 22 locations in the Tao River Valley (Table 4.3, Figs 4.9-10).¹⁹ Observations of the geology in the Huangshui and Yellow River Valleys were possible during this author's short research trips to the Liuwan Museum of Painted Pottery and to the Bronze Age Lajia site 喇家遗址 in Qinghai province. A geological field sampling trip to these valleys was planned for spring 2020 but was not possible due to the outbreak of the COVID-19 pandemic.

Each sample was given a unique signifier consisting of GSC for "Geological Sample China" and a location number from 1 to 22. Rock samples have designations such as GSC3-1 or GSC22-4 because more than one rock sample was collected in that

¹⁸ In the present study the term clay refers to clay-rich sediment with high plasticity and ability to hold its shape when formed into a coil.

¹⁹ For the description of each geological sample see Catalogue 4.

location. Two clay samples GSC5 and GSC6 were collected at a clay source used by modern potter Mr Ma Youzhong 馬有忠 to make replicas of the Majiayao-style pottery (Fig. 4.10). The geological sampling method is described in detail in section 4.4.2. The raw clay was processed and fired at three different temperatures producing in total 48 pottery briquettes in the firing experiment described in section 4.4.3.

Table 4.3. Geological sample types and ID on Figs 4.2-3.

ID	Sample number	Sample Type	ID	Sample Number	Sample Type
1	GSC1	Clay	12	GSC12	Loess
2	GSC2	Sand	13	GSC13	Clay
3	GSC3 (1-9)	Rocks	14	GSC14	Clay
4	GSC4	Clay	15	GSC15 (1-3)	Rocks
5	GSC5	Clay	16	GSC16	Clay
6	GSC6	Clay	17	GSC17	Clay
7	GSC7 (1-4)	Rocks	18	GSC18	Clay
8	GSC8	Clay	19	GSC19	Clay
9	GSC9	Clay	20	GSC20	Clay
10	GSC10	Loess	21	GSC21	Clay
11	GSC11	Loess	22	GSC22 (1-13)	Rocks

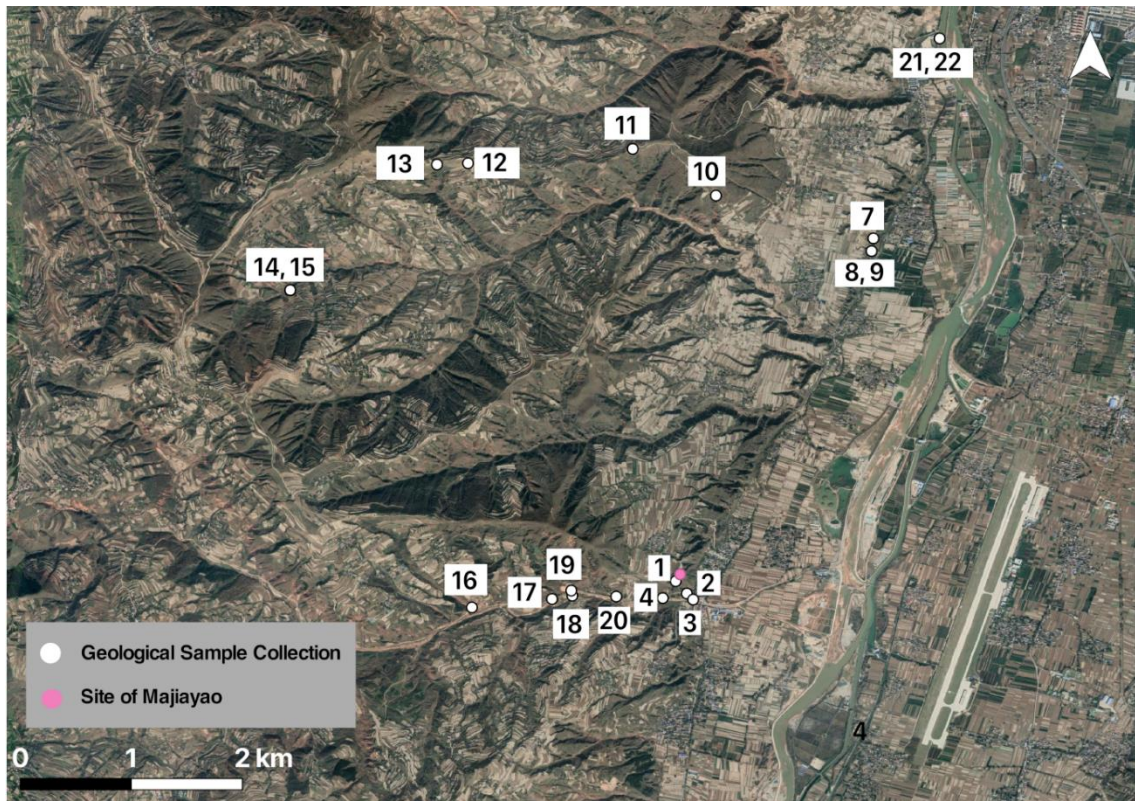


Fig. 4.9. Geological field sampling itinerary in the Tao River Valley; see Table 4.3. for the number ID.

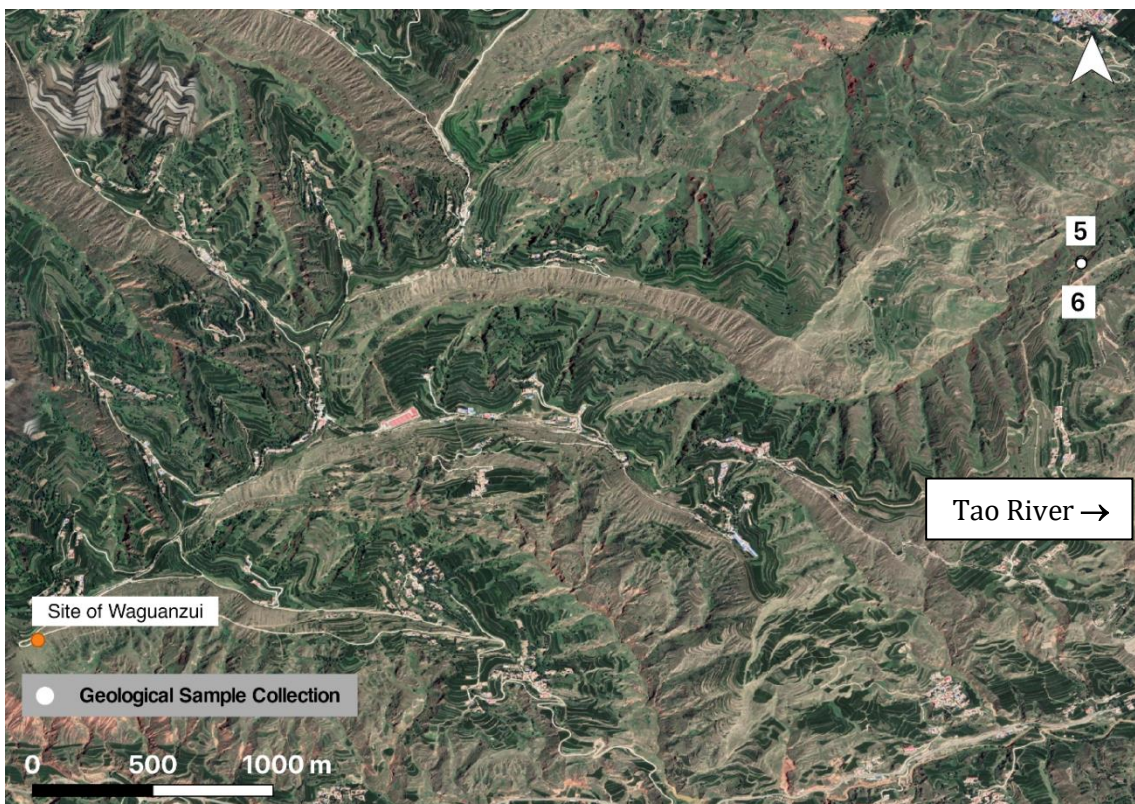


Fig. 4.10. Geological field sampling itinerary in the Tao River Valley (continued); samples GSC5 and GSC6 taken from a modern potter's clay source; see Table 4.3. for the number ID.

4.2 Macroscopic analysis

The aim of the macroscopic study of the pottery was to recognise and describe traces left from shaping process and record information about visible tool marks. Since Majiayao-style pottery shows extensive surface treatment on the outside – it is either polished and painted or has a relief decoration – traces left from construction techniques cannot be seen clearly there. Therefore, an examination of the interior surface of the complete vessels was included in the study. Since most complete vessels selected for this study had narrow openings, the inside was observed with an endoscope camera. The model “Pancellent” USB Android Endoscope 2.0 Megapixels was chosen because of its affordable price, and it does not require special training to use it. It is light, robust and easy to transport. This camera has a built-in LED light and is most convenient for observing the vessels with narrow openings from the inside, providing a good view of the neck and body joint. This camera was plugged into a smartphone and pictures were taken with the free app “CameraFi”. The photos have the resolution of 96 dpi and dimensions 640 x 480 pixels, which is quite low but still suitable for macroscopic study as shaping marks are clearly visible on the photos. Another minor limitation of the camera is the intense white LED light that turns the otherwise reddish-yellow colour of the ceramic surface into grey or white. This must be taken into consideration during any vessel study using just the photographs because the surface picture is distorted by the LED light. Despite the medium to low resolution of the photographs it was possible to distinguish shaping marks and collect data with this type of camera. The study of the vessel exterior was conducted using a 10x magnifying lens and a photo camera.

Identifying and studying the traces left by tools or hands during the construction process helps to understand what techniques were used to make a vessel. There are different areas on the vessel where traces of construction process and surface treatment can be observed macroscopically: the inside of the vessel including the inside surface of the base and neck/rim, the cross section of a vessel sherd, and the outside surface of the vessel. Roux and Courty conducted experimental studies to identify the indicators of primary and secondary construction techniques on the vessel inside (Roux 1994; Courty and Roux 1995; Roux and Courty 1998; 2019). They demonstrated that it is possible to recognise coil-building and turntable finishing as primary and secondary or combined building techniques by the creases and striations left on the inside surface. Roux and Courty (2019) further demonstrated that beating, as a secondary construction technique, can be identified on coarse vessel surface by studying the embedment of the coarse grains on the surface.

Primary building techniques such as coiling can be seen on the cross-section of a sherd. The different overlapping and layering of clay in the core can indicate different ways of coil joining techniques (Roux and Courty 2019; Martineau 2000; Gomart et al. 2020). In their macroscopic study of European Neolithic pottery, Gomart et al. (2020) were able to identify different methods of coil-building by examining the joining area of the base and wall coils. The broken edges of sherds indicate joint areas of coils and their sizes.

Schreiber (1999) has demonstrated on the red- and black-figured Athenian pottery of the Archaic and Classical periods how surface finishing techniques can be identified macroscopically. Athenian pottery has a smooth burnished or polished surface. Schreiber (1999) distinguished between burnishing and polishing as

separate techniques and further between burnishing a vessel by hand and on a wheel. According to him, burnishing on a wheel leaves long parallel striations around the vessel body while burnishing with one hand and holding a vessel with the other results in short irregular strokes (Schreiber 1999:45-46; Ionescu and Hoeck 2020:3). Polishing with a soft cloth can be done after burnishing to remove the marks or it can be done instead of burnishing (Schreiber 1999:52; Rice 2015:149).

Firing atmosphere and firing control was assessed through examination of the colours seen in sherd cross-sections. The firing patterns are described as “oxidised” if the core is uniform orange, red or yellow; “reduced” if the core is grey or darker; “oxidised core, reduced margins” if the core is red, yellow or orange and the outer surfaces are grey or darker; “reduced core, oxidised margins” if the core is grey or darker and the outer surfaces are red, orange or yellow; “other firing pattern” refers to cores which show several differently coloured layers. The data from the macroscopic analysis of sherds in Annex 3 is sorted according to these firing pattern categories for each fabric type.

The geological samples of sand, rocks and experimentally made clay briquettes were studied macroscopically using a binocular microscope Brunel DM2 with a magnification of x30 focusing on changes in the fabric and comparing different unfired and fired clay samples to each other (see 5.2.1 for analysis results).

4.3 Thin-section petrography

The method of thin-section petrography in pottery analysis is borrowed from geology and soil micromorphology for studying the microstructure and origin of rocks and sediments (Rice 2015:292). It involves a polarising light microscope and a 30 µm thin sample cut from a pottery sherd and mounted on a glass slide (Reedy

2008:1). When a pottery sample is viewed under plane- and cross-polarised light (PPL and XPL), the minerals interact with polarised light in different ways providing a basis for their identification (Quinn 2013:4; Rice 2015:292). In archaeology, petrographic analysis of the pottery microstructure, often combined with other scientific techniques, is applied to address questions such as raw material selection and production technology (e. g. Roux and Courty 1998; Quinn 2009; Gauß and Kiriati 2011; Spataro et al. 2019), investigating interaction and trade (e. g. Stoltman 1991, Whitbread 1995; Boileau et al. 2010; Spataro and Fletcher 2010); changes in production technology (e. g. Spataro 2014; Womack 2017), and technological transfer and knowledge exchange (e. g. Kiriati 2010; Czekaj-Zastawny et al. 2017).

The reason why such a diversity of questions can be addressed through petrographic analysis is because this method provides insights into the different stages of the production process. First, it is a tool to describe pottery fabric composition. Following Whitbread (1989) and Quinn's (2013) approaches, the present study uses three parameters for pottery composition characterisation: non-plastic inclusions, matrix, and voids. Studying the data on composition of the pottery samples allows to investigate what type of clay – coarse or fine was used to make pottery and whether any extra material was added to the clay by the potter. Second, textural features of the matrix, such as homogeneity or heterogeneity, indicate how well the clay was kneaded and homogenised before constructing a vessel. If the distribution of the non-plastic inclusions is uneven or if it contains high amount of clay pellets, the matrix is described as heterogeneous (Quinn 2013:94, 174). Third, by observing the matrix colour and behaviour under plane- and mainly cross-polarised light, it is possible to roughly estimate the firing

temperature (Quinn 2013:94, 191). The degree of optical activity and texture of the clay matrix can indicate whether the firing temperature was very high causing its microstructure to melt, or low if the clay matrix is optically active, i. e. still propagates light (Quinn 2013:191). Fourth, different types of surface treatment can be observed on the margins of a cross-cut thin section. Burnishing can be identified by compressed mineral particles and matrix along the outer surface of the sampled pot (Quinn 2013:182). Slip, paint or glaze can be seen on the sample margins in form of a thin separate layer (Quinn 2013:181). If the slip is made from the same clay as the body, it may be indistinguishable from the clay matrix. Slip or paint may sometimes come off the sample during thin section preparation process.²⁰ Fifth, though not directly related to petrographic examination, high resolution scans of thin sections, cut at specific orientation, offer further insights into construction techniques by clearly showing the orientation of voids and inclusions in some cases (Eramo 2020:9). Petrographic data on its own cannot always provide information on whether the differences in fabrics imply human choice or reflect natural clay deposit variation in the study area. Only in some cases related to the grain-size distribution and obvious added temper such as grog, potter's actions and choices can be assumed. Therefore, this study also includes a petrographic comparison between the geological samples and prehistoric sherds in the investigation of potter's choices.

After data about each sample is recorded, they can be classified according to their similarities in composition into fabric groups to study the diversity of pottery paste (Quinn 2013:79-80). The criteria for classification are determined according

²⁰ More thorough analysis of slip, paint and glaze can be done under very high magnification by scanning electron microscopy (SEM) which was not possible to conduct in this study due to COVID-19 pandemic.

to specific research questions investigated by the researcher. Therefore, although these groupings are based on collected scientific data, they are already a result of subjective interpretation (Albero Santacreu 2014:111). This interpretation forms the basis for the subsequent investigation of raw material selection and clay mixing.

For this study petrographic analysis was conducted on thin sections cut from each of the 187 prehistoric sherds, 13 rock samples, eight experimentally fired clay samples, and one sand sample. The description of each archaeological and experimental ceramic sample included the frequency, type and size of inclusions and voids, and the nature of the clay matrix (Table 4.4).

Table 4.4. Characteristics of the pottery and fired clay samples which have been included in the petrographic description.

Non-plastic inclusions	Matrix	Voids
• Sorting²¹ • Inclusion frequency in % • Coarse fraction in %; inclusion shapes and types from dominant to rare in %²² • Fine fraction in % from dominant to rare	• Abundance in % • Colour in PPL and XPL • Homo-and heterogeneity • micaceous/ non-micaceous • Optical activity • Textural features	• Abundance in % • Type and size • Distinctive characteristics

The inclusion frequency was estimated using the estimation chart after Terry and Chillingar (1955; here Catalogues 1 & 2 Table 1). The shapes of inclusions are described using the terminology after Quinn (2013; here Catalogues 1 & 2 Table 1). The inclusion sizes are described according to the ISO 2017 standard for grain size measurement (ISO 2017; here Catalogues 1 & 2 Table 1). The shape and size of the

²¹ In the entries of the Catalogues 3 and 4 “Sorting” is a characteristic in the “Matrix”-table because it was put in the same context as homo-/ heterogeneity of the matrix by the author at first. In the descriptions of the main thesis “Sorting” is defined as inclusions’ characteristic.

²² The average % is calculated individually for each inclusion type. Therefore, in some cases the total amount of inclusions may be less than 100%.

voids are described using the terminology after Kemp (1985; here Catalogues 1 & 2, Table 1).

It was not possible to clearly identify petrographically whether the matrix is calcareous or non-calcareous in this pottery material. There are few samples which contain calcite in the coarse or fine fraction, but it was not possible to determine for certain if these inclusions indicate a calcareous matrix. The main types of sediment in the study area are brown loess and underlying deposits of red clay, both of aeolian origin (Gylesjö and Arnold 2006) as will be further discussed in sections 4.1.1 and 6.1.1. The top loess deposits are calcareous, but the red clay deposits below can have various amounts of calcium carbonate due to decalcification processes (Gylesjö and Arnold 2006:185). Red clay deposits can also contain coarse carbonate nodules (Liu 1988:19; Gylesjö and Arnold 2006:189-190; for an example of red clay with carbonate nodules see section 6.1.1.2). The content and nature of the calcite in those cases is discussed together with the other petrographic data. Determining the calcareous nature of the clay macroscopically by the colour of pottery (Simpson 1997:54) has proven to be not very reliable since the cross-section shows different layers of colours ranging from dark red to pale yellow. Determining whether a clay sample is calcareous or not, can help the investigation of the raw material provenance. Calcareous clays often come from marine deposits (Quinn 2013:44). Calcareous clays exhibit different physical properties than non-calcareous clay when exposed to heat, such as thermal conductivity, which can be useful for the investigation of pottery usage (Hein et al. 2007). Clays containing fine and evenly distributed calcite can be preferred for pottery production because they remain a stable vitrification phase after being fired within the range of 80-1050° C (Maniatis and Tite 1981:65; Elert et al. 2003;

Allegretta 2016). Further, firing calcareous clays containing a high amount of coarse micrite or carbonate inclusions during production process requires specific knowledge in techno-science due to these inclusions being chemically unstable when subjected to high temperatures and potentially causing damage to ceramic body (Albero Santacreu 2014:94). In a future study, bulk chemical analysis can be used to determine the calcite content in the archaeological and experimentally fired clay samples (Quinn 2013:94).

Individual description of each sample is provided in Catalogue 3. The table provided at the beginning of the Catalogues 1 and 2 with petrographic groups includes detailed information about shape types and size measurements of inclusions and voids, as well as percentage estimations of inclusion frequencies. The criteria for petrographic grouping are presented below in section 4.3.1.

The selected prehistoric sherds were sampled using the “PLASPLUGS Diamond Wheel Tile Cutter” and steel pincers. The thin sections of ceramics and fired clay samples were prepared at the Fitch Laboratory of the British School at Athens, Greece. Nine ceramic thin sections from the samples from Waguanzui site were prepared at the laboratory of the Earth Sciences Department at the University of Oxford. The analysis was conducted on the “James Swift MP3500” polarised light microscope. Photomicrographs were taken with a generic LCMOS 14-megapixel unit (supplied by Brunel Microscopes Ltd) attached to one eyepiece. The image capture and processing software used was ToupTek ToupView v3.7.

Petrographic grouping

The fabrics were grouped according to the amount, size and type of non-plastic inclusions. After the first observation of all the material under the microscope, the following parameters were set for grouping: first, the fabrics were separated

according to the size of the non-plastic inclusions into coarse – coarse sand (CSa) to fine gravel (FGr), semi-coarse – medium sand (MSa) to coarse sand (CSa), and fine fabrics according to the ISO grain-size chart (ISO 2017; here Table 1 in Catalogues 1 & 2). The coarse fabrics were further divided by the frequency and types of predominant coarse non-plastic inclusions. The inclusion types include the three rock types: sedimentary, metamorphic and igneous, as well as shell and nannofossil fragments. As no significant amount of organic material was detected in any of the ceramic fabrics, this was not a grouping criterium. The main fabrics can also have sub-fabrics. The samples classified as sub-fabrics have the same dominant coarse inclusions as the main fabric but exhibit minor differences in their size or frequency. Beside the main non-plastic inclusion type coarse sub-groups can also include lesser amounts of other coarse rock fragments, varying amounts of clay pellets, shell or nannofossils.

The semi-coarse fabrics contain inclusions which are significantly smaller in size than those in the coarse fabrics but larger than those in the fine fabrics, ranging between 0.2-0.7 mm (MSa-CSa). Grouping of the fine fabrics was conducted according to the size of rock fragments and mineral inclusions (<0.2 mm) and their frequency. Following the same procedure as with the coarse fabrics, fine fabrics were further separated according to the type and frequency of dominant inclusions. Each fabric group is named after the type of dominant inclusions and other prominent features, e. g. “Quartz-Feldspar and Granodiorite fragments.” The groups from each site are discussed separately at first and then an inter-site comparison is carried out. The results are discussed in Chapter 5.

4.4 Experimental firing

Many studies on ancient pottery include a comparative study with geological material collected in the study area (e. g. Carney 2010; Nodarou 2011; Gauß and Kiriati 2011; Sahlén 2012; Michelaki et al. 2015; Jacobs et al. 2015; Womack 2017). These studies address the questions of the usage of local or non-local clays for pottery production in a study area. The comparative study between geological clays and ancient pottery is often conducted by combining thin-section petrography and chemical analysis (Nodarou 2011; Gauß and Kiriati 2011; Sahlén 2012; Michelaki et al. 2015; Jacobs et al. 2015). The analyses of the geological samples in most of these previous studies were performed after the samples were processed and fired. Jacobs et al. (2015) and Womack (2017) analysed unfired material, which potentially could complicate the comparison with pottery because of the changes the ceramics undergo when fired. The same raw samples can be used in one firing experiment at one temperature (Carney 2010), or the material can be split and fired at two or three different temperatures (Nodarou 2011; Gauß and Kiriati 2011; Sahlén 2012; Michelaki et al. 2015). The firing experiment in the present study includes three different firings at 700°, 900°, and 1050° C to assess the changes in clays at the lowest and highest estimated firing temperatures and in the middle (cf. Chapter 2). The experiment was conducted following the procedures described by Gauß and Kiriati (2011:78) during their experimental firings for the following reasons (see section 4.4.3 for the description of the experiment). First, the approach by Gauß and Kiriati (2011) did not involve extensive sediment purification and the samples were largely fired in their natural state keeping the initial grain-size. Second, the firing temperatures chosen by the

authors were close to the estimated firing temperature for the Majiayao-style pottery.

Working with clay collected in the study area offers an insight into the experience that prehistoric potters may have had when they selected clays for themselves. The aim of this experimental study was to observe the behaviour and changes of clay when mixed with water, kneaded, and fired. Working with raw clay gives an idea of the steps in the *chaîne opératoire* needed to process the material and prepare it to be used for pottery construction.

The comparative petrographic study with the prehistoric pottery samples and the fired geological clays samples aims to investigate how the nature of matrices and types of inclusions of geological clays related to the composition of the prehistoric samples (Nodarou 2011:22). This comparison addresses the questions of potential addition of temper or purification of the clay. The limitation of this experimental study is that it is approaching prehistoric pottery production from the functional and technical perspective. The non-material actions or mind-sets potters when selecting raw material might be influenced by different factors which cannot be recreated in the experiment (Albero Santacreu 2014:121). However, studying a variety of clays available in the study area contributes to the understanding of the choices made by prehistoric potters (Nodarou 2011:26). To provide a context for the sediment and rock material collected, the geological setting in the study area is described below.

4.4.1 Geological setting of the study area

The study area is situated in the west of the Longzhong Basin which is located at the west edge of the Chinese Loess Plateau facing the eastern Tibetan Plateau (Zhai and Cai 1984:19; Gao et al. 2020:3). The geological setting is characterised by fault

zones of mountain formations, river valleys, deposits of sandstone, mudstone and conglomerate, as well as deposits of loess and red-brown clay (Zhang and Cai 1984:19; Fan and Du 1999:33; Guo et al. 2016; Gao et al. 2020). Loess is a wind-blown silt sediment consisting of quartz, feldspar, mica, calcium carbonate and gypsum (Zhang 1980; Pye 1995; Derbyshire et al. 2000:65; Potter et al. 2005:17;). The origin of the red and brown clays is not certain. The upper layers of red clay in the Chinese Loess Plateau are considered to be of aeolian origin, and the lower layers closer to the riverbeds have fluvial origin (Lu et al. 2001:96-97). The red and brown clays contain iron oxide (Fe_2O_3) and titanium oxide (TiO_2) – 5-8% of Fe_2O_3 and < 1% of TiO_2 - which gives them the orange to red colour after firing (Hamer and Hamer 2015:302). The following description of the geologic landscape in the river valleys summarised from the scholarly literature is combined with author's observations made during the survey in the Tao River Valley and research trips to the Huangshui and Yellow River Valleys in 2019. The study area has been georeferenced in GIS using the geological maps from the Geological Atlas of China (Ma and Liu 2002:326-327, 334-335) to locate the sites in the landscape as accurately as possible.

4.4.1.1 Tao River Valley

The Tao River Valley is located between fault zones of mountain ranges (Guo et al. 2016: Fig. 1; Gao et al. 2020: Fig.1a-b; here Fig. 4). The Tao River (length 673 km) begins in the east of the Tibetan Plateau and is a south tributary of the Yellow River (Gao et al. 2020:3). The Tao River flows through the Xiqing mountains 西倾山 and West Qinling Foldbelt carrying sandstone, slate, limestone, gypsiferous lacustrine sediments, and granite which are distributed and deposited along the valley (Wu et al. 2005:5281; Li et al. 2015:2104; Gao et al. 2020:3).

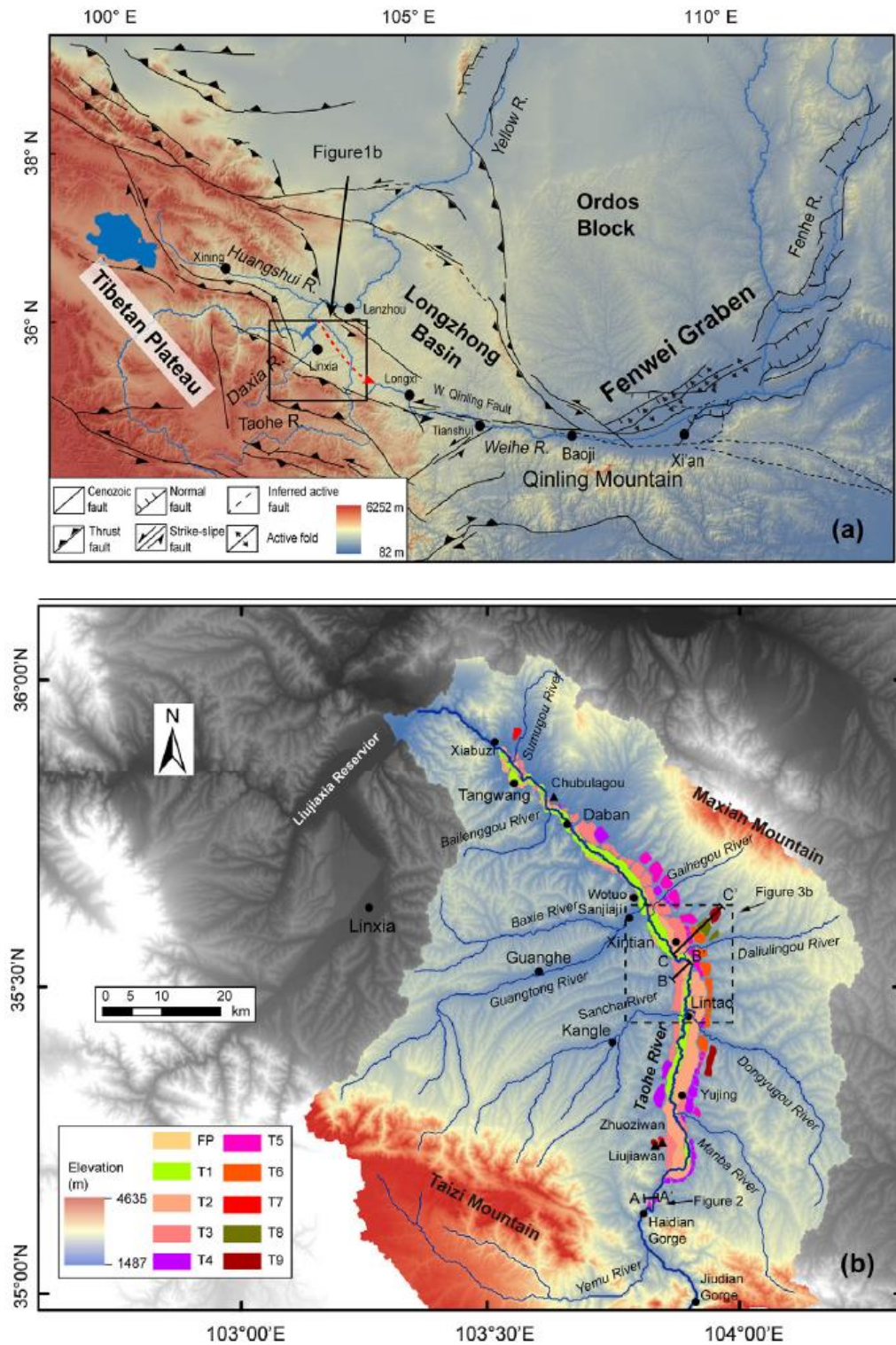


Fig. 4.11. a-b: The landscape setting in the Tao River Valley; from Gao et al. 2020: Fig.1a-b.

A geological map of the Loess Plateau published by Pang et al. (2018: Fig. 2) shows what kind of rocks can be found in the river flow. From the Xiqing mountains the Tao River carries fluvio-lacustrine sediments and carbonate rocks (Fig. 4.11a; Pang

et al. 2018: Fig. 2; Gao et al. 2020:3; Ma and Liu 2002:326-327). There is a dam trapping most of the sediment flow and large boulders carried along built at the Haidian Gorge (Gao et al. 2020:3). The sedimentary deposits in the valley are characterised by interbedded orange-red sandy mudstones, loosely consolidated sandy conglomerates, and red mudstones with calcareous concretions (Zhang and Cai 1984:23).

The geological environment around the Majiayao site area is shaped by loess hills and gullies and ravines (Fig. 4.12).



Fig. 4.12. Area around the Majiayao site (view from the northwest).

The hills show two distinct colours of sediment: red brown clay and pale-yellow brown loess. As observed in the field, the red brown clay is mostly soft moist and sticky to the touch or hard compact and dry. Both soft and hard clay are found mostly in the middle to lower half of the hills. The sediments located along the riverbank and in the lower terraces are mostly unconsolidated with a grain-size ranging from sand to clay (Gao et al. 2020:9). The fine pale-yellow loess is located in the upper half of the hills (Gao et al. 2020:9). It is loose and fine; it feels dry but soft to the touch. According to the geological map, the sediments contain gypsum and clastic rocks which has also been observed during fieldwork (Ma and Liu

2002:326-327). The hills are covered with natural vegetation, mostly grasslands and rare trees. The landscape is further shaped by artificially made terraces for agricultural use (Fig. 4.12). These dried out tributaries are important for geological and archaeological research, as they expose geologic profiles for study and for archaeological survey. Based on his observations Andersson (1925:7-8) suggested that the geology of the area stayed largely the same since the prehistoric time, except for the river level which was higher in the past. The previous river level can be seen today in the sand layers with large boulders protruding from inside the hills (Fig. 4.13).



Fig. 4.13. Layer with gravel and boulders above a red clay deposit on the bottom of a dried-out river tributary, Tao River Valley.

At the Tao River near the Majiayao site many smaller boulders and cobbles are dispersed all over the exposed riverbank. These boulders and cobbles are of similar size as the rocks which are usually found in the riverbed load and roll along the stream (Murck and Skinner 2012:206). The large rocks on the riverbank indicate that the water level changes with time and might rise and pick up the

rocks again. Large rocks move slower than sand, silt and clay which are carried by saltation (Murck and Skinner 2012:206). The further the rocks are carried by the river from the parent bedrock, the more they weather until they disaggregate into smaller parts and minerals (Velde and Druc 1999:68). It can be assumed that the larger rocks – boulders and cobbles – that were on the exposed riverbank did not move too far from their bedrock (Velde and Druc 1999:68). The lithic material found along the river is dominated by sedimentary rocks such as quartzite, limestone, marble, sandstone, siltstone, mudstone, chert and clastic rocks (Ma and Liu 2002:326-327; Fig. 4.14). These rocks likely represent the eroded material from the river catchment which was there when the dam was built, rather than the eroded material from the upper reaches at the Xiqing Mountains.

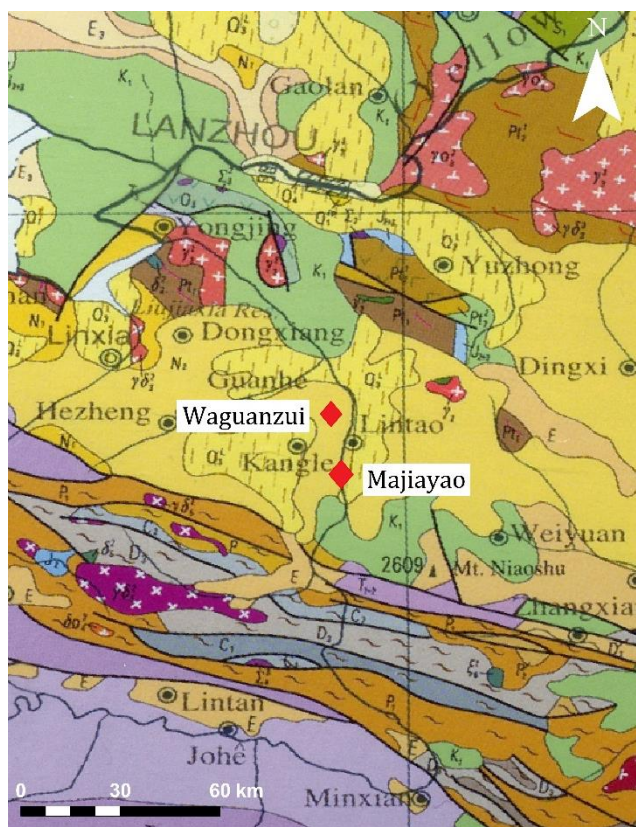


Fig. 4.14. GIS geo-referenced geological map of the Tao River Valley; map taken from the Geological atlas of China by Ma and Liu (2002:326-327); geo-referencing and captions by the author; for legend see Fig. 1 in Catalogue 2.

Igneous rocks include coarse-grained granite and granodiorite, possibly gabbro, as well as rocks with porphyritic texture (pers. observation). The bedrock characteristics of the Xiqing Mountains that the Tao River is flowing through largely correspond with the different types of rock found in the study area. The mountains are rich in plagioclase-rich granite and granodiorite, limestone and clastic rocks, as well as mudstone and carbonate rocks (Ma and Liu 2002:326-327). The area closer to the foot of the mountains is rich in sandstone and is also a source of hematite (Ma and Liu 2002:326-327).

Additional sources of granitic rocks are found west from the Majiayao site at approximately 70 km linear distance. The granite and gabbro outcrops are located in the northeast from the Majiayao site (Ma and Liu 2002:326-327; Figs 4.14-15). They form the Maxian mountain formation 马衔山 (Figs 4.11b). This formation is rich in granite and has also an ancient jadeite quarry on one of its peaks (Womack et al. 2021:12; and this author's personal observations). It has a few dry river channels in the proximity which could have been carrying sediment and lithic material into the Tao River. Manganese ore deposits have been found close to the Maxian mountain in Kanjiayao 康家窑, Lintao County 临洮县 (Su 2006:61), and at Nanpu (or Nanbao) 南堡, Lintao County. More deposits are located further north near Lanzhou (Su 2006:61). Manganese is a mineral used as pigment on the painted Majiayao-style vessels (Palmgren 1934: 174, ft-note 2; Ma 2000:54-58; Li and Yu 2018:50).



Fig. 4.15. Freshly broken granite boulder from the bedrock at the Maxian mountain; examined by the author during the TRAP geological survey in 2019.

The Waguanzui site is located north from Majiayao on the Banshan hills 半山 (Figs 4.3 and 14). The hills slope towards a small river Bayanghe 八洋河 and form the ravine Bayanggou 八羊沟 (Andersson 1925:10). They are deposits of mudstone and clastics, loess sediment and possibly red brown clay (Ma and Liu 2002:326-327). On the geological map Majiayao and Waguanzui area are classified as the same geological environment (Fig.4.14). The Bayanghe flows in a west-east direction into the Tao River, possibly down from the mentioned granitic bedrocks in the west.

4.4.1.2 Huangshui River Valley

The depositional and lithologic characteristics of the Huangshui River Valley are similar to those in the Tao River Valley (Zhang and Cai 1984:23). The area is dominated by fluvio-lacustrine sediments, aeolian red clay and loess (Zhang et al. 2017:88). The deposits consist mainly of dark red mudstones with gypsiferous sandstones, dark tan to grey silty mudstones and arkosic sandstones (Zhang and

Cai 1984:19, 21; Zhang et al. 2017:89). Yellow brown loess hills are interchanging with red brown deposits and greenish white layers of weathered rock, as seen on the road cut profiles. Similar to the landscape in the Tao River Valley, loess deposits are situated on top of the red clay (Guo et al. 2016:1209; Zhang et al. 2017:91). One noticeable difference between the two locales is that the red clay and mudstone deposits have a deeper and darker colour than those in the Tao River Valley (Fig. 4.16).



Fig. 4.16. Red clay and mudstone deposits; road cut in Xining.

The Huangshui River (length 374 km) has its source in the southern slope of the Qilian Mountains (Miao et al. 2008:434; Ma and Liu 2002:334-335; Tan et al. 2012:156; Guo et al. 2016:1208). It flows in the west-east direction through Xining city and feeds into the Yellow River (Zhang et al. 2017:89). The river has an approximate length of 60-70 km when it reaches Xining and vicinity of Zhujiashai. The Zhujiashai site is located on flatland between loessal hills. The area has deposits of carbonates, clastic rocks and mudstone (Fig. 4.17; Ma and Liu

2002:334-335; Miao et al. 2008: Fig.1B). There are smaller north-south directed tributaries flowing into the Huangshui located east and west from the site (Fig. 4.17). The tributaries and the Huangshui flow through Quaternary sediments of loess, clay, sand and gravel, metamorphic rock deposits, monzogranite and plagiogranite deposits, the nearest to the site being at about 30 km to the west (Fig. 4.17; Ma and Liu 2002:334-335 Miao et al. 2008: Fig.1B). The rock outcrops in the Huangshui River Valley include quartzite, sandstone, slate, phyllite, limestone, siltstone, mudstone, marlite, conglomerate, feldspar and shale (Tan et al. 2012:157). The gravel found on Huangshui terraces in the Xining Basin further include granite, gneiss and migmatite (Miao et al. 2010:51). Granite and sedimentary rocks and red brown clay outcrops were visible in the road cut profiles.

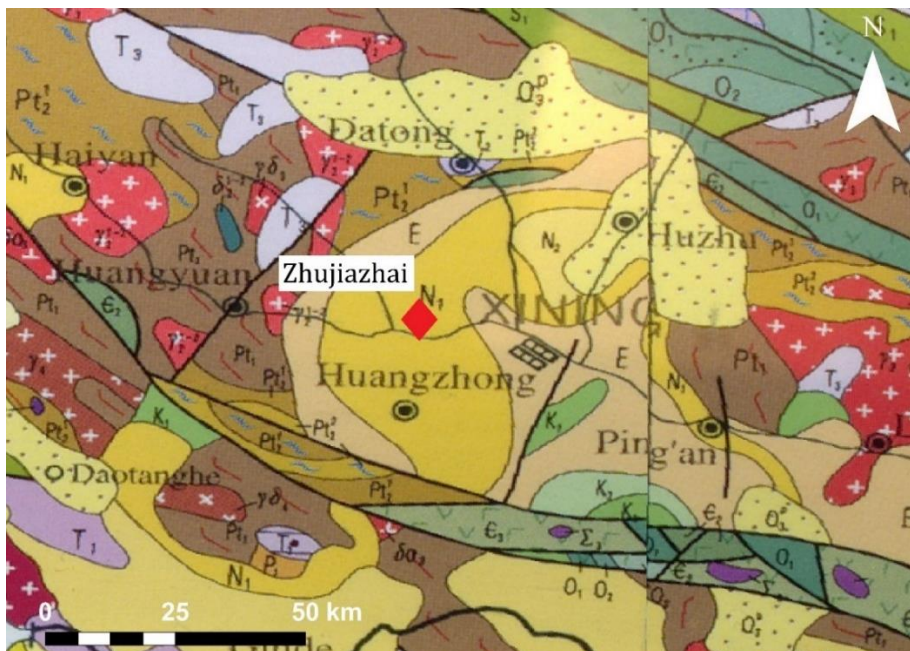


Fig. 4.17. GIS geo-referenced geological map of the Huangshui River Valley; map taken from the Geological Atlas of China by Ma and Liu (2002:334-335); geo-referencing and captions by the author; for legend see Fig. 2 in Catalogue 2.

4.4.1.3 Yellow River Valley

Luohantang is located in the Guide Basin in the upper reaches of the Yellow River Valley (Jia et al. 2017:324). Personal observations could only be made around the Bronze Age Lajia site 喇家遗址, that is closer to the Qinghai-Gansu border. Lajia is located in the Yellow River Valley and is approximately 150 km (aerial distance) to the east from the Luohantang site. According to the loess distribution map in the National Physical Atlas, the Loess Plateau does not fully enclose this area (Fan and Du 1999:33-34) but there are still areas with loess deposits (Fig. 4.18). This has also been noted by Andersson who wrote that Luohantang site is situated on a Malan terrace (Andersson 1939:45). Malan is a name for the youngest loess strata in a deposit (Derbyshire et al. 2000:48-49; Liu 1988:15). The area of the Lajia site has the same sedimentary deposit rich in clastics, mudrock and gypsum as the Guide Basin, as seen on the geological map (Ma and Liu 2002:334-335). Deposits of yellow brown sediments have been observed around Lajia and on the road along the Yellow River (Fig. 4.19).

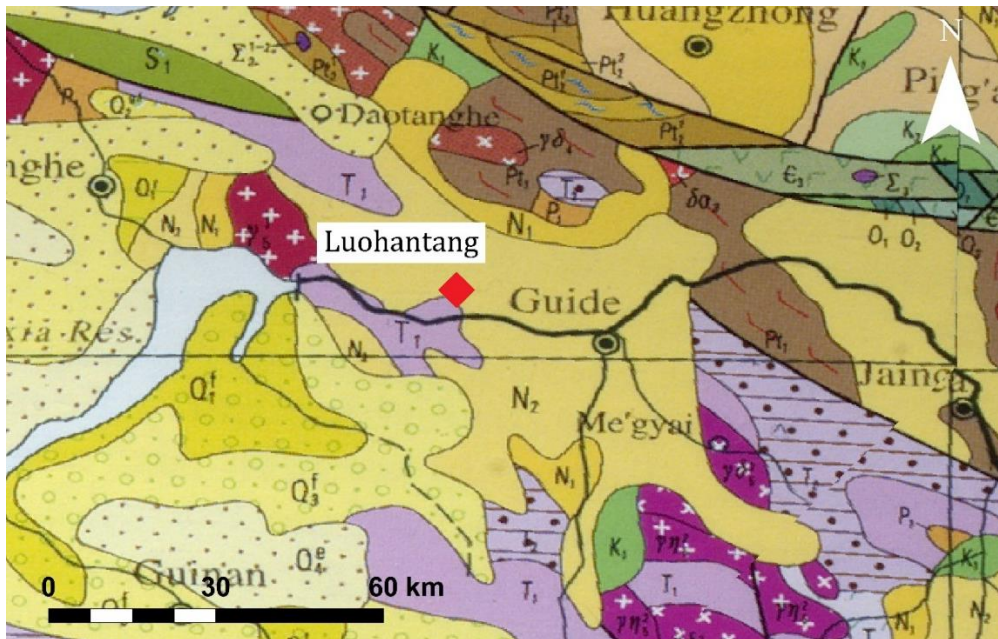


Fig. 4.18. GIS geo-referenced geological map of the Yellow River Valley; map taken from the Geological Atlas of China by Ma and Liu (2002:334-335); geo-referencing and captions by the author; for legend see Fig. 2 in Catalogue 2.



Fig. 4.19. Deposits of yellow brown sediment in the Yellow River Valley on the way to the Lajia site.

The Guide Basin is surrounded by different mountain faults; the nearest to the site are the Riyue Mountain in the north and Zhamazari Mountain in the east (Jia et al. 2017:324, Fig.1). From its source in the Qinghai-Tibetan Plateau the Yellow River (length 5464 km) makes a long detour before it reaches the Guide Basin flowing through different geological segments (Wu et al. 2005:5281; Ran et al. 2012:1248; Pang et al. 2018:77, Fig. 2). Before its stream enters the basin, it flows through the Longyangxia reservoir. This reservoir is located approximately 45-50 km away to

the west from the Luohantang site. The stream is slowed down by a dam in the reservoir, and it reduces the sediment load it is carrying. Larger boulders and cobbles get trapped in the reservoir. There is a granite outcrop to the north of this dam and the water flows through sediments containing carbonate and volcanic rocks (Fig. 4.18; Ma and Liu 2002:334-335). An outcrop of granodiorite is located on the Riyue mountain at ca 20 km linear distance north from Luohantang (Fig. 4.18).

4.4.1.4 Summary

The geological setting appears to be similar in all three valleys. There are deposits of red clay and exposed bedrocks as well as large riverbeds in site vicinity (Table 4.5) The results of the firing experiment and thin-section petrography of this study will be discussed with regard to the described geology of the study area.

Table 4.5. Summary of the geological characteristics in the three river valleys.

Tao River Valley	Huangshui River Valley	Yellow River Valley (Guide Basin)
Sediment		
Deposits of aeolian red clay with deposits of loess on top; alluvial deposits of red clay along the river; layers of loose river sand can be seen in lower the red clay deposits in dried out river tributaries suggesting a higher river level in the past	Fluvio-lacustrine sediments, aeolian loess and red clay; red clay has a darker shade than the red clay in the Tao River Valley.	Not fully situated on the Chinese Loess Plateau, there are areas with loess deposits; aeolian and alluvial red clay deposits.
Rocks		
Sedimentary: orange-red sandy mudstones, loosely consolidated sandy conglomerates, and red mudstones with calcareous concretions; sandstones, quartzite, siltstone, chert, clastic rocks, gypsum, limestone; Igneous: granite, granodiorite, gabbro, rocks with porphyritic texture; manganese ore deposits and	Sedimentary: dark red mudstones, gypsiferous sandstones, dark tan to grey silty mudstone, arkosic sandstones, limestone, quartzite, sandstone, slate, siltstone, mudstone, conglomerate Metamorphic: phyllite,	Sedimentary: clastic rocks, mudstone, gypsum Igneous: granite and granodiorite.

jadeite quarry near Maxian mountain.	marlite, gneiss, migmatite; Igneous: granite, feldspar.	

4.4.2 Geological sampling

Geological sampling was conducted by the author during a geological survey of the area around the Majiayao site by foot and by car during dry sunny weather. Sampling in dry weather helped to distinguish between deposits not only by colour but also by their consistency undisturbed by water accumulation. A route which included road cuts through hills and easy access to geological profiles was chosen for the field sampling in the Tao River Valley (Figs 4.9-10). It was a round trip on the periphery at ca. 5 km distance from the Majiayao site. The route was planned using satellite images on Google Maps so that it includes as much geologic variety in the landscape as possible – from the riverbank to a mountain top. The sampling was conducted using a geological hammer, an archaeological trowel, and a handheld GPS “Garmin eTREX 10” to record the coordinates of sampling locations.

The sampling process involved the following steps:

1. Taking the surface layer off with the hammer or trowel.
2. Filling the sampling bag with ca 0.5-1 kg of clay or ca 1-1.5 kg of rocks.
3. Taking coordinates on the spot with the handheld GPS.

The starting point was on the hill at the site of Majiayao. The site is located on modern terraces at the height of ca 1982 m above mean sea level. Red clay was sampled from terrace profiles on the top and at the foot of the hill on the road. The layers of fine clay sediment interchanged with sand layers containing rounded boulders and pebbles in hill profiles. Fine sand (GSC2) was collected from the layer on the terrace at the approximate hill middle. Various stones were collected at the bottom of a not completely dried out tributary to the west of Tao River. The route

went up to the mountain and down along the slopes. It was possible to sample a variety of raw material that could have been distinguished visually by colour, texture and granulometry of clay sediment and rocks.

4.4.3 Firing experiment

From the twenty-two collected geological samples sixteen were selected for making briquettes and firing. The selection included thirteen clay samples and three loess samples. The clay samples were selected based on their workability. The clay sample GSC4 was not included in the experiment because it was not considered workable at that stage (see 6.1.3, p. 343). The purpose of firing loess samples was to observe their behaviour after firing and compare to the clay samples in connection with Vandiver's (1988) suggestion that Majiayao-style pottery was made from loess.

The experiment was conducted in the laboratory for ceramic and stone analysis in the Northwest University in Xi'an, Shaanxi Province, China. Tiles of ca. 8x2x5 cm were formed from 16 clay samples to be fired at three different temperatures 700°, 900° and 1050° C. About 200-300 g were taken from each sample and crushed with a geological hammer, and large stones and organic material were removed. All samples were mixed with water to settle fine clay particles and remove coarser components and organic material. The excess water was then removed, and clay dried to a condition suitable for forming.

A test mixing with water was performed on GSC1 mixing one part water to three parts clay in a tall bucket and left to dry at room temperature (ca. 20°C according to Xi'an weather in July 2019) to check the viscosity of the clay and drying speed at this ratio because the time for the experiment was limited to 10 days. After one day of drying, it became apparent that a tall bucket is not an ideal vessel for this

experiment because it does not allow to observe the water level and slows down the drying of the clay. It was also difficult to remove excess water from this vessel without disturbing the clay mass. Sixteen transparent plastic rectangular containers were acquired for the experiment. Each sample was then mixed in a labelled container with one part of water to three parts clay. The clay was left to settle and dry for three days, during this time the excess water was removed regularly to allow quicker drying. As soon as the clay was plastic and malleable, four tiles ca 8x2x5 cm in size were formed for firing (Fig. 4.11). One tile of each sample was left unfired for reference. The sample number and the firing temperature were incised on each briquette. After one day of drying at room temperature, the tiles were dried in an electric oven ZRD-A5210 (Table 4.6).



Fig. 4.20. Examples of briquettes made for the firing experiment, dimensions of each piece within 8x2x5 cm.

Table 4.6. Drying process of the briquettes made from the GSC clay.

Oven temperature °C	Duration h	Samples GSC	Notes
80-100	1-1.5	1, 6, 9, 10, 11, 12, 13, 16, 17, 18, 19, 20	These briquettes were put in the oven after one day of drying at room temperature.
100	0.5	5, 8, 14, 21	These briquettes were made a day later because this clay dried at a slower pace. The briquettes were put in the oven after one day of drying. The temperature was lowered after 0.5 h because GSC5 and GSC21 started to dry unevenly and crack.
60	1		

After drying in the oven, the briquettes were left to cool down at room temperature overnight. Three days in total were necessary to conduct three firings. The first firing at 700° C was conducted the next day after drying the samples (Table 4.7). All tiles were arranged on a platter and loaded into the electric kiln “SHIMPO DFA-06” with 35° C as the starting temperature.²³

Table 4.7. First firing: starting temperature in the kiln 35° C.

Temperature °C	Duration
increasing 35-700	3 h 35 min
hold 700	1 h
cool-down from 700	overnight

The samples were left in the kiln for the following reasons:

1. The slow cooling rate of the kiln did not allow from opening on the same day.

²³ The starting temperatures in the kiln are determined by the cool down pace of the kiln from the last firing that took place in that kiln.

2. Leaving the tiles in the decreasing heat overnight recreated a more natural/authentic cooling down environment as it would be in an actual workshop firing.

After opening the kiln, all samples, except for GSC5 which exploded at an unknown time²⁴, remained intact throughout firing. The second firing took place the next day with the starting kiln temperature of 85° C in the kiln (Table 4.8). After opening the kiln, all samples, except for GSC5 which exploded, remained intact. (Fig. 4.21).

Table 4.8. Second firing: starting temperature in the kiln 85°C.

Temperature °C	Duration
increasing 85-900	2 h 45 min
hold 900	1 h
cool-down from 900	overnight



Fig. 4.21. Kiln opening after the first firing; GSC5 exploded into small chunks.

The third firing took place the next day after the second firing with the starting kiln temperature of 90° C (Table 4.9). After opening the kiln, all samples, except for GSC5 which exploded, “survived” firing.

²⁴ The explosion happened relatively early during firing, possibly at 600° C because a loud pop was heard from the kiln at that time. However, this cannot be proven for certain.

Table 4.9. Third firing: starting temperature in the kiln 90°C.

Temperature °C	Duration
increasing 90-1050	3 h 35 min
hold 1050	1 h
cool-down from 1050	over night

All 64 tiles were packed individually in plastic bags and labelled with sample number and firing temperature. Briquettes were made from GSC4 six months after the experiment. This sample was first considered as not suitable for briquette making as it contains a large proportion of coarse materials and river sand. However, after a second try of mixing with water it proved to be plastic and workable. Firing of GSC4 and a second attempt of firing GSC5 were planned to be conducted using an electric kiln in the Department of Scientific Research at the British Museum but it was not possible due to Covid-19 outbreak. This work is going to be included in a future project focusing on the geological samples from the study area.

5 Analysis: prehistoric pottery

5.1 Macroscopic analysis

5.1.1 *Chaîne opératoire*: building, decorating, firing

Fifty-two vessels with painted and impressed decoration were analysed for this study (Fig 5.1).²⁵ These vessels have a globular upper body with a conically shaped lower body. A pair of loop handles is attached at the approximate middle of the body. The vessels can have tall or low necks. The average dimensions of the large vessels are a height of 38 cm and a width 40 cm. Many vessels from the Tao River Valley do not have a record of their exact find spot, as they were bought by Andersson around site areas. In this case the vessel provenance is specified in the picture captions as “bought by Andersson”. Otherwise, the vessels were excavated by Andersson and his team.



Fig. 5.1. Examples of painted and impressed vessels: a) Painted, K-05058, Banshan, bought by Andersson b) Impressed, K-06384, Zhujiazhai.

²⁵ Detailed macroscopic analysis of each part of the vessel body and surface treatment is presented in the tables in the Annex 2.

This section summarises the results of the macroscopic analysis of the 52 vessels and suggests a reconstruction of the *chaîne opératoire* including forming, decorating, and firing. The steps before these actions, such as raw material selection and paste preparation are discussed in sections 5.2-4 together with the results of the experimental firing and petrographic analysis of geological samples and of the prehistoric sherds. The suggested sequence of the Majiayao-style *chaîne opératoire* from the raw material procurement to the finished product is discussed in Chapter 7.

Each step of the *chaîne opératoire* is illustrated with photographs of examples of traces of the individual steps as identified on the vessels. The inside of vessel bodies has a white-grey colour on most photographs. This is due to the white-light LED that was attached to the endoscope camera and the original inside body colour is usually reddish orange or yellow. Some vessels have a white-grey crust of secondary calcite covering their inner surface (Fig 5.2). The colour distortion of the inside surface will be clarified in the figure captions in the following analysis and in the figure captions in Annex 2.

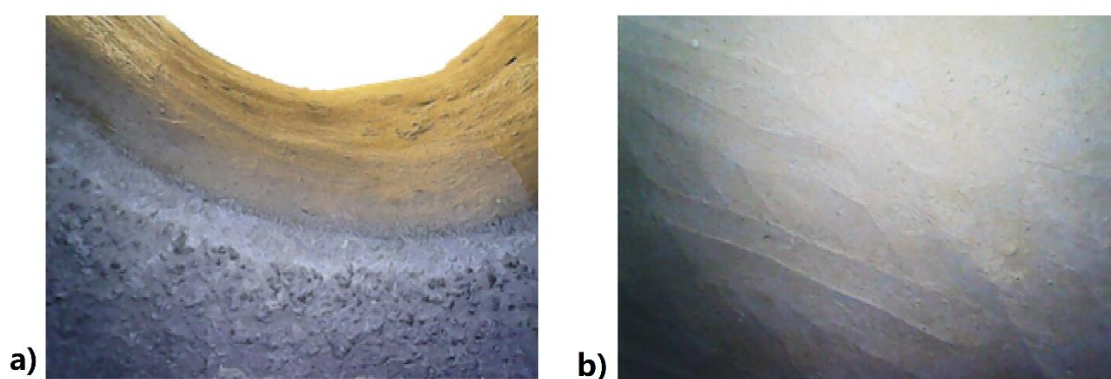


Fig. 5.2. a) White-grey crust on the inside of vessel K-05085 concealing its body colour on the inside; b) the inside of the vessel K-05126 illuminated by the white-light LED; the original body colour is yellow or reddish/orange yellow.

5.1.1.1 *Chaîne opératoire*: building methods

Step 1: Constructing the lower body

The vessels were all hand-built without using a fast wheel (Palmgren 1934:1; Bylin-Althin 1946:435; Hung 2011:50). The round bases are completely flat on the outside. They may have been flattened by hand first, then turned over and placed on a flat surface or a piece of weaving/ basketry work for the clay material to compress and stabilise the vessel (Fig 5.3).

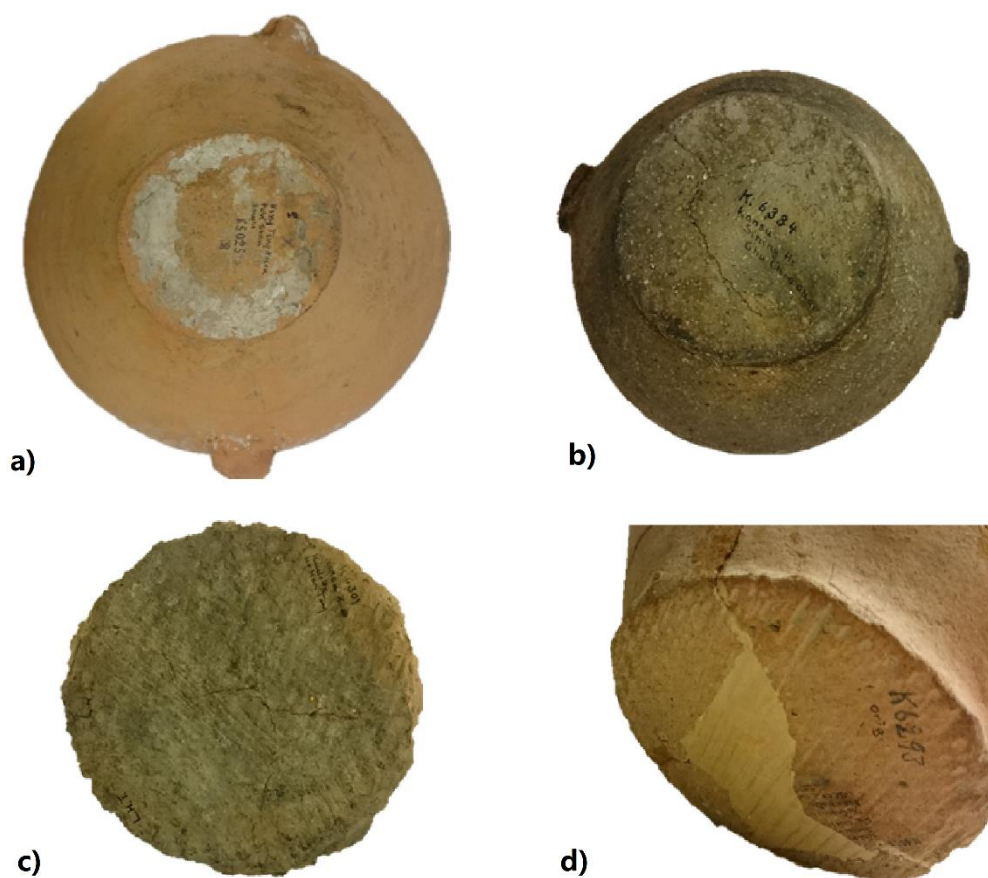


Fig. 5.3. Flat bases: a) K-05025, Banshan, Tao River Valley b) K-06384, Zhujiazhai; bases with weaving work or basketry imprints: c) K-06309, Luohantang d) K-06381, Zhujiazhai.

The joint between the base and lower body is angular, but on the inside of the vessel the transition from the body wall to the base is smoother and not angular (Fig 5.4). This means that the base was connected in a more organic way to the body before the angularity of the outside was shaped. Still, the round shape of the

base is clearly visible on the inside, and the surface can be bumpy. The traces of smeared clay inside the vessels K-05123 and K-05006 indicate applying extra layer of clay paste to thicken the wall and strengthen the join between base and wall (Roux and Courty 2019:145).

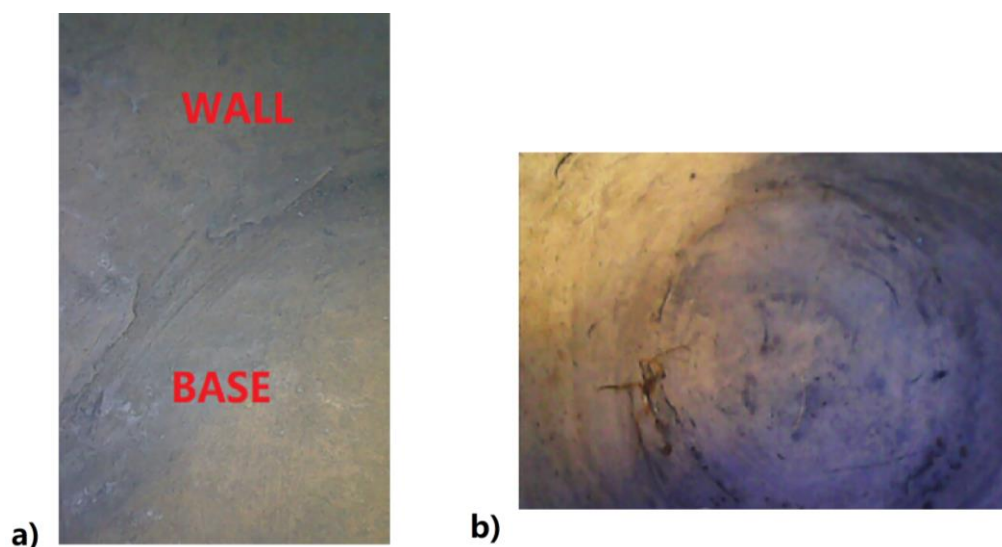


Fig. 5.4. Body wall and base joint on the inside: a) round bumpy base inside K-05123, Lanzhou, bought by Andersson original body colour yellow b) K-05006, Waguangzui, bought by Andersson, original body colour yellow.

The lower body wall on some vessels, clearly seen on K-05021 (Fig. 5.5), has rings of furrows running around the body from the middle to the base (or from the base to the middle). As the vessels were not wheel-thrown, these furrows indicate that K-05021 was built using coiling technique. Palmgren (1934:1) suggested that the vessels were built from bands of clay while Wu (1938:91) referred to them as coil building.



Fig. 5.5. Undulated ring furrows on the lower body; K-05021, Waguanzui, bought, original body colour yellow.

Coiling is a hand building technique used to construct pots of various sizes without a fast wheel (Rice 2015:135-136). Coils are long rounded bands of clay which are stacked on top of each other and then pressed and connected together with hands to shape the vessel walls. The bases of the Majiayao vessels appear to be made from a rounded slab around which coils were placed onto each other to create vessel walls. Vandiver (1988:156) suggested that the base was not coiled but made from a slab because she did not observe any coil rings at the base of radiographs of the five Majiayao-style (Banshan type) vessels she analysed. This technique to start coiling a vessel on a base slab is described and tested by Martineau (2000:125-130) in his research on Neolithic Horgen pottery in Switzerland. The base slab is thinned out at the edges which are then folded into the middle creating a groove around the inside of the base (Fig. 5.6).



Fig. 5.6. Experimental building of the base replicating Neolithic pot of Hogen culture; from Martineau (2000: Figure 43).

A coil is then attached to the edge of the base (Fig. 5.7), creating the starting point for constructing the vessel walls with additional coils.

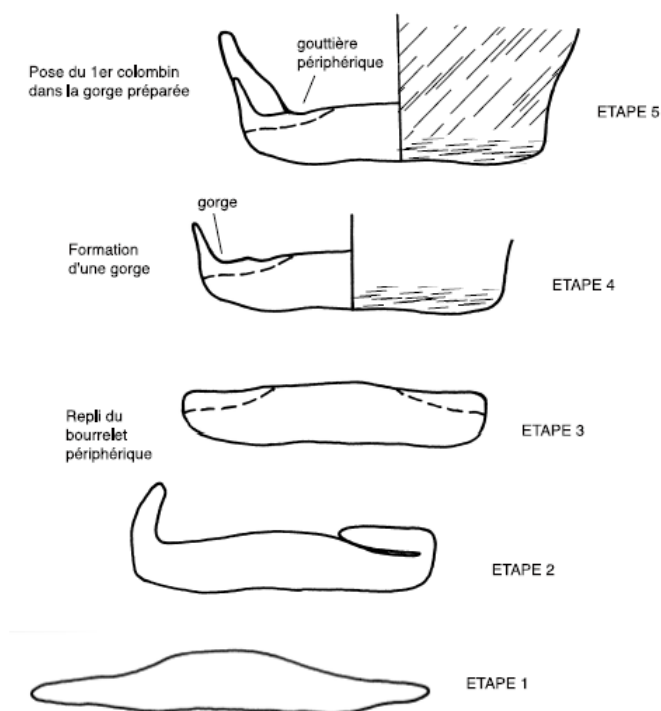


Fig. 5.7. The construction sequence of a Neolithic pot of Hogen culture as recreated by Martineau; from Martineau (2000: Figure 50), cropping by the author.

This technique shapes the rounded base inside the vessel similar to what can be observed in vessel K-05006 (Fig. 5.4b), and it is possible that the vessels of

Majiayao-style were constructed this way, although very few samples have been tested so far. Coarse and fine base sherds from Majiayao and Luohantang show traces of a similar building technique that support this suggestion. Base sherds made from fine and coarse clay show layers and fissures in the base-wall area in the cross section (Figs 5.8-9). The fissures resulted from joining a coil to the base edge (Roux and Courty 2019:165, Fig. 3.27c-d).



Fig. 5.8. CNP174, Luohantang, flaky break on the base on the cross-section and on the top view; traces of broken off coils are visible around the painted base surface; horizontal fissures in the base-wall join area seen in the cross-section and in the thin section of the cross-section.

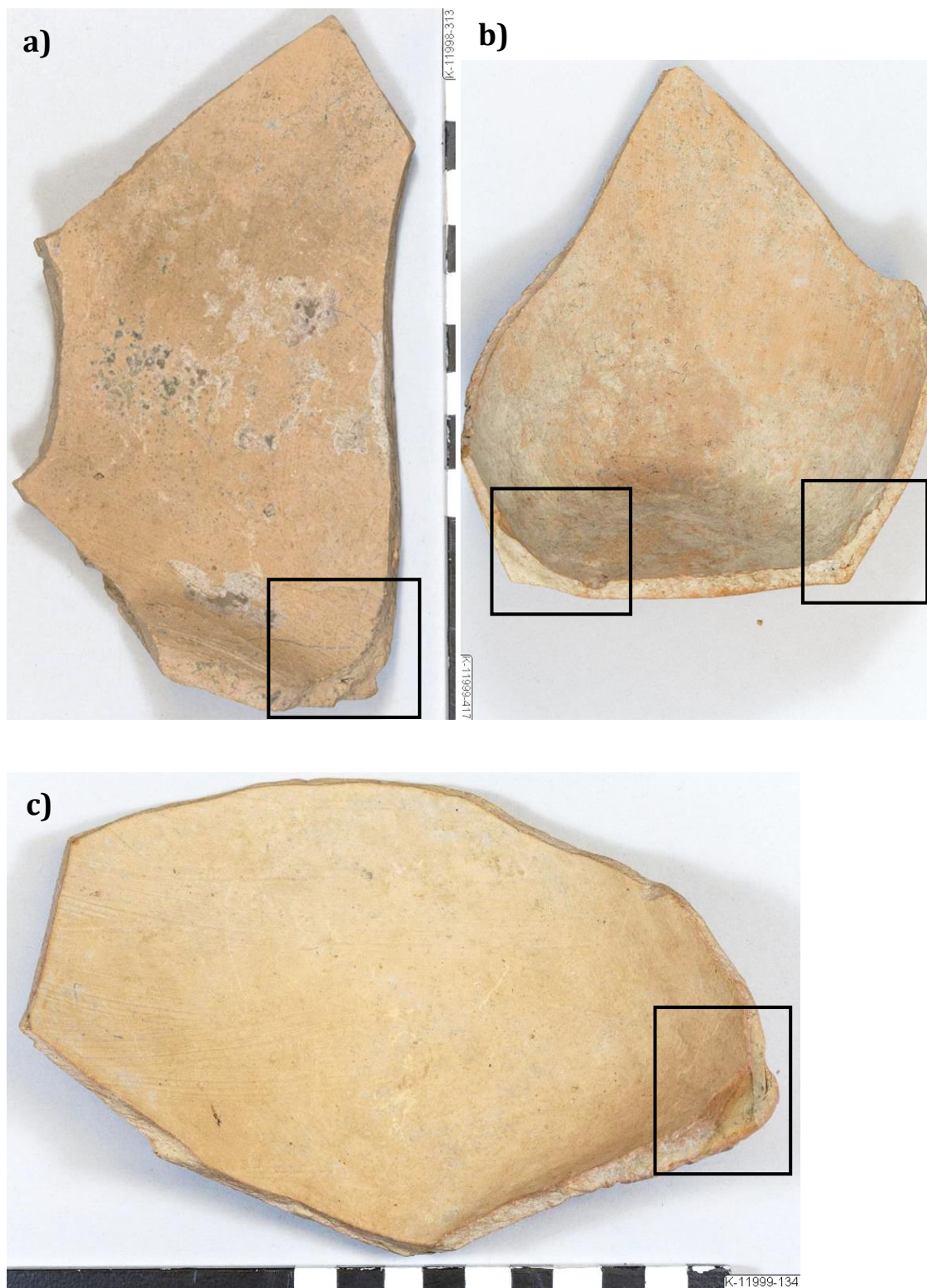


Fig. 5.9. Fine fabric sherds from Majiayao (not sampled for this study) showing layers and fissures in base-wall join area (marked); a) K-11998-313 b) K-11999-417 c) K-11999-134; photos taken from the MFEA online collection database.

Sherd K-11999-114 (Fig. 5.10, not sampled for this study) shows a prominent groove on the inside around the base surface, similar to the base shown above in the experimental work by Martineau (2000) (Fig. 5.6).



Fig. 5.10. K-11999-114 fine fabric base sherd from Majiayao (not sampled for this study) showing a groove around the inside surface of the base as a result of hand building; photo taken from the MFEA online collection database.

In the case of vessel breakage, the base disk would stay intact but the coils around it would break off as seen on the reconstructed vessels K-05797 and K-02093 (Fig. 5.11).



Fig. 5.11. Circumferential breaks at the base: left - lower body of K-05797 (max diameter 42 cm), from Palmgren (1934: Pl. XXXI, 4); right – base and lower body of K-02093 (vessel max diameter 20 cm, base diameter 9 cm), Zhujiazhai.

Since both fine and coarse vessels show similar characteristic in base building, it is possible that the basic construction techniques for both fabric types was largely the same.

The traces of coil building from the base upwards are clearly seen in cross-section on sherds from Luohantang (Figs 5.12-13). The cross-section shows diagonal folding and layering of coils which indicates coil building by pinching or spreading (Roux and Courty 2019:163; Gomart et al. 2020:53-54). Such folds are the results of pressure being applied to the coils when using either of the two techniques. Building by pinching means that each coil was placed slightly off-set onto the previous one and connected to it by pressure with the thumb on one side and fingers on the other side (Roux and Courty 2019:55). Building by spreading means that each new coil is placed against the last attached one and spread out flat creating the continuation of the vessel wall (Roux and Courty 2019:55).



Fig. 5.12. Diagonal folding and layering in the cross-section indicate coiling by spreading or pinching, CNP173, Luohantang.

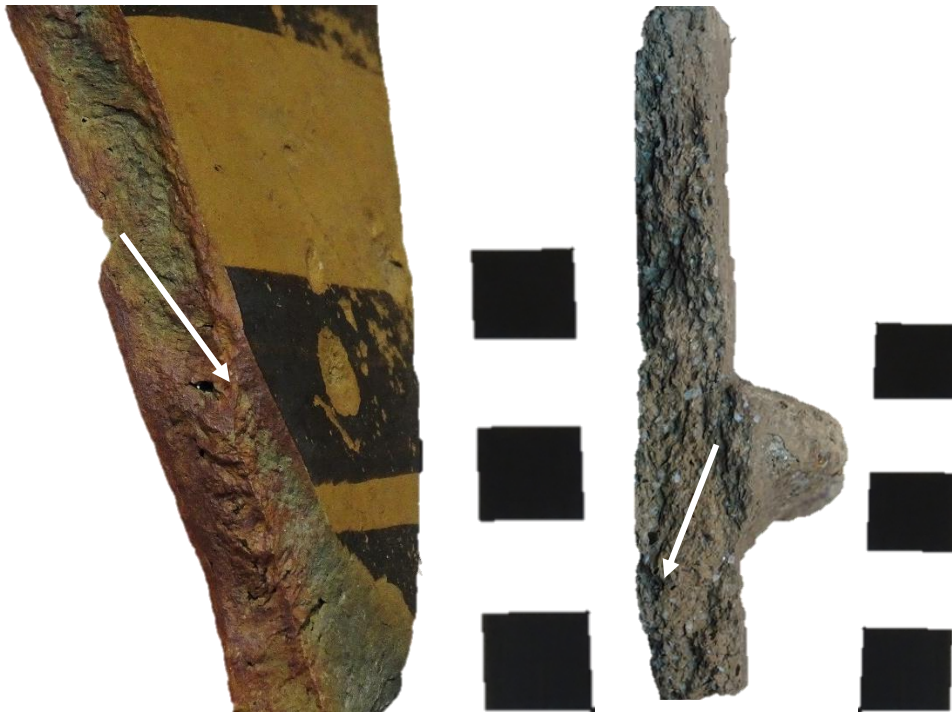


Fig. 5.13. Oblique folds of coil joints (white arrows) on fine and coarse sherds from Luohantang; left - CNP153 body sherd, right - CNP164 rim sherd.

The cross-section of a fine sherd from Waguanzui shows voids left at coil joints as a result of coils not sticking to each other completely during construction (Fig. 5.14).



Fig. 5.14. Coil joint voids in the cross-section of CNP75 body sherd, Waguanzui (the darker areas are wet from water).

A body sherd with a fine fabric from Luohantang shows flaking and oblique breaks which indicate coiling by spreading (Fig. 5.15).



Fig. 5.15. Body sherd CNP151 shows oblique breaks and layers of clay indicating coiling by spreading; Luohantang.

The cross section of the neck sherd CNP165 from Luohantang shows two or three layers of clay at the neck base which is the join area between the shoulder and the

neck (Fig. 5.16). These layers are spread-out coils and possibly an additional clay layer to strengthen the connection of the neck to the vessel body.

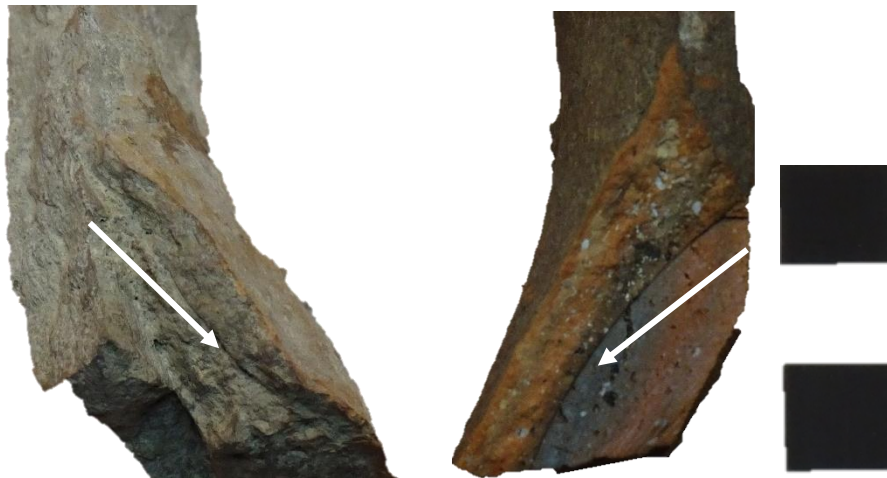


Fig. 5.16. Cross-section of a neck base showing layers of flattened out coils at the neck-shoulder join (white arrows), CNP165, Luohantang; left – before cutting; right – after cutting.

Further examples of coiling by spreading or pinching can be seen on thin sections of sherds from Majiayao and Zhujiashan (Fig. 5.17). The elongated oblique voids show the direction of pressure that has been applied to spread the coils and connect them. CNP16 (Fig 5.17) has a coarse-fine-combination fabric, and the thin section was cut at the joining area of the two parts. The diagonal orientation of the coarse (below) and fine (above) layers in the CNP16 thin section shows that the coils were connected by pinching and pressing the top coil downwards.



Fig. 5.17. Elongated oblique voids left from coil spreading and joining. Thin section scans, from left to right: CNP13 neck part of a rim sherd, Majiayao; CNP16 body sherd, Majiayao; CNP85 body sherd, Zhujiashai; CNP100 neck part of a rim and handle sherd, Zhujiashai.

Body sherd CNP181 from Luohantang with a coarse-fine-combination fabric shows a straight horizontal connection of the two parts in thin section (Fig. 5.18). The first coil of the fine fabric was joined by placing it on the coarse part without pinching or spreading.



Fig. 5.18. Straight horizontal coil joint of coarse and fine parts in CNP181, body sherd, Luohantang; left – cross-section, right – thin-section scan.

CNP181 is the only example identified among the analysed pottery material in this study that shows this type of coil joining technique. Hein and Stilborg (2019; Stilborg and Hein forthcoming), who included CNP181, CNP16, CNP36, CNP145, CNP155 CNP156 and CNP187 in their macroscopic and petrographic study of sherds with coarse-fine-combination fabrics, suggest that the coarse and fine parts of CNP187 were joined in a similar way as in CNP181. The cross-section of CNP187 shows oblique folds and layers and diagonal orientation of the coarse particles meaning that the straight coil joining is unlikely the case here (Fig. 5.19). CNP187 appears to be a part of the same vessel as CNP155 which also shows diagonal joining in cross-section.



Fig. 5.19. CNP187 body sherd, Luohantang; the arrows point out the direction of oblique coil joining by pinching or spreading.

One reason for using the straight joining technique in CNP181 might be that the lower – coarse – part was drier than the upper fine coil at the moment of joining. Therefore, it could not be merged with the coarse part by pinching or spreading. The joining of these coils was probably done by scoring the upper coarse coil and covering the surface with a clay slip acting as a strong glue and preventing the parts breaking apart (Roux and Courty 2019:55).

There are macroscopic and microscopic clues in CNP181 that support the assumption of the lower coarse part having a different water content during the upper body construction, which are discussed in the following. The juncture between coarse and fine is observable on the sherd surface (Fig. 5.20). The cord impression, which is the primary decoration of the coarse part, extends onto the fine part as well.

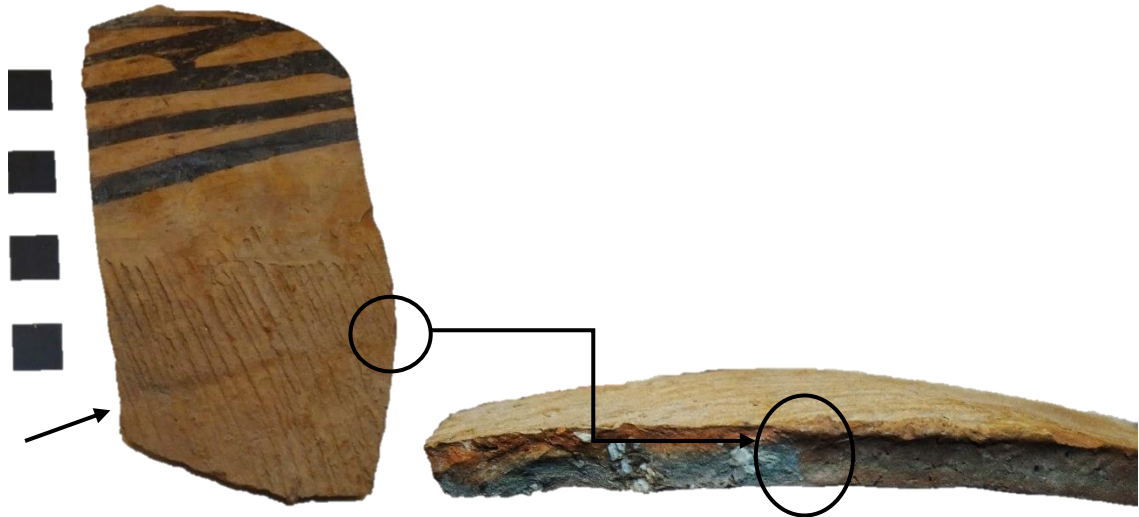


Fig. 5.20. Juncture line (arrow) between coarse and fine parts on CNP181 body sherd, Luohantang.

There is a slight difference in the depth of the cord impression below and above the juncture area on the sherd. The cord impression on the fine part looks a little bit deeper and more prominent than the impression on the coarse part (Fig. 5.21).



Fig. 5.21. Difference in the depth of the cord impression on the coarse part (left from the dotted line) and on the fine part (right from the dotted line); CNP181 body sherd, Luohantang.

This observation implies that the upper portion of the fine clay was wetter allowing for more prominent cord impression. The drying stage of the coarse part was probably between soft and firm leather-hard, where the shape was not likely to collapse or be further manipulated but the surface could still be impressed (Schreiber 1999:27). Drying the lower part of the pot is a known practice in hand-building of large vessels to prevent collapsing of the shape which can occur if the clay in the bottom part is still plastic (Roux and Courty 2019:160). If a large vessel built this way breaks, then the fracture commonly occurs along the juncture in the middle between the parts that had different water content during construction. An example of such fracturing and breaking is the painted vessel K-05797 (not analysed in this study), documented in Palmgren's study (1934: Pl. XXXI, 4 and 7) but now fully reassembled on display in the MFEA (Fig. 5.22).



Fig. 5.22. Vessel K-05797, found at Bianjiagou burial site (Tao River Valley), before complete reconstruction, showing the circumferential break between the lower and the upper part, max. diameter 42 cm; from Palmgren (1934:Pl. XXXI, 4 and 7).

The original vessel, which CNP181 was part of, did not necessarily break along the junction of the different fabrics. According to the profile of the sherd, the vessel was smaller and had a different shape than the typical globular shape of the complete vessels discussed here. The CNP181 vessel was probably a tall bottle

with a broad shoulder and an elongated neck. Microscopic study provides another possible explanation why the sherd did not break at the juncture and supports the assumption about the different water content in fine and coarse parts which therefore could not be connected by the commonly occurring pinching or spreading techniques. As seen in cross-section (Fig. 5.18) the coarse and fine parts of CNP181 have completely different core colours after being subjected to the same firing conditions. The fine part is dark red with a dark grey core, the coarse part is orange to the outside and bluish grey to the inside. However, the outside and inside surfaces of the pot are the same yellow colour. The difference in the core colours indicates that different clays were used to construct the two parts, whereas for example in the cross-section of CNP187 (Fig. 5.19) the parts show the same colour and groundmass (fine fraction and matrix) and differ only in coarse fraction. Petrographic analysis of CNP181 has shown that the fine part not only lacks coarse fraction but also has a different groundmass with a fine fraction of medium-silt size or smaller (Fig. 5.23). Under cross-polarised light the two matrices show different optical activity: the matrix in coarse fabric is less active but not vitrified, which is a further indication for the difference of these two clays on the elemental level.

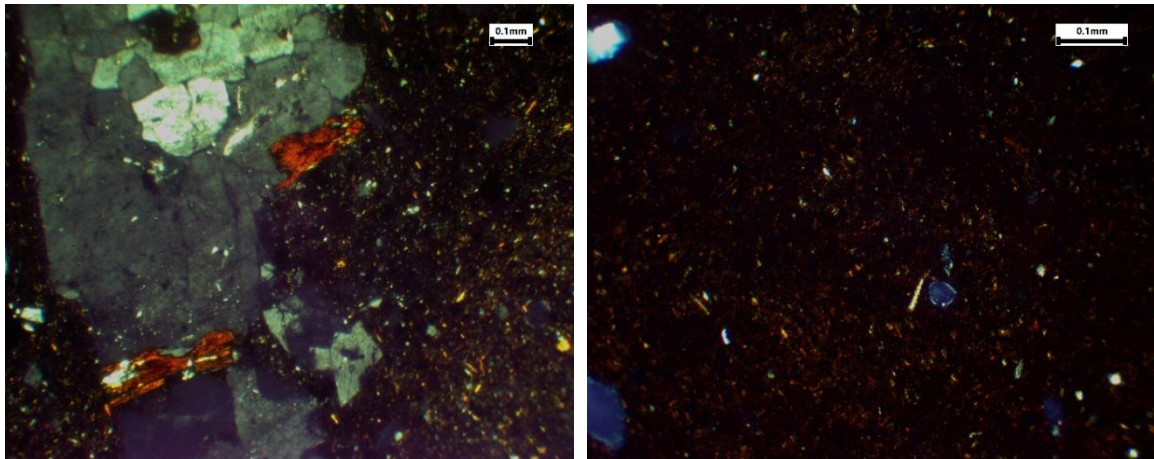


Fig. 5.23. Different clays used for lower and upper body of CNP181, Luohantang; photomicrographs taken under XPL, scale size 0.1 mm.

Chemically different clays with a different coarse inclusion frequency will have different shrinkage rates which can cause damage to the vessel during drying and firing. Stilborg and Hein (forthcoming) suggested that the shrinkage damage was avoided by keeping the coarse fraction of the coarse part not higher than 10% as seen in thin section, which they suggest is manually added temper. Low coarse fraction makes the clay less porous and therefore stronger (Schreiber 1999:4-5). Voids take up about 5% of the CNP181 fabric, so low amounts of coarse non-plastic inclusions might have played a role in keeping the vessel intact minimising the changes in fabric volume during drying. Stilborg and Hein (forthcoming) further pointed out the expertise and experience of the potter who made CNP181 in using the correct proportions of coarse and fine material. Indeed, the prehistoric potters must have been aware of the changes in clay paste volume and wall thickness of the vessel in the wet or dry condition. CNP181 has a predominantly uniform wall thickness of 5 mm which implies the potter's experience in being able to create uniformly thick vessel walls out of two different clays. This observation is directly related to the above discussion of the lower coarse part being soft to firm leather-hard when the fine part was attached. The potter was aware of the volume changes

in the coarse fabric during drying and was able to calculate the initial amount of fine clay needed to produce the same wall thickness in the finished vessel. Consistent wall thickness would minimise the risk of damage from shrinking during firing. It is unknown, however, how much the shrinkage rates of the two fabrics differed from each other.

Step 2: Letting the lower body dry for a short period so it can support the upper part

Letting the lower body dry was likely a step in the *chaîne opératoire* of the large/tall Majiayao vessel construction. Vandiver (1988:157) suggests that there were several drying phases as the body was constructed. She interprets the faint straight horizontal lines on the radiographs of a Banshan type vessel as coil joints between parts that had a different water content when they were connected (Fig. 5.24). This suggestion seems plausible because the joins are still visible even after being subjected to percussion treatment as the diagonal traces seen on the radiograph indicate. Vandiver (1988:157) argues that the walls of the Banshan type vessel were beaten after being constructed as the dents and diagonal lines seen on the radiograph around the body indicate.

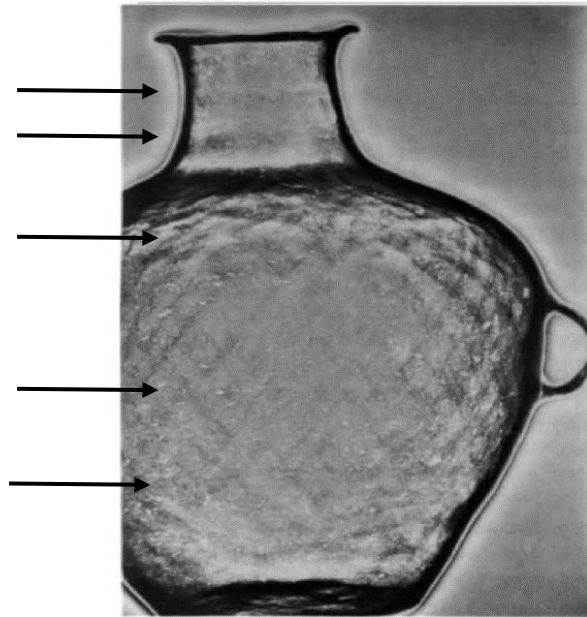


Fig. 5.24. Horizontal lines (arrows) from coil joins indicating drying phases during vessel construction; radiograph of a Banshan vessel from Peabody Museum, D2661 (Peabody number 2004.24.7703), max. diameter 30 cm, h 29 cm (from Vandiver 1988, Fig. 12a).

Although the radiograph of a second Banshan type vessel in Vandiver's study does not show similar indentations on the vessel walls (Fig. 5.25), she suggested that the beating was done after the vessel started drying so that no traces of this construction step were preserved (Vandiver 1988:159). It is not possible to be certain if all large Majiayao-style vessels were further shaped by beating from the results of Vandiver's study as only five vessels of different sizes were analysed there. The second Banshan type vessel (Fig. 5.26), however, shows parallel horizontal striations on the body which could either be traces of the primary forming technique – coiling, or secondary forming technique – wheel finishing, scraping, or burnishing. Judging from the straight horizontal orientation of the striations, these actions could have been performed using a turntable. In the present study, traces of wheel finishing found on vessel necks and will be discussed with regard to the vessel body construction in Step 6 in greater detail.



Fig. 5.25. Banshan type vessel, Peabody Museum, D7162 (Peabody number 41-92-60/7162), from Vandiver (1988: Fig.15).

The evidence for beating was also recorded by La Duc and Chang (2017) in their study of the Bronze Age Qijia-style vessels from the Harvard Museum collections. Qijia-style pottery is found across the study area and got its name from J. G. Andersson who studied it along with the Majiayao pottery. Chronologically, the Qijia style follows Majiayao style as established through archaeological research (Xia 1949). Large Qijia-style vessels show similarities in shape to the large Majiayao-style vessels examined in this study: a rounded upper part and conical lower body with loop handles. The radiograph of the upper body of a large Qijia vessel studied by La Duc and Chang (Fig. 5.26) shows dents from beating covering the body which cannot be seen with the naked eye on the vessel surface.

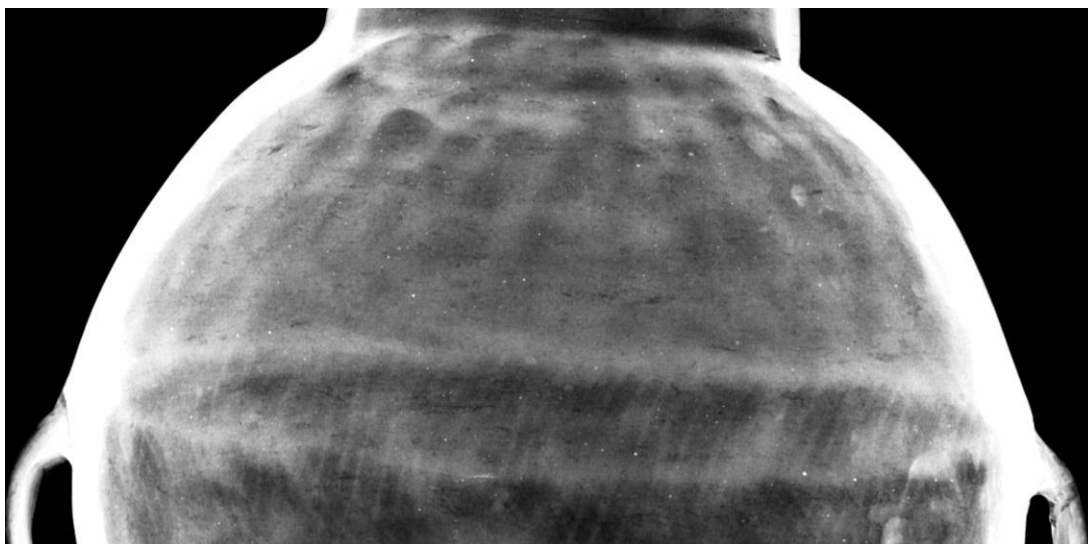


Fig. 5.26. X-radiograph of a large Qijia vessel; visible coil ring in the middle and indentations from beating in the upper part (from La Duc and Chang 2017: Figure 6).

Although they analysed a different vessel type to the one discussed here, Vandiver (1988) and La Duc and Chang's (2017) insights indicate that percussion technique was known and applied by the prehistoric potters in the study area and needs to be considered as a possible step in the *chaîne opératoire* here as well.

Step 3: Further shaping the lower body by beating with percussion tools and scraping

There are macroscopic indications that secondary forming techniques were applied on the lower body of large vessels with a height over 30 cm before the upper body was constructed. This is clearly observable on vessel K-05797 (Fig. 5.23) where the inside of the lower and upper parts shows strokes of different orientation. The lower body shows diagonal drawing marks running around the wall. Vandiver identified similar diagonal marks on the first Banshan type vessel (Fig. 5.25). She suggests that these traces could have been left by the next step after beating – rotating and shaping – to achieve the fully rounded shape (Vandiver 1988:157). As the photographs of K-05797 were taken from Palmgren's catalogue (1934: Pl. XXXI, 4 and 7) they do not have a high resolution and details of the inside marks are difficult to see. It is also not possible to acquire a modern photograph of

the inside because the vessel is now fully reconstructed and on museum display. However, even on Palmgren's low-resolution photo the inside surface of K-05797 is visibly uneven with possible traces left by the beating with a paddle or by a scraper. As this technique is performed in a circular motion on a vessel that is still wet or soft leather-hard, the clay could have been dragged along by the rounded anvil or scraper on the inside leaving diagonal traces (Rice 2015:147; Roux and Courty 2019:75, 178). Palmgren (1934:2) interprets these traces as smearing of clay while building the pot. This claim is disputed by Wu (1938:92) who suggests some kind of shaping technique with a wooden shield placed on to the outside surface to keep the vessel in shape. Wu does not call it beating or paddling but his idea is very similar to this technique.

Beating is commonly applied after building by coiling because it helps to strengthen the coil joints and conceal them, as well as create thin walls on large vessels (Fewkes 1941:163; Raven-Hart 1962:82; Rice 2015:147; Roux and Courty 2019:68). The wall thickness of large Majiayao-style vessels of similar shape varies and can also vary between parts of a single vessel. This has been observed on vessels that have holes from damage and on similar sized and shaped vessels with significant difference in weight. Vessel such as K-05021 (h 46 cm, d 47 cm) can have walls as thin as 3 mm (Fig. 5.27a-b). Considering the volume of this vessel, the weight reduction of the container might be practical for transportation if the vessel is full with liquid or dry content. In comparison, a smaller vessel K-05041 (h 33 cm, d 33 cm) is significantly heavier than K-05021 (Fig 5.27c). It was not possible to measure K-05041 body wall thickness because it was intact, but it stands to reason that the vessel thickness is greater than that of K-05021.

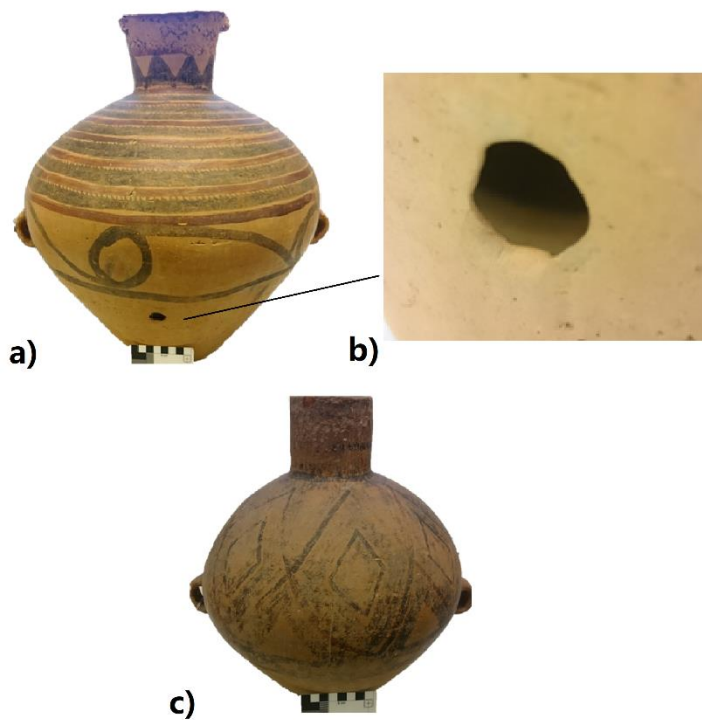


Fig. 5.27. Vessels with different wall thickness; a) K-05021, Waguanzui, bought by Andersson b) hole in the lower body of K-05021, wall thickness < 3 mm c) K-05041, Banshan (Tao River Valley), bought by Andersson.

In contrast to vessel K-05797, the inside surface on the lower body in vessel K-05152 does not show macroscopically visible shaping traces but the upper part does (Fig. 5.28).

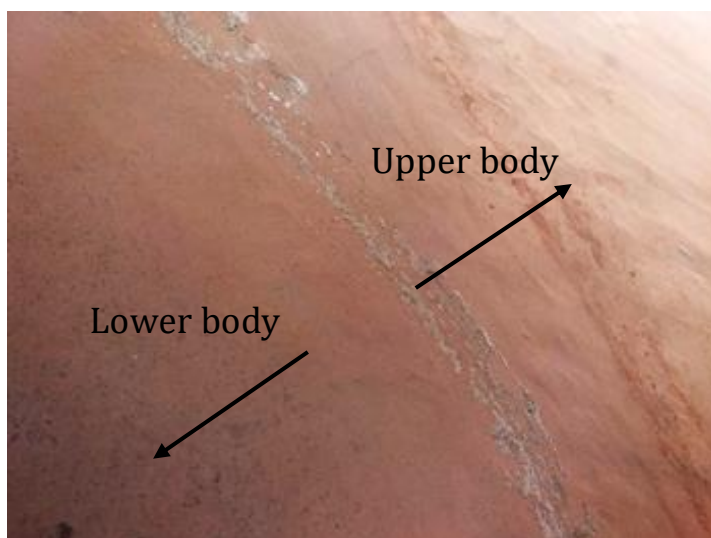


Fig. 5.28. Inside of the vessel K-05152, Lanzhou, bought by Andersson. Photo: courtesy of Michel Lee, caption by the author; original inside colour.

The smoothing of the inside surface might have happened when it was still visible to the potter – before narrowing the walls. Similar smooth surface can be seen on the inside of the open vessel K-05025 (Fig. 5.29)



Fig. 5.29. Smooth surface on the inside of the open vessel K-05025, Banshan (Tao River Valley), bought by Andersson.

Vessel K-05025 further shows similar diagonal drawing traces from shaping and connecting the upper part as K-05152 (Fig. 5.30).

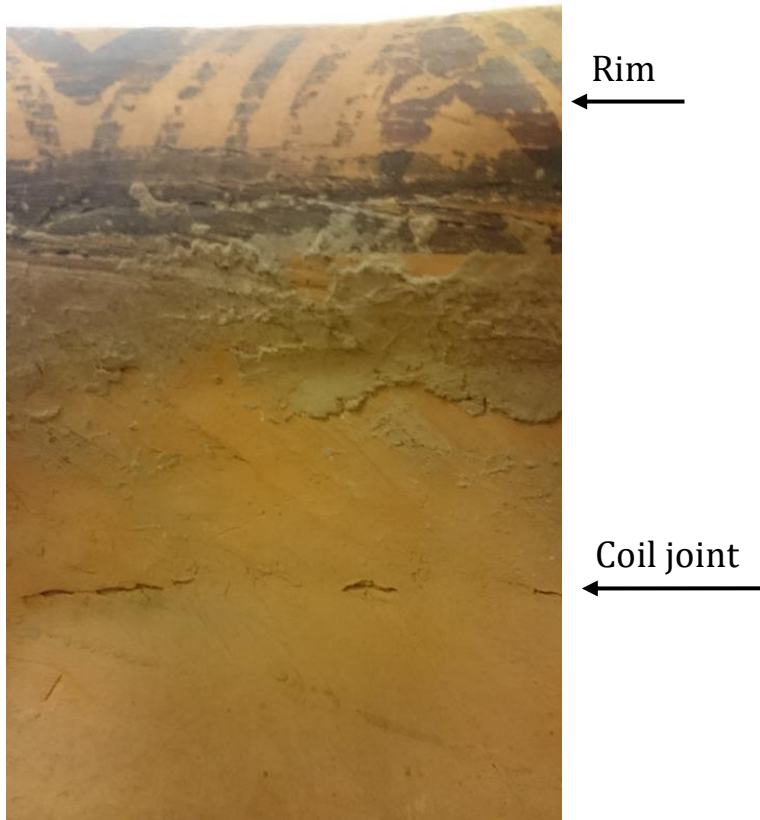


Fig. 5.30. Traces of surface smoothing and concealing the coil joints; vessel K-05025, Banshan (Tao River Valley), bought by Andersson.

About 88% of the sampled sherds have a thickness less than 1 cm. This homogeneity in wall thickness was also noted by Wu (1938:89). Therefore, it is highly likely that beating was involved in the *chaîne opératoire* of the Majiayao-style for creating thin walls. Traces of percussion treatment can also be identified on coarse sherds by looking at the position of the coarse inclusions on the vessel surface (Roux and Courty 2019:149-150). For example, the coarse parts of CNP36 and CNP187, CNP52, CNP87, CNP137 (Fig 5.31) show grains positioned at the same level as the clay surface which means that they were beaten into the paste during paddling (Roux and Courty 2019:149).

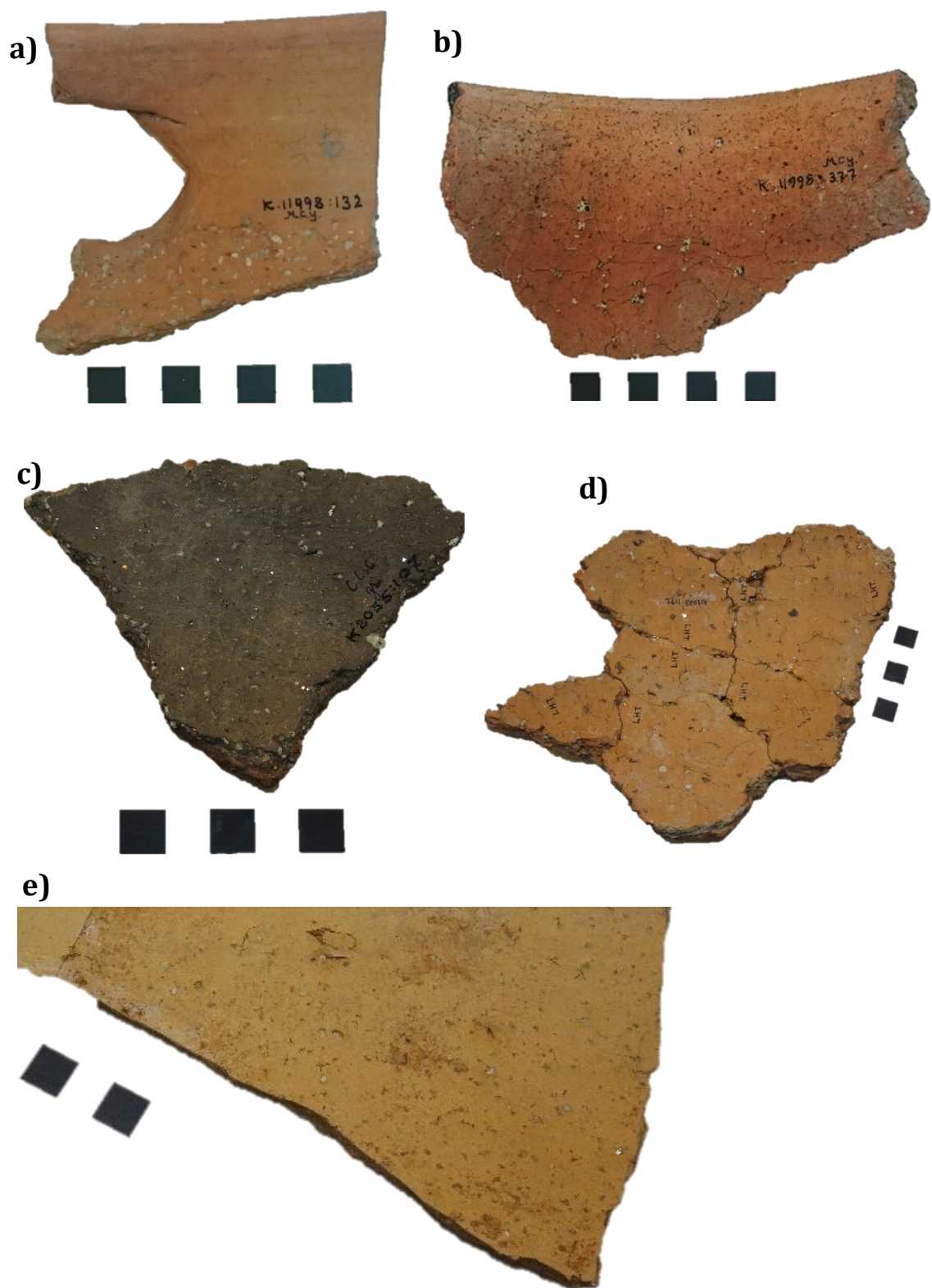


Fig. 5.31. Examples of coarse fabrics showing inclusions pressed onto the same level as the clay by percussion treatment; a) CNP36 rim and spout sherd, Majiayao b) CNP52 rim sherd, Majiayao c) CNP87 body sherd, Zhujiazhai d) CNP137 body sherd, Luohantang e) CNP187 body sherd, Luohantang.

Further, CNP137 and CNP187 show holes left from inclusions that have fallen out which could indicate that these pastes were beaten at a leather-hard stage rather than while being very plastic (Roux and Courty 2019:150).

After finishing the construction, the outside of the lower body was likely scraped into shape creating the angularity at the base. Vandiver (1988:157) and Womack (2017:325) identified diagonal scratches on the unpainted lower body of the vessels they analysed and suggest that these were left from scraping the vessel into its final shape. On the vessels analysed in the present study scraping traces are not as obvious. Some scratches have a clear direction (Fig. 5.32), and some look random (Fig. 5.33). Vessels K-05050 and K-05053 have almost perfectly smooth surface (Fig. 5.34). The variation in the presence and depth of the scratches indicates that the scraping took place at different stages in the drying process. It is difficult to tell if the lower body was scraped after the whole body was complete or before that.



Fig. 5.32. Scraping marks aligned in one direction on the vessel lower body; left - K-05282, bought in Lanzhou by Andersson; right – K-05155, Tao River Valley, exact provenance unclear.



Fig. 5.33. Randomly oriented scraping marks on the lower body of vessel K-05059, Paiziping (Tao River Valley), bought by Andersson.

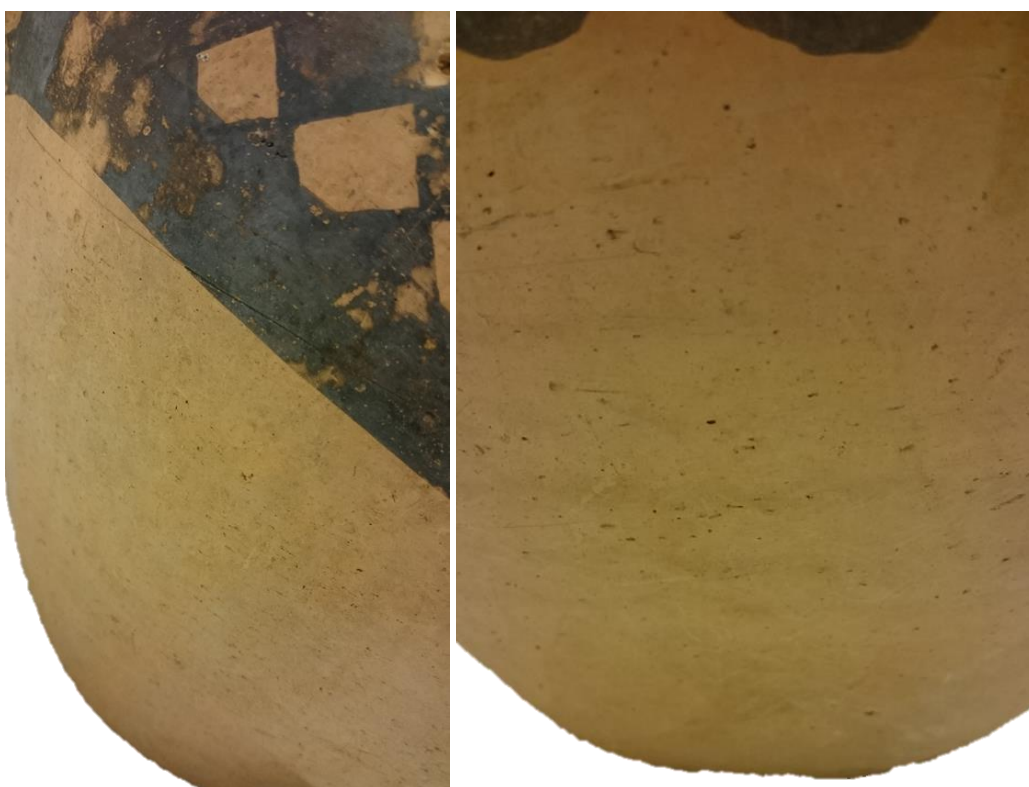


Fig. 5.34. Lower body showing almost no traces of scraping; left - K-05050, right - K-05053, both from Wanjiagou (Tao River Valley), bought by Andersson.

Step 4: Constructing the upper body on top of the lower body

The inside of the upper body does not show remnant coils but drawing marks following one direction or without clear stroke orientation (Fig. 5.35). Similar

marks are seen on the upper body of the previously discussed vessel K-05797 (Fig. 5.23). These marks run diagonally along the upper body in most vessels and may indicate the upwards drawing motion towards the mouth to shape the shoulder.

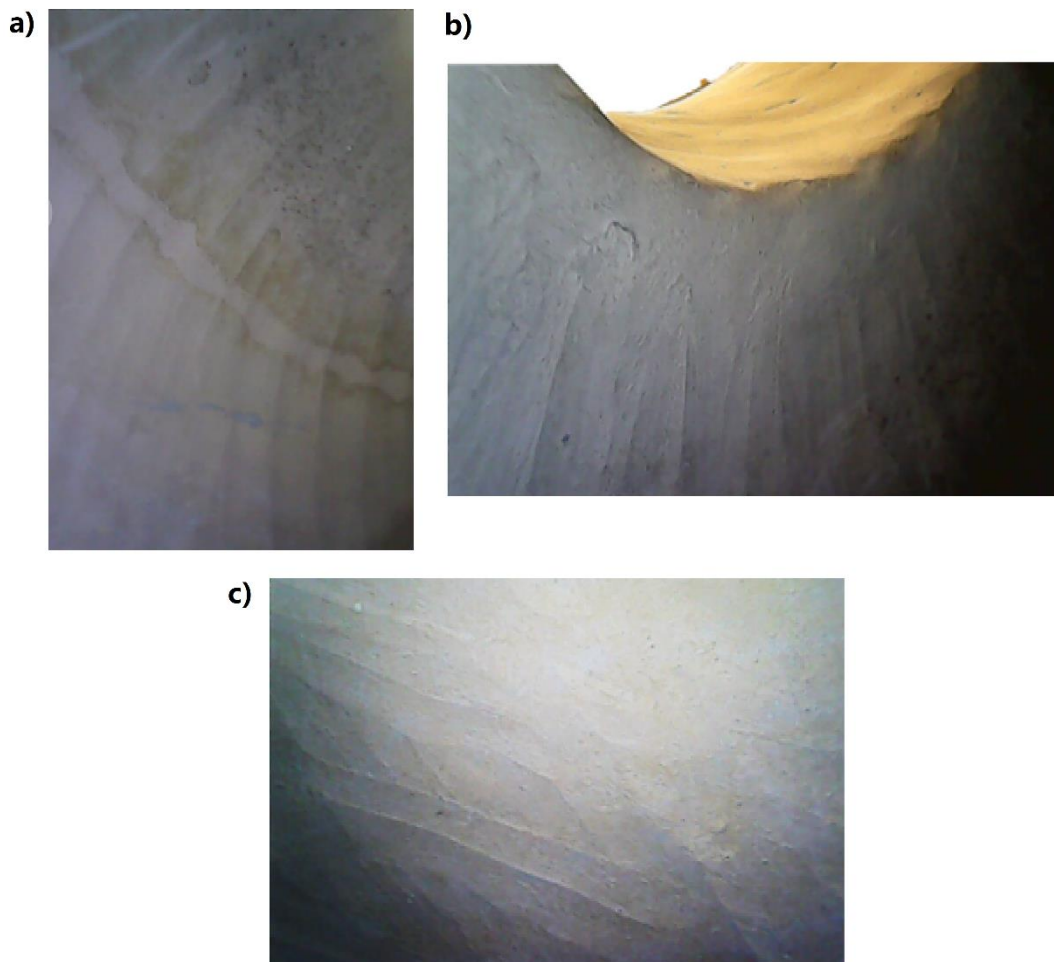


Fig. 5.35. Drawing marks on the inside of the upper body: a-b) diagonal stroke orientation towards the mouth, K-05132, Wangjiagou (Tao River Valley), bought by Andersson, original body colour yellow; c) no clear stroke orientation, K-05126, Banshan (Tao River Valley), bought by Andersson, original body colour yellow.

As in the case of the lower body, these traces could have been left during the beating process by dragging a rounded anvil or hand on the inside. Similar drawing marks are seen on the inside of body sherds (Fig 5.36). The clean horizontal breaks indicate fracturing and breaking along the coil joints. The crease pointed out on CNP99 (Fig. 5.36a) is a coil juncture in the middle of the vessel.

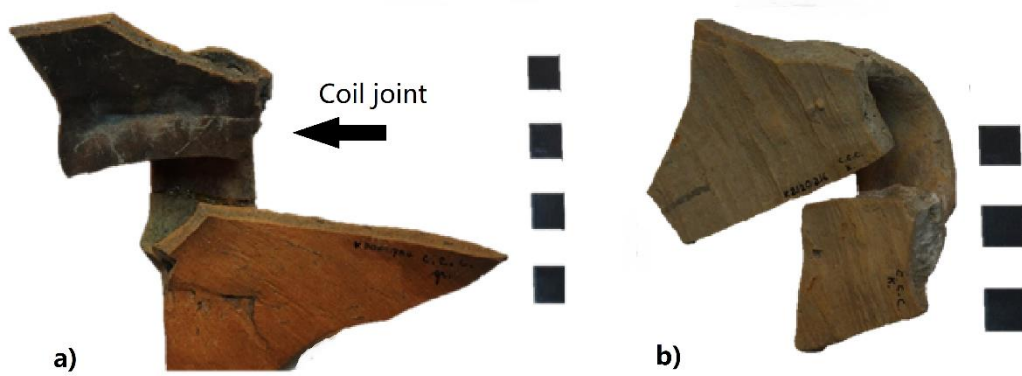


Fig. 5.36. Drawing marks on the inside of body sherds and clean breaks at coil joints; a) CNP99, Zhujiazhai b) CNP119, Zhujiazhai.

The uneven surface created by the dragging movement suggests that the beating was done on a not completely leather-hard body. A large fragment analysed by Palmgren (1934:Pl. XXXI,5) from now reconstructed vessel K-05962 shows lumps of clay that accumulated along the furrows (Fig. 5.37). Palmgren (1934:Pl. XXXI,5) claimed that the furrows were left by the potter's fingers during coiling, but they were more likely left by the secondary forming techniques such as beating or scraping, as they suggest dragging motions.



Fig. 5.37. Pottery fragment showing deep furrows created by anvil or scraper during the beating or scraping process (measurements unknown, probably min. 15 cm long); K-05962, Gaolan County, north of Lanzhou; from Palmgren (1934: Pl. XXXI, 5).

Step 5: Building the neck

The analysis of the neck has shown that it was built separately from coils after the vessel was formed into the desired shape. The base of the neck is attached almost at a right angle to the shoulder (Fig 5.38).

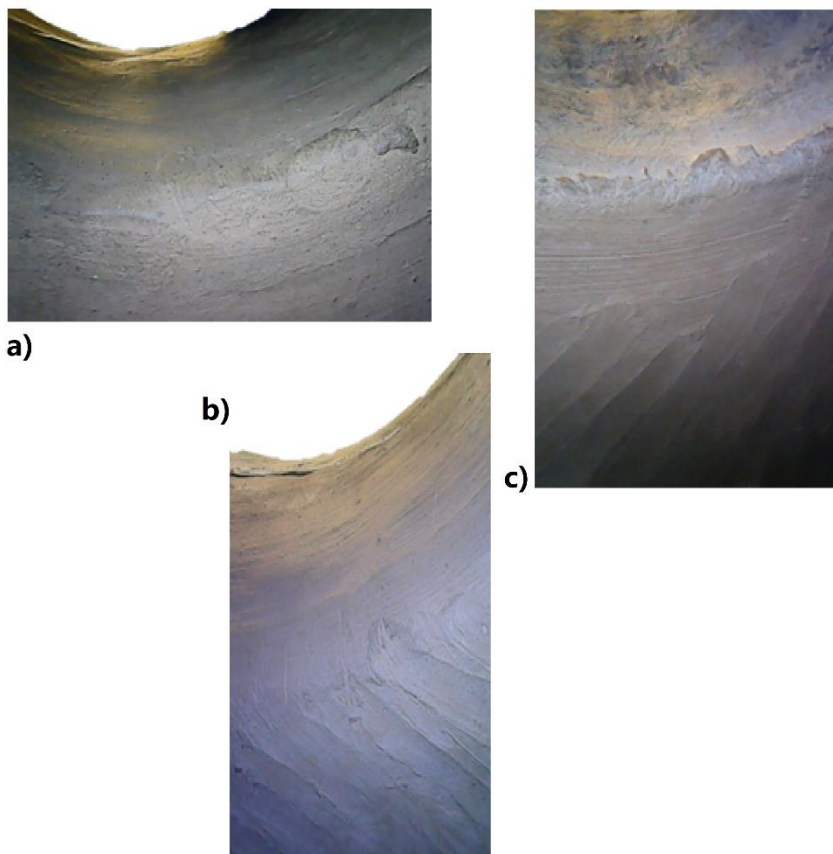


Fig. 5.38. Neck and shoulder joints seen from the inside, a) K-05050, original body colour yellow b) K-05053, original body colour yellow c) K-05465, original body colour yellow; all from Wangjiagou (Tao River Valley), bought by Andersson.

The overlapping drawing marks inside vessels K-05053 and K-05465 (Fig. 5.38b-c) suggest that additional beating took place after the base of the neck was constructed. It is also possible that after the construction the walls were further scraped or beaten to correct the globular shape after neck construction. The neck and shoulder part of vessel K-05962 (Fig. 5.39) shows the traces of circular movement around the opening on the inside performed to attach and shape the neck.



Fig. 5.39. Inside surface of the neck-and-shoulder part of K-05962 showing traces of circular motion around the opening (diameter 11 cm); Gaolan county, north of Lanzhou, from Palmgren (1934: Pl. XXXI, 6).

The traces of one possible technique for constructing the neck can be seen in the thin section of the neck and shoulder sherd CNP143 where the neck is made from a fine and the body from a coarse fabric (Fig. 5.40). The lower part of the sample is the coarse body fabric and is thicker than the fine upper part (Fig. 5.40b-c). The separation between parts is best seen in the thin section (Fig. 5.40c): an elongated void at the folding and attaching point and a clear line running from both ends of the void between the two fabrics. The clay forming the base of the neck is overlapping the clay of the body. The neck layer was pressed down and spread towards the shoulder and upwards, not fully merging with the coarse body clay.

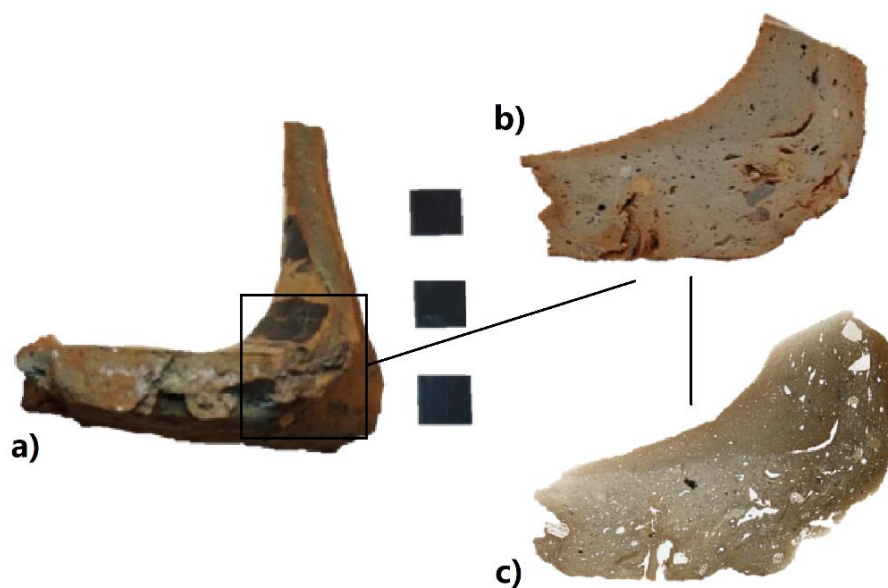


Fig. 5.40. CNP143, neck and shoulder sherd from Luohantang a) sherd b) cross-section of the neck and body joint c) scan of the thin section slide from the cut sample.

The prominent ring furrows and creases on the inside of the analysed necks indicate that they were coil-built (Fig. 5.41).



Fig. 5.41. Joint creases from coil-building on the inside of a neck. K-05021, Waguanzui, bought by Andersson.

Step 6: Finishing the rounded shape of the neck and rim by drawing on a turntable

The inside of the necks of vessels K-05159, K-05041 and K-05132 show similar diagonal marks from rotational motion on the inside as on the main body (Fig. 5.42). These indicate that the finishing steps for neck construction also involved pulling or pinching movements to connect the coils and create even wall thickness.

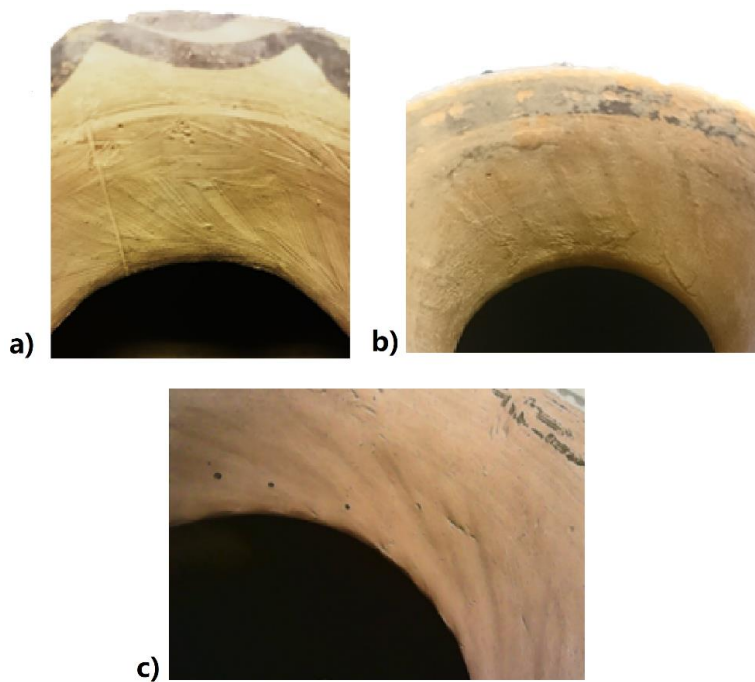


Fig. 5.42. Shaping marks on the inside of neck and rim; a) K-05159, Waguanzui, bought by Andersson b) K-05041, Banshan, bought by Andersson c) K-05132, Wangjiagou (Tao River Valley), bought by Andersson.

Vessels K-05465 and K-05282 have a slightly flared rounded rim with striations from rotational movement (Fig. 5.43). Palmgren (1934:3) suggests that the rims were moulded by using a round template that left these striations. Wu (1938:90) disagrees with Palmgren's suggestion and presents several arguments against the use of the mould. Wu (1938:90) argues that in case of the moulding technique many vessel openings would show standardised measurements. According to Wu, identical opening diameters are very rare among the vessels in the MFEA collection. Wu (1938:90) points out that the striations are only seen on the upper neck and rim and argues that a mould would have left traces on the whole neck surface if it was used by the potter. Wu (1938:91) is therefore convinced that the necks and rims were fashioned on a turntable and the striations were left by the potter's fingers. Sommarström (1956:84), Li and Huang (1993:73), and Vandiver (1988:157) come to the same conclusion that a turntable was used in vessel construction.

Indeed, the striations on the upper neck and rim look more like they were left by human fingers applying pressure from inside and outside rather than by a mould. Vessel K-05465 (Fig. 5.43a) has a thin flared rim which opens upwards from a straight neck. The rim has an even wall thickness and near perfectly rounded shape. It appears that the vessel was rotated on a turntable as the rim was pulled upwards and to the side to create the flared shape, similar to the movements in wheel-throwing.

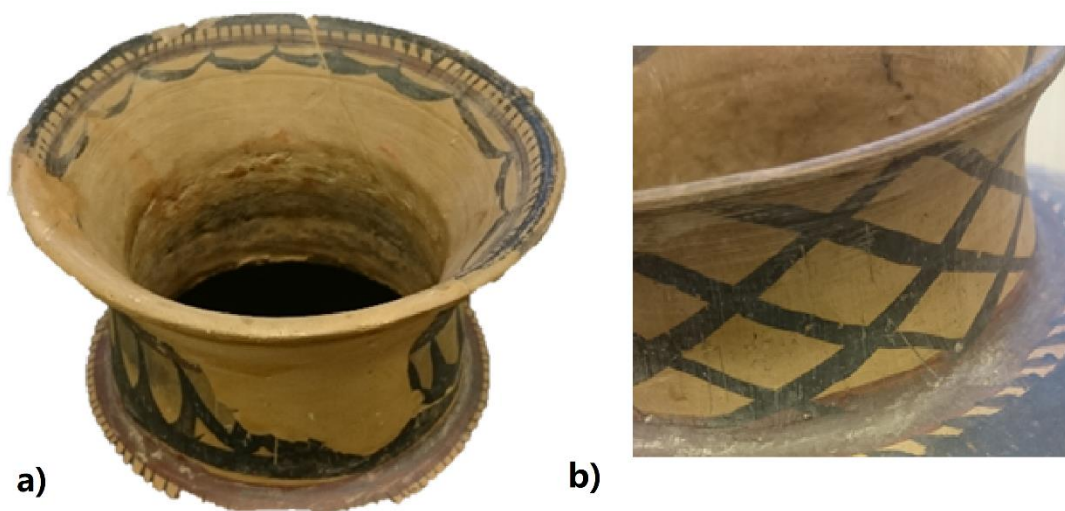


Fig. 5.43. Flared rims shaped on a slow wheel or turntable; a) K-05465, Wangjiagou, bought by Andersson (Tao River Valley) b) K-05282, Lanzhou, bought by Andersson.

Is it possible that a turntable or a slow wheel was used to construct other parts of the body and not just the neck? Roux and Courty (1998, 2019; Courty and Roux 1995) conducted experimental studies of construction traces on vessels where coil building was combined with applying the rotary kinetic energy on a turntable – a technique they call wheel coiling. The vessels in their experiment were coil-built and the turntable was employed at different stages during construction including from the beginning. The macroscopic traces left by wheel coiling – construction by coiling on a turntable – recorded by Roux and Courty (1998:751-753; 2019:180) look very similar to the striations left by wheel throwing. The macroscopic

differences between wheel coiling and wheel throwing according to Roux and Courty (2019:180-181) can be determined by the continuity of the wall thickness, visible creases from compression in the coil juncture zones, and an undulated inside surface.

The parallel striations on the inside of the lower body of K-05021 (Fig. 5.5) look similar to the compression creases described by Roux and Courty. However, the coil joins on the inside of the Majiayao-style vessels are often concealed by the secondary forming technique such as beating. The parallel striations are not found on the inside of every vessel analysed in this study and they are difficult to identify on potsherds. The wall thickness measured in Majiayao-style body sherds can vary up to 3-4 mm in different areas of the sherd. This observation confirms that they were hand-built but it is not enough evidence to suggest a turntable was involved in the building process.

The CNP126 rim-handle-body sherd from Zhujiazhai has a double-walled rim that could be characterised as made by wheel coiling (Fig. 5.44). As seen in the cross-section (Fig. 5.44, right), an extra coil was attached to the inside of the neck which was then shaped on the turntable. The inside of the body of CNP126 does not show striations or other trace that indicate construction on the wheel.



Fig. 5.44. CNP126 rim-handle-body sherd showing a double-walled rim possibly made by wheel coiling; left - top view of the rim, right - cross-section of the double-wall juncture; from Zhujiashai.

Roux and Courty (1998; 2019; Courty and Roux 1995) further suggest that wheel coiling is possible to identify in cross-section and in thin section. The vessels made by wheel coiling show elongated voids aligned almost parallel to the vessel wall in cross-section (Roux and Courty 2019:184). In the cross-section of Majiayao-style sherds where the void alignment is clearly observable, it is different from the void alignment of the experimentally made vessels by Roux and Courty. Majiayao-style sherds show oblique orientation of voids and layers left by spreading and joining the coils or from thinning the walls by beating (e. g. on Figs 5.13-15). The results of their experiments are difficult to compare to fine fabrics with low porosity, as little to no voids can be seen in cross-section.

Evidence for wheel coiling in thin section can be seen in the alignment of the particles in fine fraction, according to Roux and Courty (1998:754; 2019:185). Wheel coiled vessels would show an alternation between a randomly oriented and clearly aligned fine fraction. Random orientation indicates the coil join area, and clear alignment is the result of applying continuous pressure while rotation the vessel (Roux and Courty 2019:185). The fine fraction in several sherds from

Majiayao, Zhujiashai and Luohantang shows a clear alignment with straight or oblique orientation (Fig. 5.45a-c).²⁶ Clear alignment is characteristic for samples from rim and neck sherds, but body sherds can also have this feature.

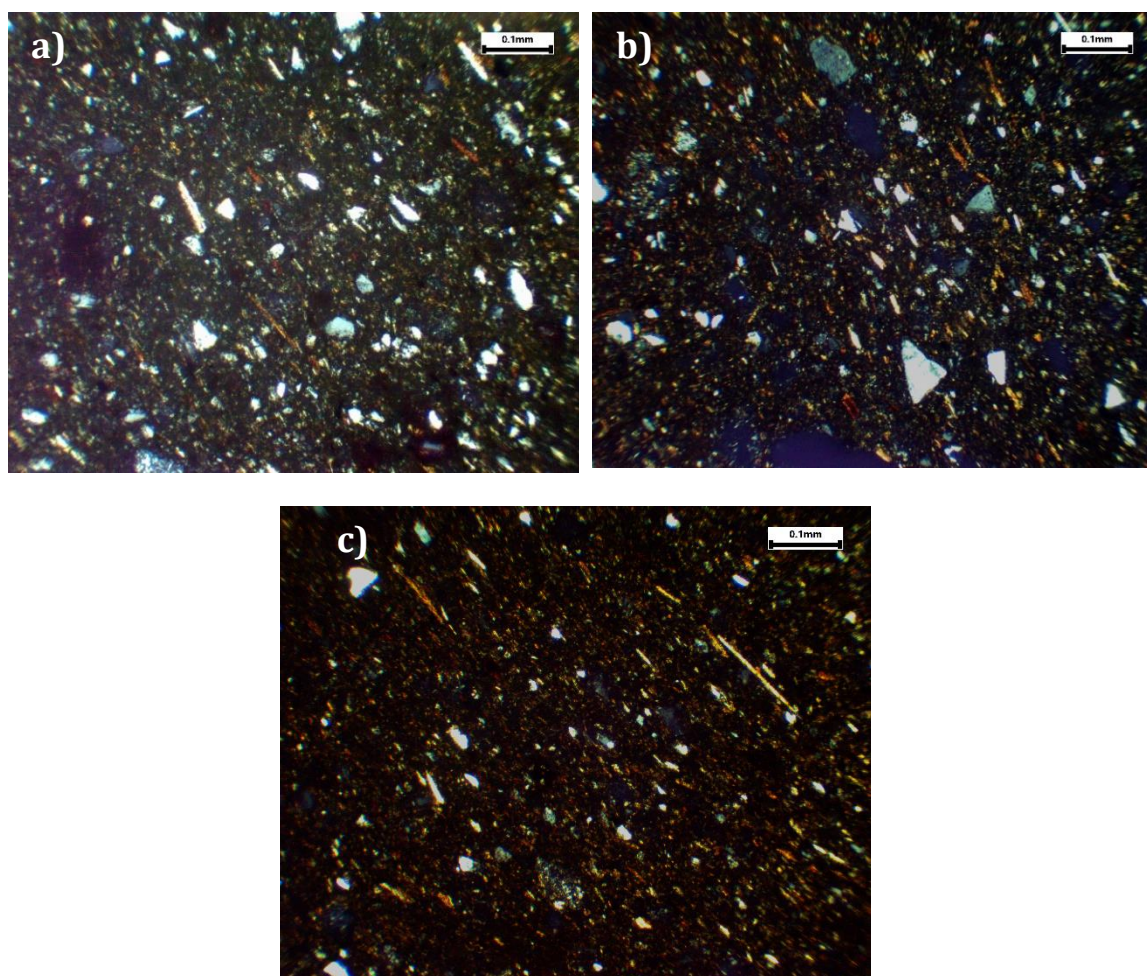


Fig. 5.45. Parallel alignment of fine fraction particles in thin sections possibly indicating wheel coiling; photos taken under XPL, scale size 0.1 mm; a) CNP50 body sherd, Majiayao b) CNP119 body-and-handle sherd, Zhujiashai c) CNP134 body sherd, Luohantang.

There are clear indications that a turntable was used in shaping the necks and rims of Majiayao-style pottery. However, there is no strong evidence that a turntable was employed in constructing the main vessel body. To approach this question, a macroscopic analysis on the inside and outside of larger number of vessels than in this study would be useful combined with a study of breaks on the sherds. Further, archaeological evidence of a turntable and an analysis of its use-wear traces would

²⁶ Fine fraction is difficult to observe on the thin sections of sherds from Waguanzui because the sections were made thicker than 30 μm .

contribute to the investigation. Archaeological evidence of the turntable alone does not reveal to what extent it was employed in construction. Roux and Courty (1998:748) point out that different motor skills are required for building on a turntable than on coiling only. Skills to use a tool is worth considering as an aspect in prehistoric technology transfer because these require close contact teaching. In the case of Majiayao-style pottery, an in-depth study of the extent of turntable employment from skills perspective could shed light on this issue though outcome of such a study might be uncertain due to the ambiguity of macroscopic features. A study of pottery skills is beyond of the scope of this thesis and will have to be approached in a future project.

The following steps 7 and 8 of the building process could be arranged in any order. It is difficult to infer from the finished product in which sequence these actions were performed.

Step 7: Burnishing or polishing the upper part of painted vessels

On painted vessels, only the upper body received extra burnishing or polishing treatment for an even paint application (Wu 1938:92-93). The outside of the upper body on vessels K-05114 and K-05163 shows horizontal furrows/ facets running around the body which have been likely left by burnishing. The moderate degree of paint preservation on the vessel K-05114 (Fig. 5.46, left) shows how the paint rubbed off along the high edges of the furrows but remained in the middle. Similar furrows can be clearly observed on K-05163 (Fig. 5.46, right) but the paint preservation there is better than on K-05114. The difference in paint preservation on vessels will be discussed below in section 5.1.1.2.



Fig. 5.46. Straight horizontal furrows running around the upper body left by burnishing; left - K-05114, Lanzhou, bought by Andersson; right - K-05163, Waguanzui, bought by Andersson.

Burnishing is a surface finishing technique that creates a smooth surface on the vessel by rubbing a hard, smooth object such as a pebble or bone when the surface is leather-hard (Rice 2015:149). This treatment not only conceals the traces of construction techniques but also aligns the clay particles in the upper layer parallel to the surface of the vessel so that they can reflect light creating a lustre (Schreiber 1999:39; Rice 2015:149; Ionescu and Hoeck 2020:5-6). The furrows on the vessels are likely traces of burnishing. Their parallel alignment indicates that the vessels were burnished on a wheel (Schreiber 1999:45; Ionescu and Hoeck 2020:3) which is an indication that the slow wheel or turntable was probably routinely used in the Majiayao-style vessel construction. Traces from burnishing not on a wheel are, for example, the vertical short lines left in the neck (Fig. 5.47). The neck was burnished while holding the vessel, e. g. on the potter's lap, but not on the wheel (Schreiber 1999:46).



Fig. 5.47. Vertical short marks on the neck below the flared rim left by burnishing not on the wheel; K-05007, bought in Lanzhou by Andersson.

Sherds that could have been used as potential tools for burnishing or scraping were described by Sommarström (1956:80-81; Pl. 8,11-15). Sommarström did not discuss the function of these sherds but called them knives or scrapers because of their elongated shapes with abraded edges. Among the scrapers there were also rounded sherds with similarly abraded edges (Sommarström 1956: PL.8,10; here Fig. 5.48). Such rounded sherds and scrapers have been excavated during the TRAP campaigns in the Tao River Valley. They are shaped like a disk or a semi-circle which resembles a rib tool. CNP93 from Zhujiashai has two perforations and a rectangular shape with an abraded and could have been used as a tool. However, these perforations might have also been left from repairing the vessel to which CNP93 once belonged and the abraded edge could be a result of post-depositional wear.



Fig. 5.48. Rounded sherd (left) and a scraper (?) (right); note the abraded paint on the right side of the rectangular sherd – this might have been left from a thumb holding the sherd; from Sommarström (1956: Pl.8,10-11).

There is research on use-wear of similar rounded sherds from prehistoric sites in Bulgaria (Vieugué 2015) and in the Ural region of Russia (Shamanaev and Zyrianova 1998). These studies have shown that ceramic sherds have been used in pottery production as tools for finishing techniques. To investigate whether this is a similar case with the rounded and rectangular sherds from the Tao River Valley the edges of these sherds need to be studied under low magnification to identify potential use-wear traces.

In contrast to the burnished surfaces above, the smooth surfaces on vessels such as K-05053 and K-05169 were probably polished as they do not show any traces of surface treatment visible by the naked eye (Fig. 5.49). Polishing is done on a dry surface, instead of a leather-hard surface, by using soft material such as cloth which does not leave any traces (Rice 2015:149). K-05053 and K-05169 could have also been wiped with a soft cloth after being burnished while still being leather-hard. This action would remove the burnishing marks and increase the lustre effect (Schreiber 1999:52). It is not certain that the wiping on the leather-hard or polishing on dry surface took place, but it is a possible explanation for the even and smooth surface. The neck of K-05169 (Fig. 5.46, right) shows the vertical burnishing marks whereas the shoulder does not imply that the upper body underwent extra treatment.



Fig. 5.49. Smooth, probably polished surfaces on upper body; left - K-05053, right – K-05169, both from Wangjiagou (Tao River Valley), bought by Andersson

On two painted vessels from Zhujiashai, the contrast between smooth and rough surface on a vessel was observed on the base and body wall (Fig. 5.50). The base surface is left rough showing the coarseness of the clay paste. There are two possible explanations for this contrast. The first one is that the base surface shows what the vessel surface looked like after construction and was then polished to press the coarse grains further into the body. The second suggestion is that the vessels could have been placed on a pile of crushed rock while wet so that the rock fragments stuck to the bottom. On the practical side, rough surface increases vessel stability. For example, when placed on an uneven ground, such as earth, the vessel could be slightly screwed into the ground for the coarse particles to cling on it. Another possible purpose of the coarse grains on the base would have been to prevent the clay from sticking to the turntable during construction and removal of

the finished pot.²⁷ If this was the case then coarse bases could serve as evidence for turntable usage during coiling of the body.

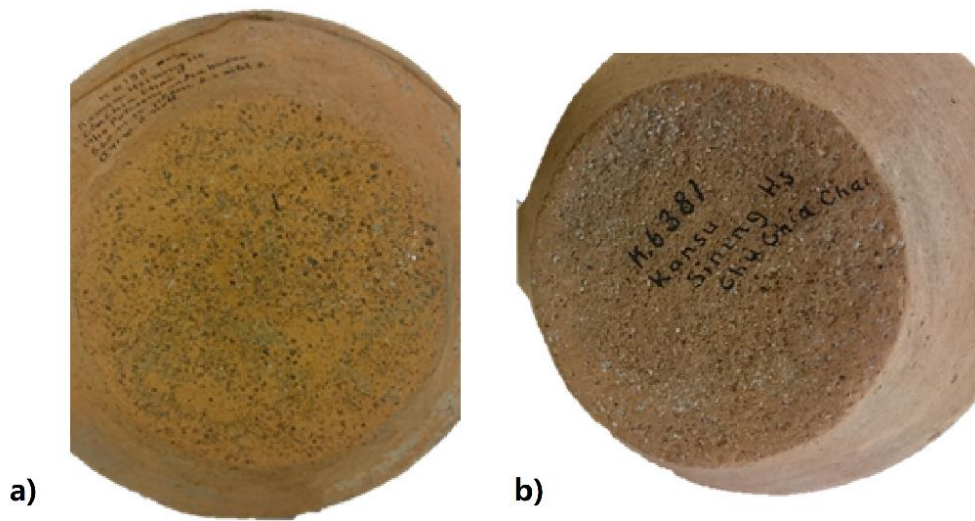


Fig. 5.50. Vessels with rough bases, a) K-06150, Zhujiashai b) K-06381, Zhujiashai.

Step 8: Building and attaching the handles/ grips and lids.

Handles/ grips

The handles on the vessels are small, ca 5 cm in diameter. They appear to be made from one coil. The coil was curled into a loop and both ends were pressed into the body from the outside. The sherd CNP91 shows that the body surface was incised and likely coated with slip so that the handle can stick to the body and stay attached (Roux and Courty 2019:90) (Fig. 5.51).

²⁷ I am grateful to Dr E. Kiriati for this suggestion.



Fig. 5.51. Incised marks in the handle area underneath the paint layer for better attachment, CNP91, Zhujiashan.

The handles are attached across from each other at the corner point just before the narrowing of the lower body (Fig. 5.52).



Fig. 5.52. Handle position on the vessel; K-05059, Paiziping (Tao River Valley), bought by Andersson.

Another way of attaching handles was identified by Palmgren (1934: Pl. XXXII, 7) on the vessel K-05165. This vessel is missing one handle and there are four horizontal scores where it was attached (Fig. 5.53). Although Palmgren identifies only two scores, after a closer look it is evident that two scores were made for the

upper end and two for the lower end of the handle. Each end of the handle coils was probably horizontally split in two and then placed into the scores.



Fig. 5.53. Four horizontal scores made for handle attachment; K-05165, Paiziping (Tao River Valley), bought by Andersson.

Considering the large vessel body, the small handles may seem impractical and rather decorative at first until one actually tries to pick up these vessels. The width of the loop opening allows for the index or index and middle fingers to push through. Placing the thumb on top of the handles and other fingers below creates a firm and ergonomic grip around the vessel body that facilitates picking up and carrying. The handles stabilise the grip on the vessel which has a smooth surface and could slip out and drop if it is full and heavy. The area with the handles has the widest diameter so that the vessel body naturally sits in the hands and its weight is balanced. They were perhaps meant to be carried and moved only by human hands as opposed to vessels that are hung on a rope. The small handles might not be able to support the weight of the empty or full vessel if it is hung or carried by only holding onto the handles. Based on the dimensions of the vessels, their average

capacity is about 10-12 l, which could make them quite heavy depending on the content. There has been no systematic data collection on the empty weight of the vessels but estimating from the author's experience from handling, a large empty vessel could be as heavy as 3 kg. The purpose of the small handles seems to be to prevent the hands from slipping. This also applies to the knob-like grips. Since most of the large vessels have very thin walls, the small size and the light weight of the handles/grips could be a practical choice in design to prevent the vessel body from deformation or collapsing.

Lids

Intact lids are rare in the MFEA collection or in museum displays in general – judging from the authors' personal experience in museums in Europe and China. The lid from Majiayao kept at MFEA (Sommarström 1956:PL.10,8; here Fig. 5.54) appears to be shaped in a similar way as a lower body of a vessel. Coils were stacked upon each other and merged together. The walls were probably shaped further on a turntable to achieve an even thickness throughout the lid then a rounded slab was placed at the top to close the opening. The lid handle was built from the rounded slab. In the end the lid was scraped on the outside into a conical shape, polished and painted.



Fig. 5.54. K-011999-129, Lid, d ca 20 cm, found by Andersson at Majiayao.

5.1.1.2 Chaîne opératoire: decoration

The steps made in decorating are different for painted vessels and for vessels with relief/ impressed decoration and are therefore discussed separately below.

5.1.1.2.1 Painted vessels

The painted decoration on all vessels analysed in this study was applied on the upper body, neck, and rim. The lower body below the handles is plain. Palmgren (1934:3, 175) suggests that this unchanging location choice for the decoration placement was intentional and the best view of the vessel was from above, for example, by people standing above the grave during a funeral. Andersson and Palmgren suggested that these vessels were made as mortuary objects that were

buried together with the deceased. This suggestion is disputed because fragments of painted vessels have been found on habitation and burial sites. Painted vessels analysed by Womack (2017:174) show prominent use-wear traces which indicate that that these vessels were in use prior to being deposited in the grave. While to the modern observer the placement of the decoration on the painted pots is best viewed from above, the prehistoric people may have had a different perception. The use-wear traces indicate that the pots have been used in everyday life and their high numbers in graves prove its function as a funerary object. Possibly, these vessels were made with the objective to be used as a mortuary object at some point but were used outside the funerary context before that.

The paint would have been applied after Step 7 – shaping and polishing the upper body and after drying. Through pottery making experiments, Li and Huang (1993:74) determined that the ideal water content of clay for painting on prehistoric vessels would be 17-16%. There is an uncertainty in the scholarship whether the painted vessels were coated with a slip. Palmgren (1943:5) argued that a slip was applied because the vessel surface has a lighter colour than the core of the vessel wall. He points out that slip makes the surface smooth and ideal for painting as well as gives it an even yellow colour.

Sommarström (1956:84) pointed out that slip is rare on Majiayao-style vessels and has a whitish colour. Vandiver (1988:157) also suggested that slip was applied because she identified trails of dripping liquid on the inside of the neck on one Banshan vessel as slip. Ma (2000:27) claimed that the pottery was coated with slip which gives it the characteristic yellow colour but provided no evidence to support this claim. Although Ma identified the mineral iron dolomite as being used for yellow colour on pottery samples (Ma 2000:59), he also stated that the purpose of

this pigment is unclear (Ma 2000:74). No observation of yellow paint or slip coating on the complete vessels was made in this study by the naked eye. It is difficult to tell from macroscopic analysis of sherds as well whether any coating prior to painting was applied on the surface. It is noticeable, though, that many painted sherds from different sites have a similar surface colour – yellow or pale yellow – on the inside and outside, even though the core colours in cross-section differ from them. There are two possible ways to achieve a similar colour inside and outside. First, there could be a specific technique for controlling the last firing atmosphere to achieve the yellow colour on both surfaces. The second way would be to coat the inside and outside in slip, possibly based on a similar recipe, which would turn yellow after firing. Both ways require technical knowledge that was gained by experience and possible information exchange between potters. The cross-section of the neck on vessel K-5011 (Fig. 5.55) shows that the yellow colour in this case is likely a result of firing. The sharp boundaries with the core are too thick to be a result of slip coating.



Fig. 5.55. Cross-section of the neck on K-05011 with sharp boundaries between the core and surface colours; cross-section length 1-2 cm; Waguanzui, bought by Andersson.

The damaged area on K-05165 (Fig. 5.53), where a handle is missing, shows that this vessel has a surface layer which peeled off together with the handle. The surface layer has a clear boundary to the exposed surface and could be a slip. The missing handle was probably coated in slip as well since a significant bit of the layer was torn off with it.

While the usage of slips on Majiayao-style painted vessels cannot be ruled out, it is difficult to identify a coating layer either through macroscopic or petrographic analysis of sherds analysed in this study.

The paint was applied with a brush and likely using a turntable to create even lines around the circumference of the vessel (Wu 1938:94; Li and Huang 1993:76; Hung 2011:50). The main colour used for painting is black, the red colour is added in the case of the later-period sub-types of Banshan and Machang. Sherd CNP81 from Zhujiazhai also has white paint. White paint seems to be rarely used in Majiayao-style painting (Hung 2011:51). This colour is not as ubiquitous on vessels as black and red.

Wu (1938:93) claims that the black colour was applied first and red second. However, as seen on vessel K-05058 (Fig. 5.56), where the colours overlap, this was not always the case.



Fig. 5.56. Overlapping black and red paint, K-05058, Banshan, bought by Andersson.

Red paint on vessels occurs in different shades. They range from bright red to maroon and brown. The thinner painted lines on vessels K-05085, K-05143 and K-05165 (Fig. 5.57) have a different paint density than the broad black lines and have the colours dark brown to dark blue. This difference in shades of red was already noticed by Wu (1938:93) who attributes these differences to the poor quality of the red pigment. The different hues might be due to the chemical composition of the paint and its reaction to heat and oxygen level during firing.



Fig. 5.57. Different shades of red seen on the thin lines in the decoration, and different degrees of paint preservation; a) K-05085, Lanzhou, bought by Andersson b) K-05143, Banshan, bought by Andersson c) K-05165, Paiziping, bought by Andersson (Tao River Valley).

The results of X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses on red paint by Ma (2000:54-58) showed that red pigment consists of hematite and cinnabar and brown consists of hematite and magnetite or a mixture of hematite and zinc-iron spinel. Ma (2000:60) explained that paint made from hematite keeps its red colour after firing with possible minor changes due to trace elements. Addition of zinc-iron spinel would give the paint a red brownish hue (Ma 2000:68). Paints made from cinnabar might change their hues – cinnabar needs to be mixed into other pigment and a binder to stay on the vessel surface (Ma 2000:60).

It is uncertain whether the colour shades are definite signs of poor quality, since the red pigment is sometimes better preserved than the black, as will be discussed below. The variety of shades, as investigated and pointed out by Ma (2000) are the result of different pigment minerals used for paint preparation. The paint

preparation as a technological activity includes recipe experiments and errors but also raw material selection that can result in a poor-quality paint as a result.

Palmgren (1934:174, ft-note 2) mentioned the results of the first chemical analysis of the black paint on the Majiayao-style vessels.²⁸ Two samples taken from K-05039²⁹ (Waguanzui) and revealed that the black paint consists of manganese and iron oxides. Further chemical analyses of the black paint carried out by Ma (2000), Chen et al. (2000) and Yan et al. (2013) using XRD, XRF and SEM-EDS confirm these first findings published by Palmgren. Ma (2000:58) provided a more detailed study of the black paint. He found that beside manganese and iron oxide, there is magnetite, hematite, and zinc-iron spinel (Ma 2000:58). Ma (2000:68) further notes that magnetite gives the black paint a bluish or grey colour, and zinc-iron spinel and magnetite give black a deeper shade. The black paint on the vessels from Liuwan burial site in Huangshui Valley was also confirmed through XRF and Raman spectroscopy to be made from manganese (Li and Yu 2018:50).

The poor preservation of black paint is the case on vessels that do not have a glossy surface (Fig. 5.58a-b). Vessels with a glossy surface show the best paint preservation of both colours (Fig. 5.58c-e).

²⁸ Analysis technique not specified.

²⁹ Not analysed in this study because this vessel is on museum display.



Fig. 5.58. Vessels with matt surface a) K-05058, Banshan (Tao River Valley), bought by Andersson b) K-05114, Lanzhou, bought by Andersson; vessels with glossy surface c) K-05465 and d) K-05169, Wangjiagou (Tao River Valley), bought by Andersson e) TEMP-0158, no find place data, presented by Hillevi Forsander.

This contrast is clearly observable on the painted vessels from Zhujiashai in the MFEA collection (Fig. 5.59). The painted designs on the matt surface of K-02093 are almost faded but colours black and red/ brown are still recognisable (Fig. 5.59a). The smaller vessel K-05913 (Fig. 5.59b) has a similar glossy surface like the vessels from the Tao River Valley (Fig. 5.58c-e).

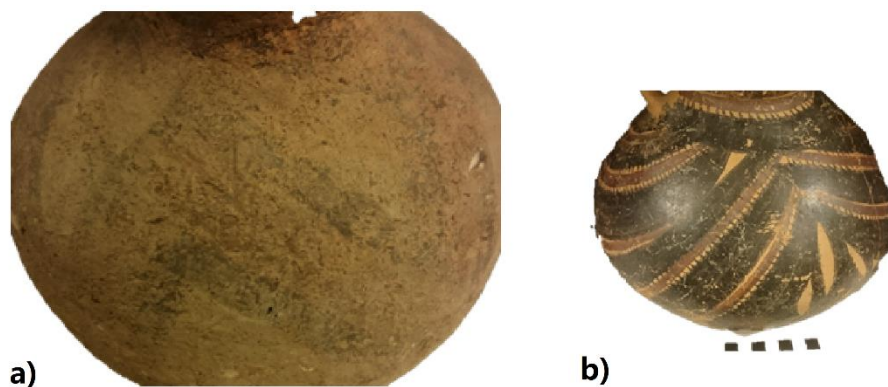


Fig. 5.59. Different paint preservation on vessels from Zhujiashai, a) K-02093 b) K-05913.

The faded decoration on K-02093 does not seem to have been caused by use-wear because it is consistently poorly preserved on the entire vessel surface. Both vessels were deposited as grave goods in the same environment at the Zhujiazhai burial area. Womack (2017:174) conducted macroscopical analysis on vessels with different paint preservation but coming from the same post-depositional environment. He concluded that the burial conditions do not significantly affect the degree of paint preservation and argued that the continuous poor preservation on vessels is due to the low quality of the paint or to the vessels being exposed to different environmental condition while being used by prehistoric people.

Hung (2011: Fig.3.13) macroscopically studied similar pottery with contrasting paint preservation found at the Liuwan burial site. She demonstrated that the pottery with less well-preserved paint is made of coarser clay than the pottery with well-preserved paint. Hung (2011:291, Fig. 3.13) suggested that the coarse painted pottery is a local product from Huangshui Valley and that the fine painted vessels were imported from the sites situated in Gansu. The macroscopic study of K-02093 (Fig. 5.59a) indicated that it was made of coarser clay than K-05913 (Fig. 5.59b). If Hung's (2011) suggestion is correct, different texture and paint preservation could indicate different technological choices in the *chaîne opératoire* to produce painted Majiayao-style pottery. Not only the clay composition but also the paint preparation could have been different.

Based on experimental work, Li and Huang (1993:76) claimed that to acquire the lustre and for a better adhesion of the paint the vessels are polished after painting. According to their experiments, the paint was applied after drying, and they do not mention any additional treatment in between these steps (Li and Huang 1993:74).

Ma (2000:28-29) put forward a similar argument: the pigments were rubbed into the vessel surface with a pebble or a shell and then fired. He further added that after firing the vessel is coated in a glue-like substance to prevent the pigment from detaching (Ma 2000:29). The differences in lustre between different Majiayao-style vessels was also discussed by Hung (2011:52) who suggested that the vessel with glossy surface were polished twice before and after being painted. Unfortunately, there is no photographic evidence of the paint being burnished into the vessel surface provided in these three studies. It would be useful to see what a vessel surface looks like after the paint was rubbed into it. In her manual "Ceramics for the archaeologist" Shepard (1985:39) mentions the action of rubbing the pigment in, though not in a connection with lustre as a result of this action but for better adhesion of the paint. As described above, the purpose of burnishing is to clear the surface from the forming and fashioning marks and create a smooth non-porous surface for painting. This step also needs to happen on a leather-hard vessel which could result in paint to be absorbed into the clay or cover the surface in uneven layers. Rubbing the paint in might result in flaking if coarse grains on the surface are pushed in or out by the pressure.

There are no examples of such paint burnishing applied to Majiayao-style pottery to the author. The difference in surface sheen could have been caused by different technological choices. First, it might have been caused by differences in porosity of the clay used in vessel construction. Burnishing vessels made from clay with fine grains and with low porosity will result in the surface having a lustre (Schreiber 1999:39) because this action will further compact the clay and arrange the particles flat side up so they will reflect light. Burnishing more porous vessel bodies made from coarser clays will result in a matt surface (Schreiber 1999:42-

43). Experimental research by Shepard (1985:123) has shown that there are clay types which remain matt after burnishing. Shepard (1985:123) further suggests that the lustre on the vessels is not a necessary deliberate technological choice of the potter – the types of available raw clays played a role in it as well.

The second reason for the surface sheen could be a slip coating (Shepard 1985:122). Application of slip on Majiayao-style vessels has not been thoroughly researched, yet. Nevertheless, slip coating would give the vessel a uniform colour and cover imperfections contributing to the lustre effect.

The third possible reason is discussed by Shepard (1985:124) as shrinkage of the clays during firing. High temperatures cause the clay to shrink eliminating the surface shine. Therefore, Shepard (1985:124) suggested that vessels with a lustre are low fired and soft. The shiny painted pots were likely fired over 850° C, so the lustre is unlikely the result of burnishing. The shine might have come from the vitrification of the black paint similar to the case of the glossy iron rich black slip on the Athenian pottery (Schreiber 1999:55; Dr E. Kiriati pers. comm.) However, previous research on paint used to paint Majiayao-style pottery showed that its main component is manganese (Ma 2000:58) which causes the paint to stay matt after firing and do not become lustrous (Dr E. Kiriati pers. comm.). This observation contradicts with the fact that some of the pots exhibit a bright lustre (e.g. Fig. 5.58 c, e). Investigating this issue in paint preparation would be a part of a future project involving SEM analysis.

Another clue to the surface treatment steps before firing can be found on vessels K-05001, K-05007, K-05021, K-05123, K-05026 as well as on CNP78 which show faded black and red painted marks repeating the Majiayao-style motifs (Fig.

5.60).³⁰ Palmgren (1934:6) called these brand-marks and suggests that these are imprints of decoration from other vessels when they were stacked together in the kiln. K-5831 (Fig. 5.61) has one of the largest marks documented so far on vessels in the MFEA collection.



Fig. 5.60. An example of the faded painted mark; K-05007, Lanzhou, bought by Andersson.

Most of them are located on the unpainted lower body part, which reinforces Palmgren's hypothesis.

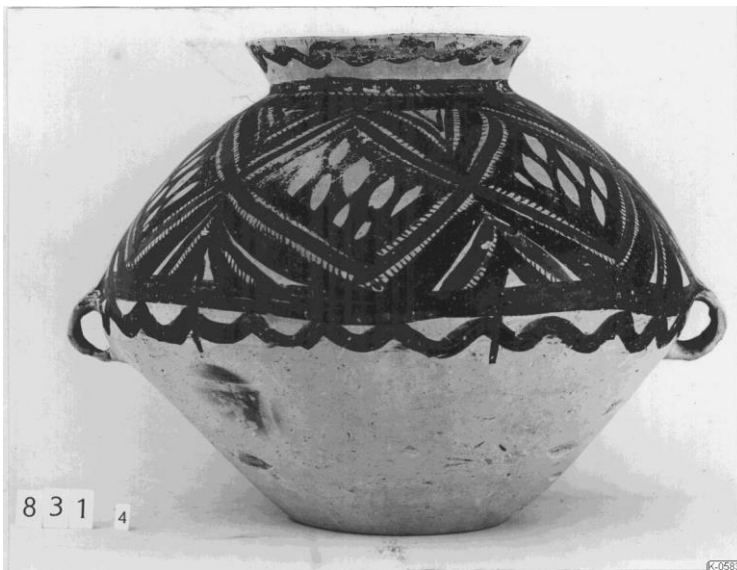


Fig. 5.61. Faded imprint of a painted motif on K-05831, Banshan (Tao River Valley), bought by Andersson. Not analysed in this study, photo from MFEA online collection database.

Womack (2017:169; Womack and Wang 2020:8-9) calls these faded marks “fire shadows”. He also concludes that these marks were left from pots touching in the kiln during firing, so that parts of the paint were burned from one vessel onto

³⁰ See also “Macroscopic analysis: Special features” in Annex 2.

another. Womack (2017:170) further argues that the marks were unlikely imprinted after firing because according to his experience the paint layer is permanent and does not rub off easily.

The faded marks as the result of too close stacking in the kiln seems plausible as they resemble an imprint more than a painted mark which are also present on painted vessels and are discussed below. It is worth noting that most of these imprints are from black paint. As discussed above, black paint does not seem to adhere as well to the vessel body as the red paint. The faded marks indicate that the poor preservation state of the black paint on some vessels is not completely caused by use-wear, post-depositional environment, or post-excavation treatment. Black pigment being more prone to abrasion points to a difference in paint recipes and raw materials not only between black and red but also between the black pigments on different vessels (Figs 5.57-59). The faded marks show that the paint at least on some vessels was unlikely rubbed into the vessel surface as suggested by Li and Huang (1993), Ma (2000) and Hung (2011). The specific technological choices leading to a glossy vessel surface are still unclear. Addressing this issue in a future study might also shed light onto the different degrees of red and black paint preservation.

For the black painted marks such as on vessels K-05160 and K-05146 there might be two possible explanations (Fig. 5.62a-b).³¹

³¹ See also “Macroscopic analysis: Special features” in Annex 2.

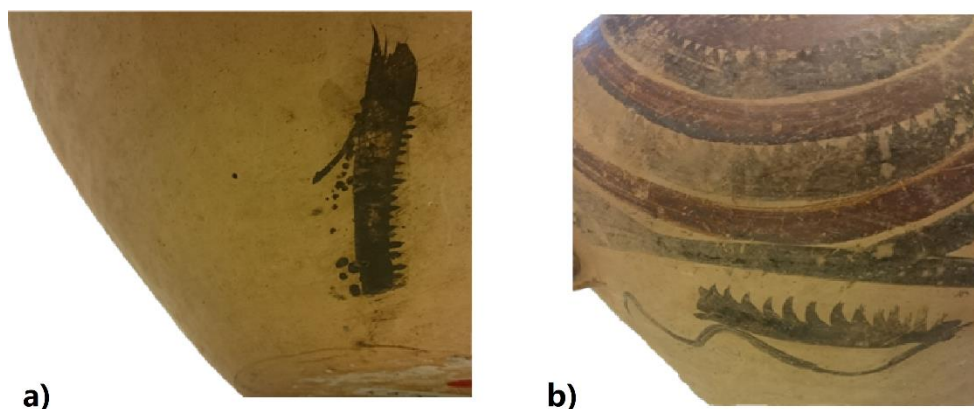


Fig. 5.62. Black painted marks on vessels, a) K-05160, Banshan, bought by Andersson b) K-05146, Banshan, bought by Andersson.

One explanation was suggested by Palmgren (1934:176) who called these marks a “practice sketch”: the painter could have tried out the brush or paint to see if the results were as hoped. Both marks show lines of different thickness and curvature and the spikey line pattern. K-05160 (Fig. 5.62a) additionally has dots of various sizes. The question here is: why would they test out the brushwork on the vessel they are about to decorate instead of picking another surface such as a discarded sherd? The second explanation, also suggested by Palmgren (1934:176), could be a potter/ painter/ workshop mark.³² Painted marks are not uncommon on Majiayao-style large globular vessels. Altogether 198 different types of marks have been identified by Chen (2012:93) on the vessels found at the Liuwan burial site (柳湾墓地) in Qinghai (Fig. 5.63). Palmgren (1934:177) further noted that no identical marks were found on the pots in the MFEA collection and similar marks are very rare.

³² In his book, Palmgren (1934:174-179) gives further examples of such marks on vessels which were not included in this study because they are on museum display.



Fig. 5.63. The variety of painted marks found on vessels from the Liuwan burial site in Qinghai. From a poster in the Liuwan Museum of Painted Pottery.

These marks are prominent and easily seen at first sight, in contrast to the faded marks described above (Figs 5.60-61).



Fig. 5.64. Vessels with marks on display at the Liuwan Museum of Painted Pottery.

The largest painted mark observed by the author on the vessels kept at MFEA is located on the lower body of K-05464 (Fig. 5.65). Palmgren (1934:175) thought that the mark resembles a running animal, but he was not convinced that the mark was intended as an actual drawing. Its amorphous silhouette stands in contrast to the elaborate decoration on the upper body of the vessel (Palmgren 1934:175). The strokes look rather random like an actual brush or paint trial. Accidents in production cannot be ruled out, as well as the possibility of a child playing with the brush and leaving their own mark.



Fig. 5.65. Large painted mark on the lower body of vessel K-05464.

5.1.1.2.2 Vessels with cord-impressed and appliqué decoration

The most frequently occurring relief decorations are cord impressions and appliqué. The cord texture is recognisable by its wavy shape, and it is different from, for example, the basket impressions or carvings that occur on Bronze Age Qijia-style pottery which are lines of wider and more shallow impressions (Womack 2017:182; La Duc and Chang 2017:1864-65). The cord lines can follow different directions.³³ Three common orientations of the cord decoration were identified by studying vessels and sherds: straight, diagonal, and crossing cords (“cross-cord” in the sherd description table; Fig. 5.66).



Fig. 5.66. Cross-cord decoration, a) CNP22, Majiayao b) CNP169, Luohantang.

³³ See also “Macroscopic analysis: Surface treatment” in Annex 2.

The cord impression had to be made on a leather-hard pot to achieve the depth of texture. Vessels K-06292 and K-06384, both from Zhujiashai, have a diagonally oriented continuous cord pattern (Fig. 5.67). Turning the vessel upside down and looking on top of the base gives the impression that a “cord-sheet” was wrapped around the vessel to create such a regular pattern. The design is wrapped around the base in a spiral-like way.

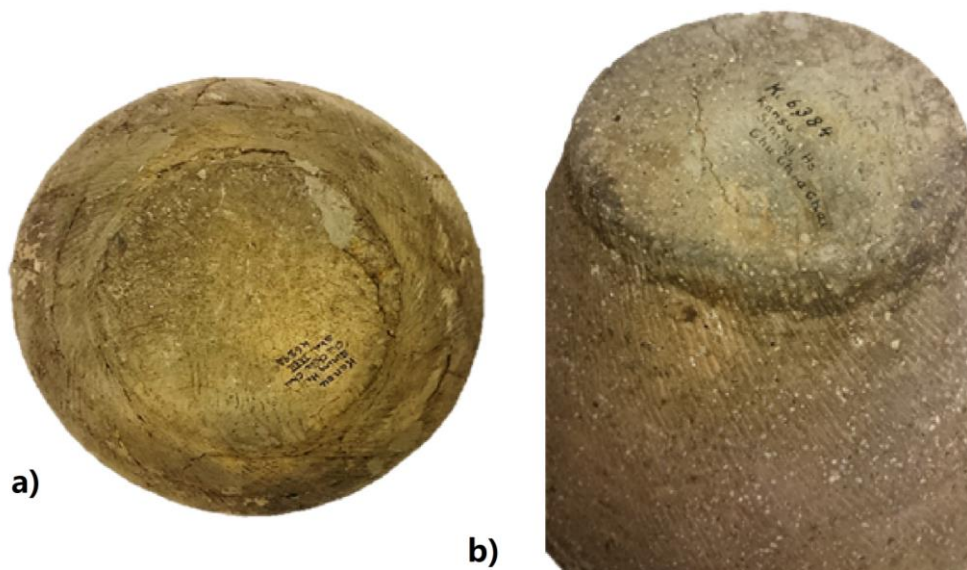


Fig. 5.67. Continuous diagonal cord pattern on vessels from Zhujiashai, a) K-06292 b) K-06384.

The vessel K-05279 from Waguanzui serves as another example of the cord-wrapping-like decoration. It has a polished upper body and cord-impressed lower body (Fig. 5.68). The cord pattern is wrapped diagonally around the body, like the one on the vessels from Zhujiashai. Looking closer at the transition between the upper and lower body surface, it seems like the cord texture was applied across the whole body and then removed from the upper body by polishing. The smudged transition between the parts and faint diagonal lines on the upper body following the direction of the cords indicate this sequence of actions.



Fig. 5.68. Vessel K-05279 from Waguanzui, polished upper body and cord-impressed lower body.

Similar cord pattern can be seen on some Bronze Age Qijia-style vessels (e. g. Fig. 5.69), which implies that this pattern was not uncommon and the technique for its application was known for a long time and in different parts of the study area.



Fig. 5.69. Continuous diagonal cord pattern seen on a Bronze Age Qijia-style jar; 2006.170.59, no archaeological record, Harvard Arts Museum; photo: Harvard Arts Museum.

Bylin-Althin (1946:434) suggested that the cord decoration was applied via a mould from which the vessels were also made. As has been discussed above, it is unlikely that a mould was used in construction; there is more evidence for them being coil-built. However, it is possible that the uniform diagonal cord was pressed onto the vessel in one go.

The experimental study on Qijia-style pottery by La Duc and Chang includes a study of tools used to make cord decoration (2017:1853). Qijia pottery also has cord impressions as a common design feature. The Qijia-style cords appear to have been finer than the cords used in decorating Majiayao-style vessels. Cross-cord design seems to be uncommon on Qijia-style ceramics, as personal observations of Qijia sherds and vessels in collections in China and Europe. In their experimental work aiming to recreate Qijia-style decoration patterns, La Duc and Chang wrapped a woven cord string ten times around a paddle (ca 5 cm width) and around a dowel (ca 7 cm length). These tools were pressed onto studio-made stoneware tiles (ca. 10x10 cm) to create a straight cord pattern. The resulted pattern was straight but the interruptions where the tool had to be lifted and pressed again to continue are seen clearly in a line running across the pattern (Fig. 5.70). A cord wrapped paddle or dowel can be used for creating textural patterns as La Duc and Chang's study shows.

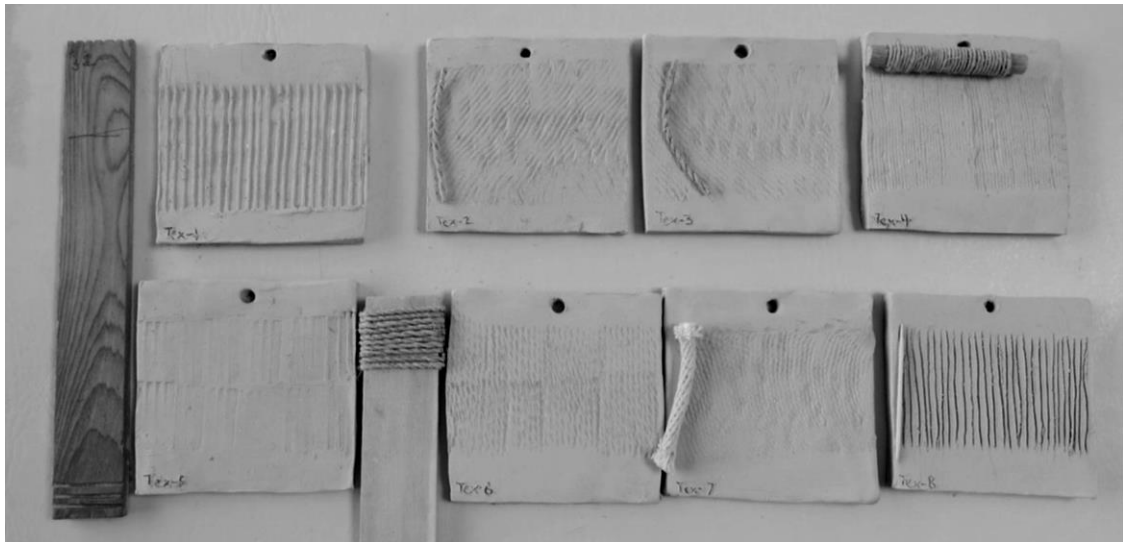


Fig. 5.70. Experimental tools and cord-impressions from La Duc and Chang's study.

However, the vessels K-06292 and K-06384 from Zhujiashai, and K-05279 from Waguanzui do not have the interruption lines described above and their design appears to be continuous. Perhaps, the prehistoric potters used a woven sheet with cord texture to wrap around and press onto the pot. The uniformity of the diagonal cord pattern cannot be observed on sherds because they are only pieces of a whole. However, the sherd K-12003-913³⁴ (Fig. 5.71) shows an exceptionally clear diagonal cord impression. It can be observed in the crook of the neck on this sherd how the cord pattern bends to follow the contour of the shape. Could this be another evidence for the usage of a flexible woven cord sheet wrapping?

³⁴ Not sampled for this study.



Fig. 5.71. Rim sherd K-12003-913 from Luohantang showing a clear cord pattern with distinct cord strings; photo taken from the MFEA online collection database.

Alternatively, the diagonal cord pattern could have been created by using a large paddle that was wrapped in cord. Considering that a vessel had to be leather-hard for both beating and cord-impression, this decoration could have been applied while the vessel was beaten in a rotational motion which created the diagonal direction of the pattern. Such a rotational motion can be seen on the inside of the lower body of K-05797 (Fig. 5.22). The technique using a paddle with a design on it was noticed by the author in a video of a Korean potter creating traditional onggi jars (Keskin and Francescutti 2021). The potter was turning the large jar on a turntable and simultaneously beating the walls. This technique created a pattern similar to the diagonal cord pattern seen on the Majiayao-style pottery. Using a cord-wrapped paddle in the beating step of the *chaîne opératoire* may explain why the impressions on vessel K-05279 (Fig. 5.68) were applied to the whole body and then removed but not initially just to the lower body.

The application of the straight cord pattern may have required different tools. This pattern appears to follow a vertical direction also without interruptions, although the texture is not well preserved on vessels K-05443 from Majiayao and K-06309 from Luohantang. The design on vessels K-05443 and K-06306 is a fine cord pattern that wraps around the whole vessel (Fig. 5.72a-b). Because of the poor preservation of the fine cord texture, it is difficult to determine whether there are interruptions in the pattern from lifting the tool. The straight pattern does not create a similar visual effect as the diagonal pattern, when looking at the vessel upside down.

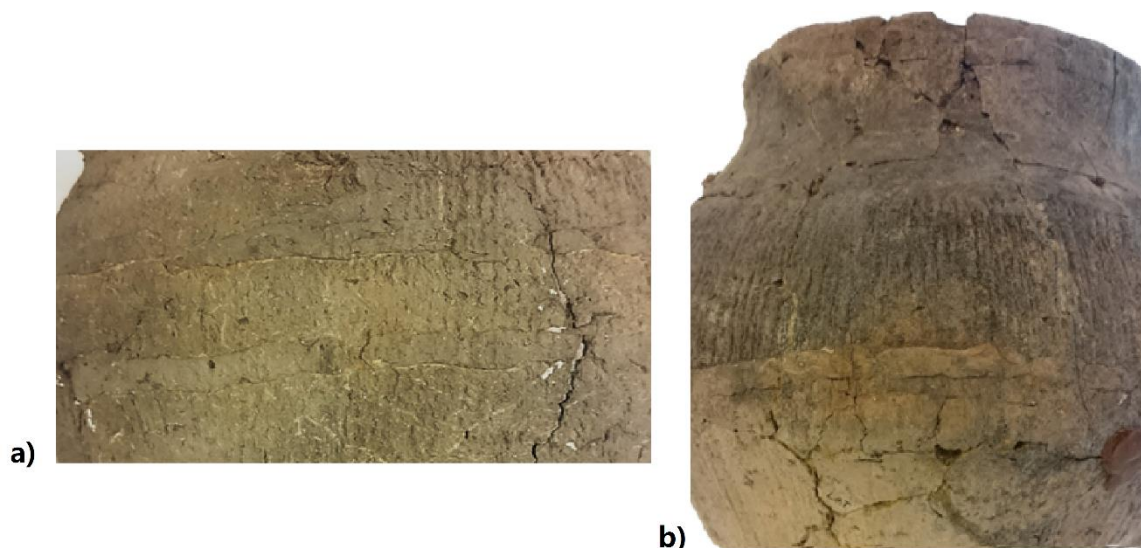


Fig. 5.72. Vertical fine cord pattern covering the whole vessel, a) K-05443, Majiayao b) K-06309, Luohantang.

The cross-cord pattern is less regular. This is possible to observe on sherds (see section 5.1.2) where the straight or diagonal cords running in different directions do not form a uniform lattice (Fig. 5.66a-b). No complete vessels with cross-cord decoration have been seen in the MFEA, the British Museum or the Ashmolean collections. The irregular orientation and sometimes overlapping of the crossed cords imply a different application technique than used for the single cord-pattern. For example, similar tools to the paddle or the dowel used in La Duc and Chang's

study could have been used to apply this decoration. The conclusion from the cord pattern analysis is that its application required different tools and likely different techniques. The creation of this design appears to be more complex than initially thought.

The appliqué decoration appears to be mostly horizontal clay bands wound around the vessel bodies. If the vessel is covered in cord pattern, appliqué decoration can be attached on top of it and given cord impressions on its own, have finger impressions or be plain. On vessel K-05443, appliqué bands were attached first as shown by the overlapping vertical cord pattern (Fig. 5.72a).

Painted vessels can have appliqué elements as well. On the complete vessels in this study most of the appliqué decoration are small, rounded attachments at the rim (Fig. 5.73a), vessel K-05114 has clay bands on the handles (Fig. 5.73b.) Other combinations of appliqué and painted decorations were observed on sherds, mostly as short clay bands (Fig. 5.73c; see also “Decoration” tables in section 5.1.2).

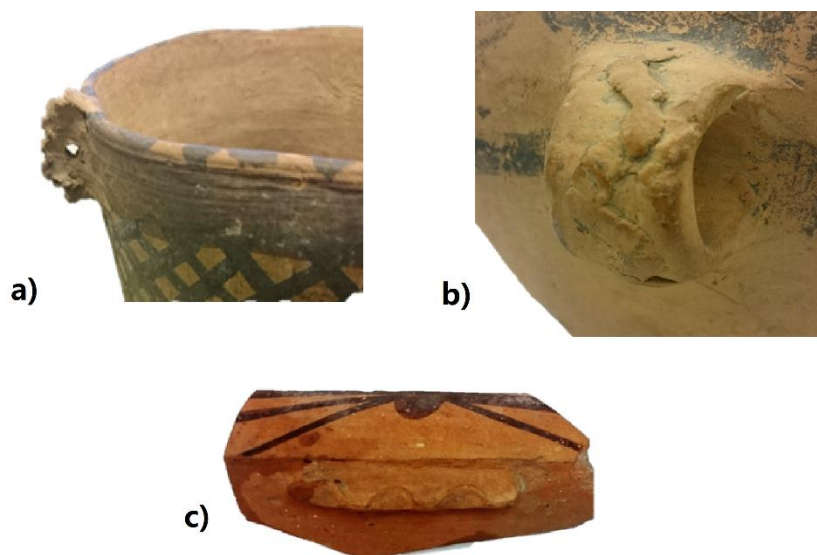


Fig. 5.73. Combinations of painted decoration and appliqué, a) K-05163, Waguanzui, bought b) K-05114, bought in Lanzhou c) CNP1, Majiayao.

5.1.1.3 *Chaîne opératoire*: firing

After the drying phase for the decoration, the vessels were likely fired in a kiln, as the paint marks from stacking indicate. To reinforce his suggestion of pottery having been stacked in the kiln Palmgren (1934:6) pointed to the collapsed vessel K-05080 (Fig. 5.74). He suggested that the break damage on the shoulder of the vessel is the result of it collapsing under the weight of the pots which were put on top of it. He further suggested that the vessel must have been still semi-plastic when it was loaded into the kiln (Palmgren 1934:6). It is unlikely that K-05080 was burnished, decorated and fired while it was still plastic. However, the vessel does look like it collapsed while it was quite soft with its neck being pulled down and stretched. Such deformation of the neck would not occur in a rigid leather-hard or dry state (Schreiber 1999:27). In that case the vessel would fracture and break, and one would expect flaking of the paint off the unfired surface. The damage crack on the shoulder does not look like a fracture but rather a like a tear.



Fig. 5.74. Partially collapsed vessel K-05080, bought in Lanzhou by Andersson; not analysed in this study because it is on museum display.

K-05080 looks like it was burnished and painted after it had already collapsed. It might have been repaired from the inside by smearing additional layer of clay to close the tear. It was not possible to include this vessel into the present study because it is on museum display. Palmgren pointed out (1934:7) that despite the damage the pot has been used and highlights the value this pottery must have had at the time. With the damage seemingly occurring just after construction, the pot was not reshaped or modified, but it was burnished, painted, fired, and used. Perhaps, the damage was noticed by the potter when the clay dried to the extent where no further modification would be possible. Either way, this observation reinforces Palmgren's point about the value of these vessels to their makers and users.

The types of kilns dated to the Majiayao period are downdraft and updraft kilns, with the latter becoming more common over time (Ma 2000:34). There are two kiln structures recorded by Andersson at Luohantang (Andersson 1925:5; Andersson 1943:84; Bylin-Althin 1946:431) which are described as one round feature with soot and burnt traces. Two prehistoric sites with major kiln structures are Baidaogouping (白道沟坪遗址) and Dadiwan (大地湾遗址). Twelve kilns were excavated at Baidaogouping (Gansusheng Bowuguan 1957:5; 1960:16) and thirty-three kilns at Dadiwan (Gansusheng Bowuguan 1983:21). Ma (2000:33-34) interpreted these kiln complexes as evidence for importance of the pottery production in the Neolithic. However, not many settlement sites have been systematically excavated in the study area and kilns were a very rare find.

The estimates of firing temperature for the Majiayao-style pottery do not vary significantly in the scholarly literature. Palmgren (1934:5) estimated that the pottery was fired at 900°-1000° C because of the yellow-orange colour and

hardness. Bylin-Althin (1946:435) suggested similar degrees for the fine fabrics but does not elaborate what led her to that assumption. She suggested that the coarse fabrics were fired at about 600°C because of their high porosity (Bylin-Althin 1946:439). Ma (2000:21, Table 1) investigated the firing temperature by XRD and FTIR spectroscopy. His results show that the pottery was generally fired at 900°-1050° C with lower margins between 750°-900° C (Ma 2000:21, 31). The comparative study of the optical activity of fired geological clay fabrics with prehistoric pottery fabrics yielded similar results which are discussed in section 6.2.1.

Different firing patterns can be suggested based on macroscopic observation of the core colours in cross-section on the vessels and sherds. Only the vessels which the fabric core could be seen on a damaged area on the vessel body were included in the analysis of firing patterns (Fig. 5.75a-e). Examples of each pattern are discussed in more detail the following section 5.1.2 on the interplay between fabric, firing pattern and decoration.

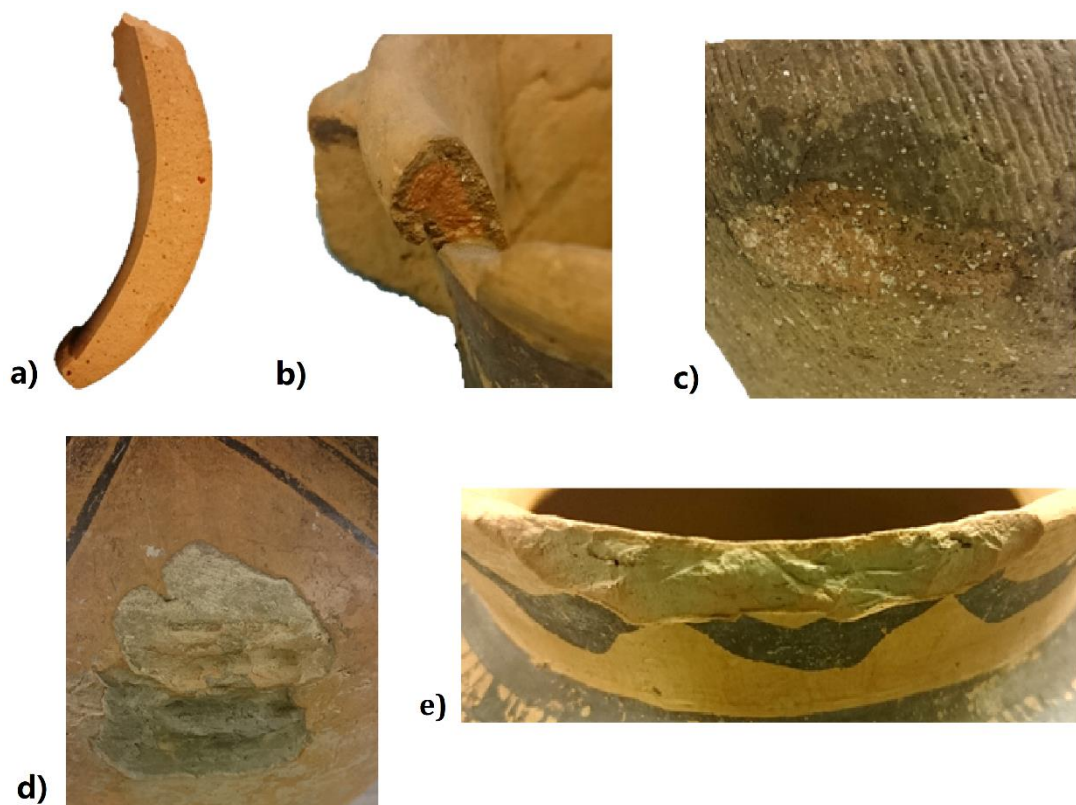


Fig. 5.75. Different firing patterns observed on vessels a) Fully oxidised orange core, sherd from the vessel K-05279 and b) Oxidised orange core and buff yellow margins on the rim, K-05011, both from Waguanzui, bought by Andersson c) Oxidised core, reduced margins, lower body, K-06384, Zhujiazhai d) Reduced core and oxidised margins or reduced interior layer and oxidised exterior, lower body K-05165, Paiziping, bought by Andersson (Tao River Valley) e) Reduced core, oxidised margins rim of K-05146, Banshan (Tao River Valley), bought by Andersson.

The different layers of core colours have been first studied by Palmgren (1934:6) and Wu (1938:88) who both concluded that the layers are the result of exterior and interior surface being exposed to different degrees of heat and oxygen. Bylin-Althin (1946:433) suggested that the reduced core and oxidised margins were caused by an incomplete or irregular oxidation of the core.

The reduced or grey core mostly occurs in the fine or semi-coarse fabrics, as can be concluded from the macroscopic analysis (Figs 5.75d-c, and 76). A black core in ceramics usually occurs if there is insufficient oxygen in the atmosphere at $>750^{\circ}\text{C}$ and the carbonaceous matter cannot oxidise i. e. burn, so it takes (reduces) the

oxygen from the iron oxide in the clay creating the black colour (Hamer and Hamer 2015:27; Rice 2015:289).



Fig. 5.76. Example of a dark core and red margins as seen in cross-section, CNP43, Majiayao.

Further, fine clay with low porosity needs more soaking time to fully oxidise than a coarse clay, and can retain a grey core when fired in oxidising atmosphere with enough oxygen at 800° C, and at a higher temperature the oxidation rate could be even lower (Shepard 1985:21; Rice 2015:279; de Bonis et al. 2017:8071). The black core could serve as an indicator for the firing temperature of the pottery. If pottery was fired at >900° C, it will not be possible to re-oxidise the black core in a refiring experiment (Hamer and Hamer 2015:27). At >900° C the core would have already started to vitrify and the black iron oxide acts as a flux in this process (Hamer and Hamer 2015:27).

Either of these phenomena could be the case for the fine and semi-coarse pottery having a black core in this study. Moderate optical activity of the matrices is common among these fabrics, all samples from Waguanzui were optically inactive and some had grey cores (see summary section in 5.2.5), so rapid firing preventing full oxidation is a possible explanation for this so-called sandwich core. Maritan et al. (2006) conducted firing experiments at 900°, 1050° and 1100° C of organic rich clay in a pit and in kiln to study the chemical changes of organic matter in the clay. Their study shows that sandwich firing with a dark core occurred mainly in kiln fired samples in oxidising atmosphere under low heating rate and long soaking

time as opposed to short high-temperature pit firing in reducing atmosphere which produced uniformly dark ceramics (Maritan et al. 2006:6, 13). Maritan et al. (2006:13) concluded that despite longer soaking time in the kiln firing, there was not enough oxygen to fully oxidise the ceramic body.

Interestingly, none of the briquettes in the firing experiment showed a grey core. This means that the heating rate, soaking time and oxygen distribution were sufficient for the carbonaceous matter to burn out even at 700° C.

Irregularities in firing conditions of the prehistoric sherds are further reflected in multiple colour layering of the core which are classified as “other firing patterns in this study” (Fig. 5.77a-d).

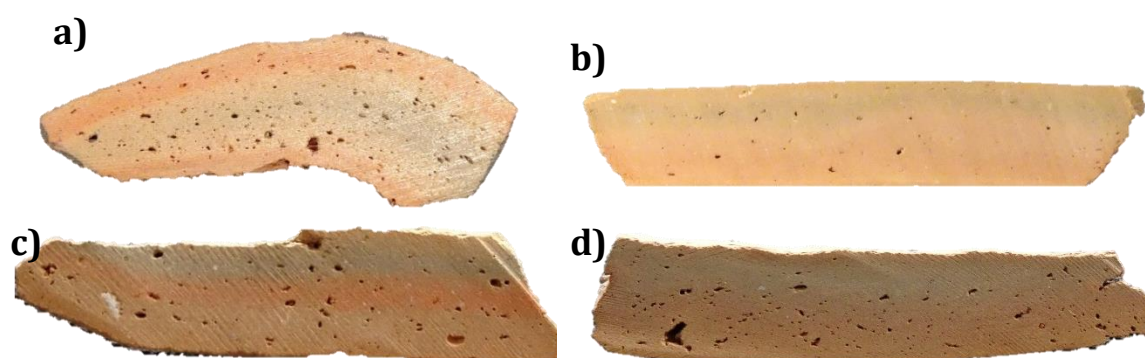


Fig. 5.77. Examples of changes in firing conditions and chemical reactions within the core as seen in cross-section; a) CNP40, Majiayao b) CNP80, Waguanzui c) CNP186, Zhujiazhai d) CNP152, Luohantang.

These layers were produced by abrupt changes in the firing atmosphere and chemical reactions within the clay paste which created the different coloured layers (Rice 2015:280; Nodari et al. 2004). Formation of iron oxides such as hematite and maghemite results in different shades of red and pink on the margins, and formation of the minerals such as diopside, gehlenite or wollastonite results in yellow and buff colours (Nodari et al. 2004:126-127; Rice 2015:282). The layering of red, orange and buff or creamy colours in the core (Fig. 5.77) indicate the presence of calcite in the paste (Molera et al. 1998:188). CNP6, CNP7, CNP8 might

belong to the same vessel based on their macroscopic and petrographic characteristics but their core layers vary slightly (Fig. 5.78a-c). The uneven firing was caused by inconsistent oxidation, changes in temperature and probably influenced by the vessel's position in the kiln as well.

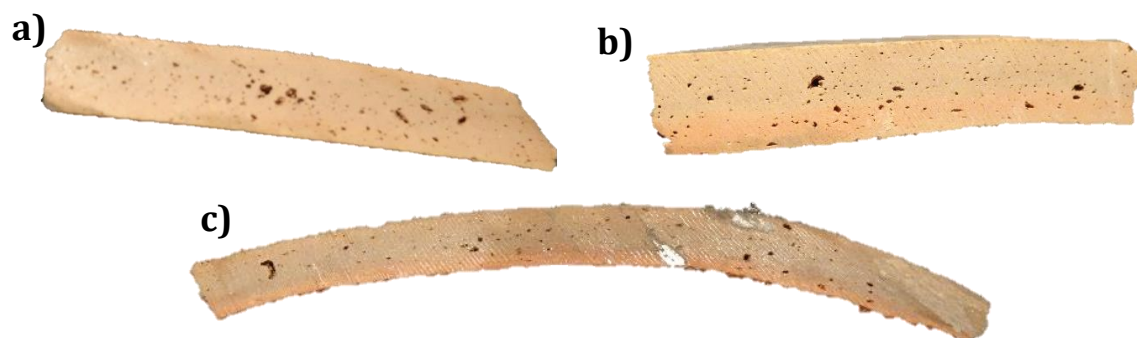


Fig. 5.78. a) CNP6 b) CNP7 c) CNP8 from Majiayao.

A clear example of a sudden change in the firing condition and a chemical reaction can be observed in cross-section of the neck of K-05011 from Waguanzui (Fig. 5.75b). The orange core shows that the vessel or this part of the vessel at least was fully oxidised. There is a sharp boundary between the core and the yellow buff margins indicating a chemical reaction due to changes in temperature. There are types of clay with a naturally high calcium carbonate (CaCO_3) content in the Tao River Valley (see section 6.1.1). At about 750°C - 800°C calcium carbonate disintegrates to lime (CaO) which at higher temperatures can react with minerals in the clay to form new minerals that alter the colour of the clay (Rice 2015:282). It seems that towards the end of firing of K-05011, the temperature increased above 900°C - 1000°C which caused lime to react with hematite to form calcium silicates and colour the margins pale yellow (Rice 2015:282; de Bonis 2017:8073; Molera et al. 1998:189). There was then a rapid decrease in heat which created the sharp boundary observed in cross-section. One could argue that this reaction was intentional, giving the vessel surface a light and pale background that enhances the

red and black decoration as opposed to bright orange. According to Molera et al.'s (1998:188) research on calcareous ceramic pastes, calcite is a widely used additive or preferred fine-grained natural component to lighten the colour of the ceramic body for painting. In fact, the lighter shades of yellow are probably the most common background colours on the painted Majiayao-style vessels but no large quantitative study addressing this question has been conducted, yet.

Further examples of colour changes in ceramics from the study area that do not fall within the typical colour range result from oxidised or reduced firings are CNP67, CNP115, CNP163, and CNP182 (Fig. 5.79a-d). These samples show pale buff and yellow colours in cross-section that indicate chemically different pastes react under different temperatures. Except for CNP182, which has an optically inactive matrix, CNP67, CNP115 and CNP163 show moderate or slightly active matrix. The combination of the vitrification degree and the buff/ pale colours implies that the clays used in production are calcareous which achieved a stable glass phase during firing (Maniatis and Tite 1981:65; Dr E. Kiriatzi pers. comm.).

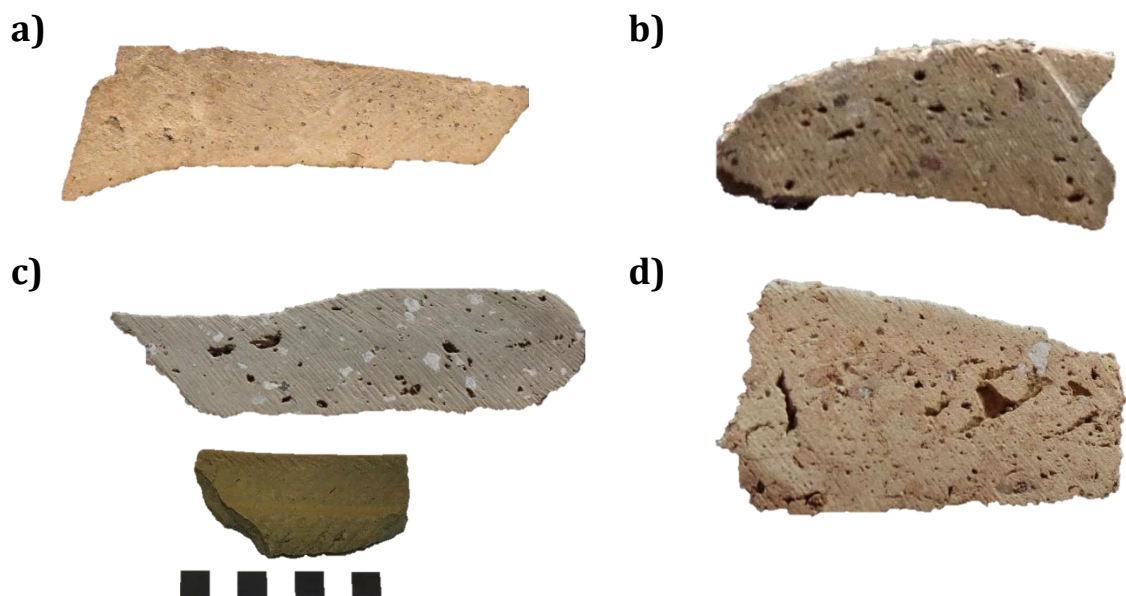


Fig. 5.79. Examples of pale firing colours a) CNP67, Majiayao b) CNP115, Zhujiazhai c) CNP163, original fabric colour is more green than grey, Luohantang d) CNP182, Zhujiazhai.

The sherds CNP157 and CNP176 from Luohantang show green coloured outer surfaces, and CNP157 additionally has paint on the outside (Fig. 5.80).

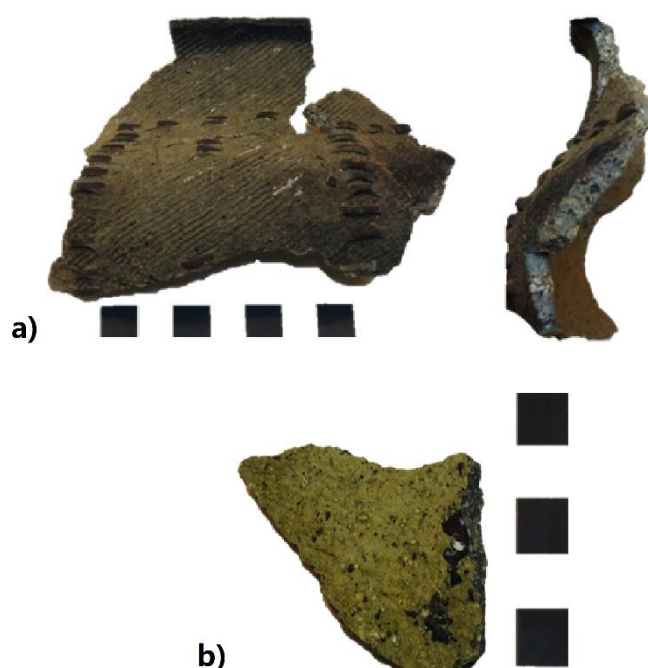


Fig. 5.80. Green coloured surface on sherds from Luohantang, a) CNP157 b) CNP176.

Both sherds were fired at a high temperature and have optically inactive matrices. CNP157 and CNP176 could present a case where calcareous clays reacted with hematite when fired above 1000° C and create the green colour on the surface. It is unclear if this colour was achieved intentionally or by accident. Chemical analysis of these fabrics could help shed light on this rare colouring, but this goes beyond the scope of this thesis and will have to be left for a future project.

5.1.2 Interconnection of fabric, decoration and firing atmosphere

This section provides a summary of the macroscopic analysis of pottery sherds, including an assessment of fabric, decoration and firing atmosphere and trends in their combinations.³⁵

³⁵ An individual description and photographs of each sherd can be found in Catalogue 3; tables of short macroscopic descriptions sorted by site, fabric type, and firing atmosphere can be found in Annex 3.

The 187 sherds from all four sites were sorted into four groups by coarseness degree of their fabrics (Table 5.1). The division into fine, coarse and semi-coarse fabrics is based on the classification from petrographic analysis. The names are based on the presence and amount of coarse (0.2 – 6.3 mm in size)³⁶ non-plastic inclusions. This is done to avoid confusion between different perceptions of the fabric by the naked eye and under the polarising microscope. The sherds with a combination of fine and coarse fabrics have a clear boundary between the two fabrics which is visible macroscopically.

Table 5.1. Fabric variety among the selected pottery sherds.

Fabric	Number of sherds	%
Fine	97	52%
Coarse	71	38%
Semi-coarse	12	6%
Coarse-fine-combination	7	4%

The majority of sherds analysed are body sherds (Fig. 5.81). Besides being one of the most common sherd types in the MFEA collection, they also provide a versatile sample of the body fabric (which might be different from attachments like handles), body decoration, and an insight into the firing of the vessel wall. The next most sampled sherd type is the rim which in addition to the listed technological aspects provides information about the size and in some cases about the shape of the vessel.

³⁶ According to ISO 2017 standard, see Table 1 in Catalogue 1.

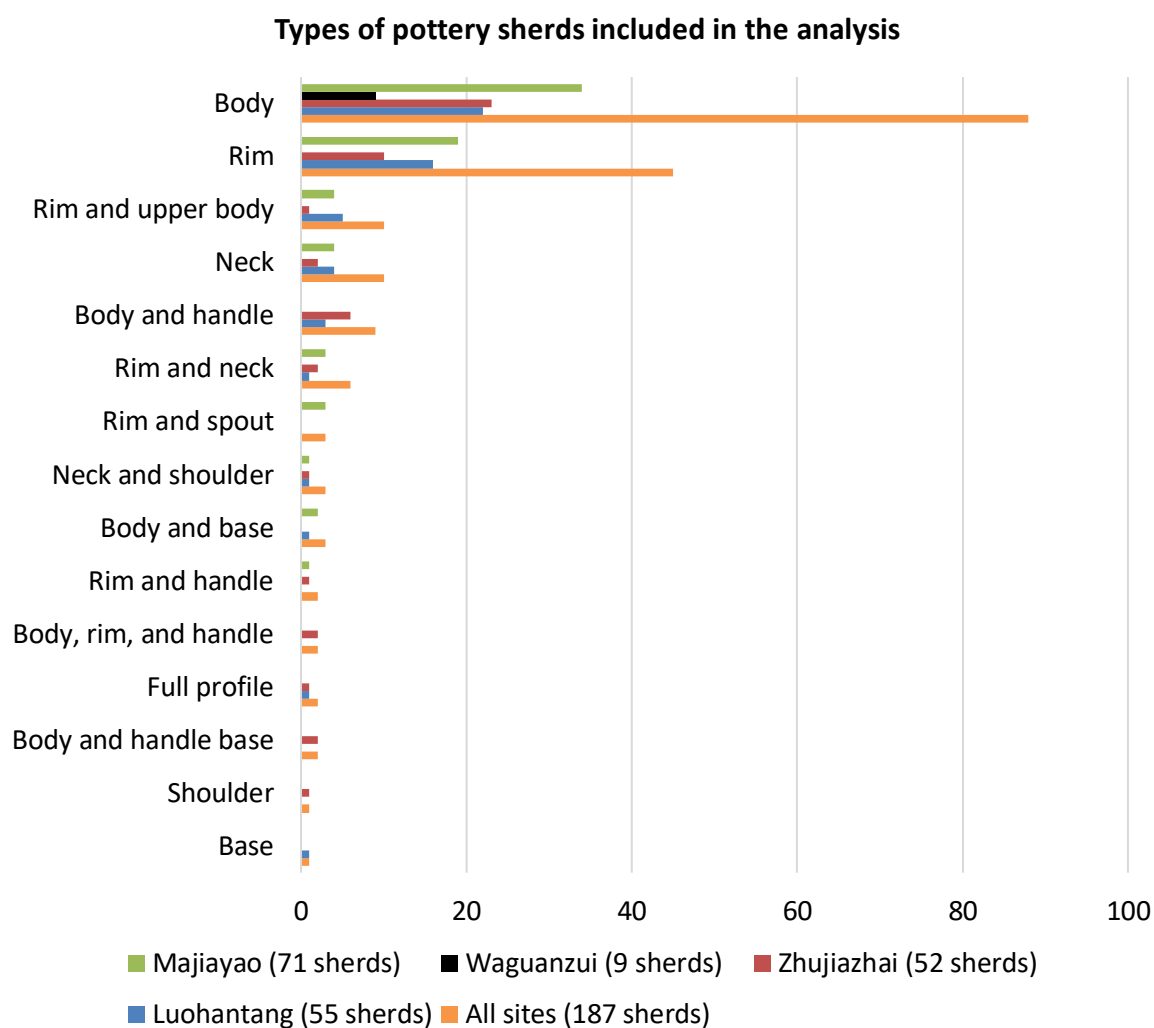


Fig. 5.81. Types of pottery sherds included in the analysis.

In this section the material from each site is analysed separately first and a summary of data from all sites is provided in the end. The sherd data from each site is presented in standardised tables and figures in the following sections:

- I. Fabrics: the types of fabrics identified in pottery sherds.
- II. Decoration: the types of decoration and number of sherds for each type.
- III. Firing patterns: the number of sherds fired in oxidising or reducing atmospheres and if the core shows an atmosphere change in the firing process.

IV. Combination of a decoration type and a fabric: the number of sherds with certain decoration and fabric combination to observe trends in pairing of any types.

V. Combination of a firing pattern and a decoration type: the number of sherds with a certain firing pattern and decoration type combination to observe trends in pairing of any types.

VI. Combination of a firing pattern and a fabric type: the number of sherds with a certain firing pattern and a fabric combination to observe trends in pairing of any types.

VII. Summary: combination of a fabric, a decoration type, and a firing pattern. This table shows trends in this tripartite combination that may indicate preferences in potter's choices. The fabric type is set as the unchangeable variable for each table and number of sherds is given for each decoration and firing combination with this fabric.

The data from all sites is summarised in the following sections:

I. Most frequent "Decoration – Fabric" combinations

II. Most frequent "Firing pattern – Decoration" combinations

III. Most frequent "Fabric – Firing pattern" combinations

IV. Most frequent "Fabric – Decoration – Firing" pattern combinations.

The charts are used to graphically illustrate and summarise the distribution of data in the tables with many samples.

In summary, the tripartite combinations were identified on 119 sherds out of 187 which is 63.6% of the total amount.

5.1.2.1 Majiayao (71 sample)

5.1.2.1.1 Fabrics

Sherds from Majiayao include fine, coarse, semi-coarse and coarse-fine-combination fabrics (Table 5.2). The cross-sections show distinct differences in inclusion size (Fig. 5.82) meaning that the prehistoric potters diversified their recipes either by using different clays or by adding temper.

Table 5.2. Fabric types identified in selected sherds from Majiayao.

Fabric type	Number of sherds
Fine	40
Coarse	26
Semi-coarse	3
Coarse-Fine-combination	2

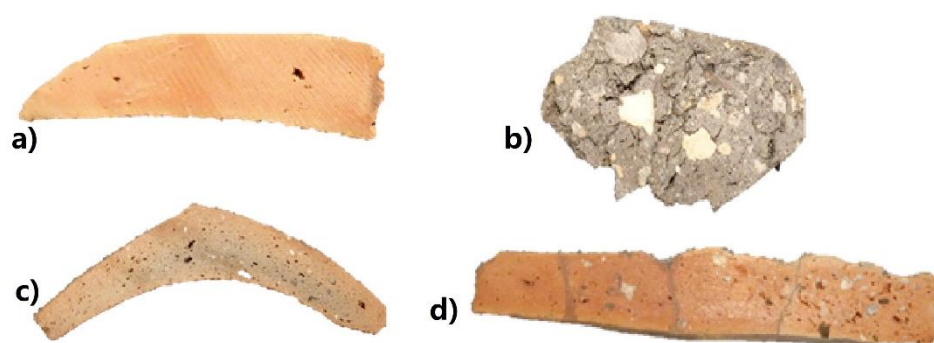


Fig. 5.82. Fabric type examples in selected sherds from Majiayao: a) fine, CNP48 b) coarse, CNP71 c) semi-coarse, CNP1 d) coarse-fine-combination, CNP16.

5.1.2.1.2 Decoration

The data presented in Table 5.3 and Fig. 5.83 does not imply that painting was the dominating decoration type of the Majiayao-style. More painted sherds were deemed suitable for the analysis because of their unambiguous typological characteristics of the Majiayao-style, which led to the minor difference in numbers.

Plain sherds and painted sherds with appliqué decoration were less common among the sherds in the MFEA collection in general.³⁷

Table 5.3. Decoration types identified on selected sherds from Majiayao.

Decoration type	Number of sherds
Painted	33 in total
Painted outside + Painted in black	25
Painted outside + Painted inside + Painted in black	3
Painted outside + Painted in brown	3
Painted outside + Painted inside + Painted in brown	2
Impression only	13 in total
Cross-cord impression	4
Diagonal cord impression	5
Cross-cord + Other impression	1
Diagonal + Cross-cord impression	1
Horizontal cord impression	1
Other impression	1
Appliqué + Impression	13 in total
Appliqué + Cross-cord impression	9
Appliqué impressed with cord + Cross-cord impression	2
Applique + Diagonal impression	1
Appliqué + Other impression	1
Appliqué only	1 in total
Appliqué + Painted	5 in total
Appliqué + Painted outside + Painted black	5
Impression/ Appliqué + Impression AND Painted	1 in total
Appliqué + Cross-cord impression + Painted black	1
Plain	5 in total

³⁷ The author looked through all boxes with sherds from Majiayao, Waguanzui, Zhujiashai and Luohantang kept at the MFEA storage facility in Tumba, Sweden.

Decoration types: Majiayao site

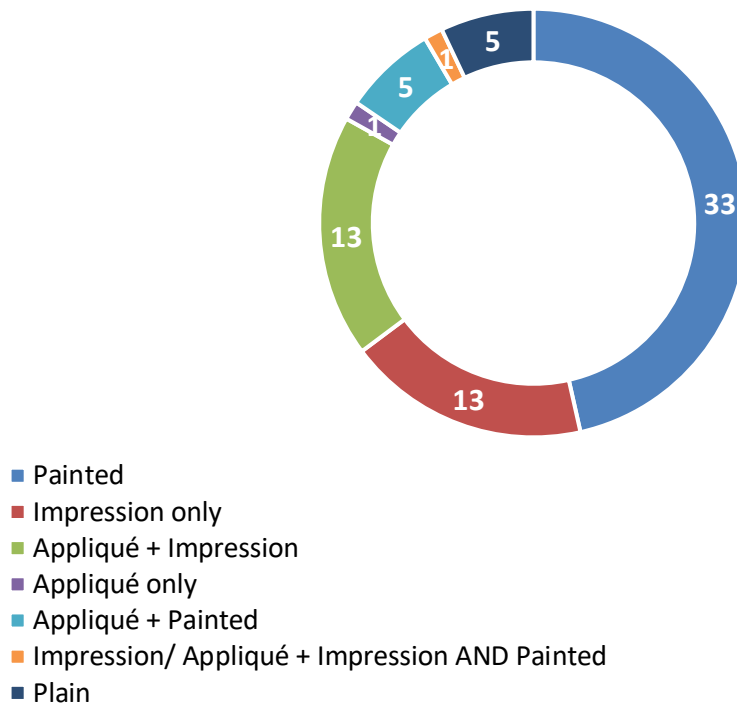


Fig. 5.83. Summary of the decoration types on selected sherds from Majiayao; numbers represent the sherd number.

The colour for painted decoration is predominantly black applied on a yellow or orange background (Fig. 5.84a). The designs consist of curves, straight lines, spirals, and dots. The impressed decoration includes three cord orientations: diagonal, horizontal and cross-cord. The cord impressions vary in their texture and can be wide and deep (Fig. 5.84b) or narrow and shallow (Fig. 5.84c). The term “other impression” used in Table 5.2 for Majiayao and Table 5.8 for Zhujiashai stands for impression decoration different from cord. That could be a finger-impressed pattern or a an impressed/ incised shallow line which runs below rim of bowls. These types of impressions are very rare among the sampled sherds (Tables 5.2 and 5.8).

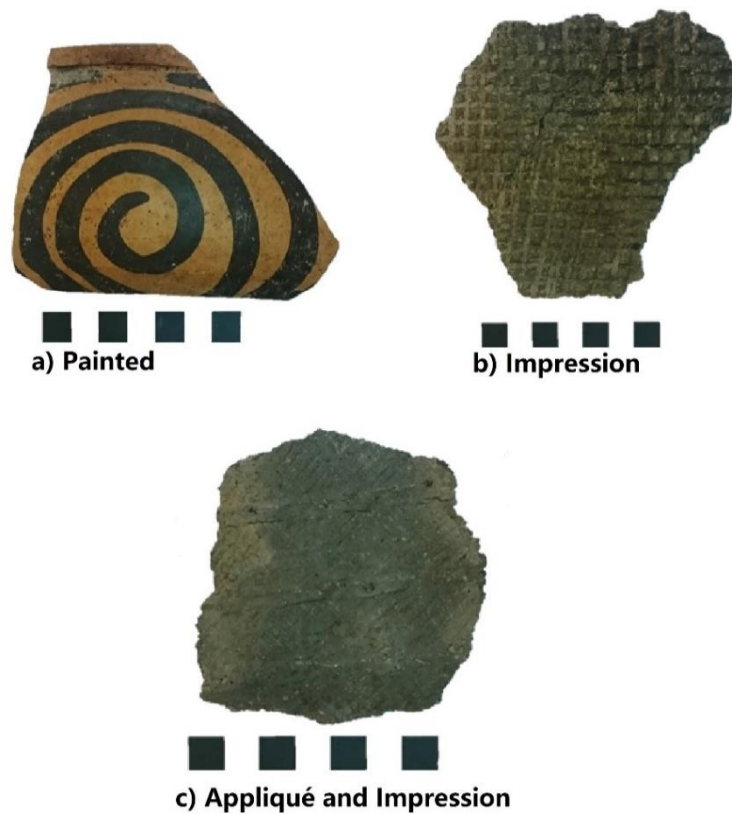


Fig. 5.84. Examples of decoration on selected sherds from the Majiayao site; a) CNP60 b) CNP22 c) CNP30.

5.1.2.1.3 Firing patterns

As observed in cross-section, the prehistoric potters were able to create both oxidising and reducing firing atmospheres (Figs 5.85 and 5.86a, b, d, e). The majority of the sherds were fired either fully oxidised or fully reduced (Fig. 5.85). The next common firing pattern is the “reduced core, oxidised margins” type (Figs 5.85 and 5.86c) whose firing conditions were discussed above (section 5.1.1).

Firing patterns: Majiayao site

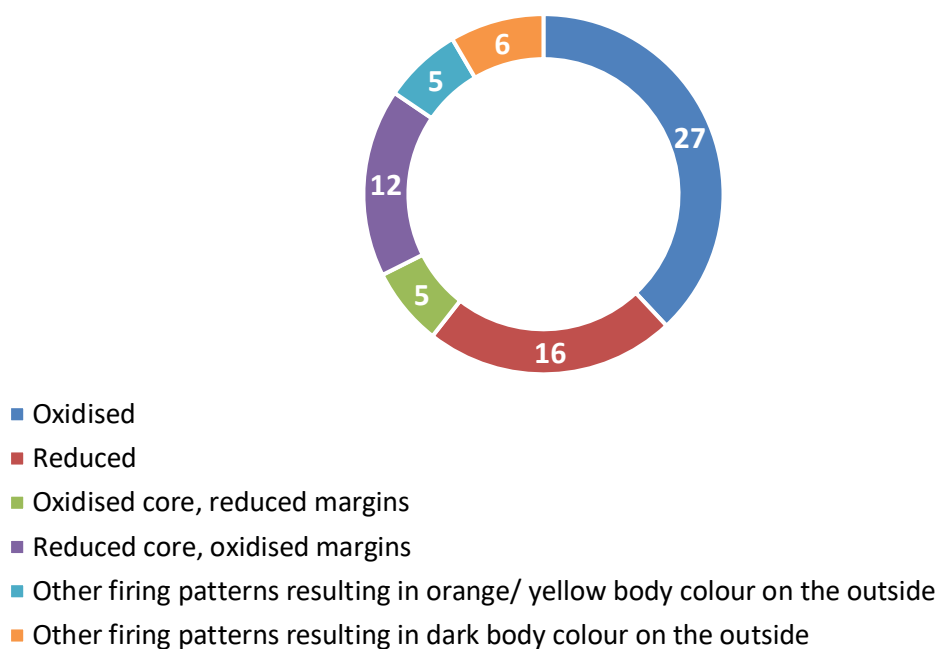


Fig. 5.85. Firing patterns identified on selected sherds from Majiayao; numbers represent the sherd number.

The firing patterns observed on CNP21 and CNP18 (Fig. 5.86d-e) show that the reducing atmosphere was the last firing atmosphere indicating that this was a technological choice. The core in CNP21 and the inside of CNP18 are both oxidised indicating that the oxygen content during firing was manually decreased at some point. The irregular firing pattern of CNP40 (Fig. 5.86f) showing a slightly reduced core and layers of creamy buff and red colours indicates fluctuations in firing conditions and chemical reactions of calcium minerals in the clay paste, as has been discussed above (section 5.1.1)

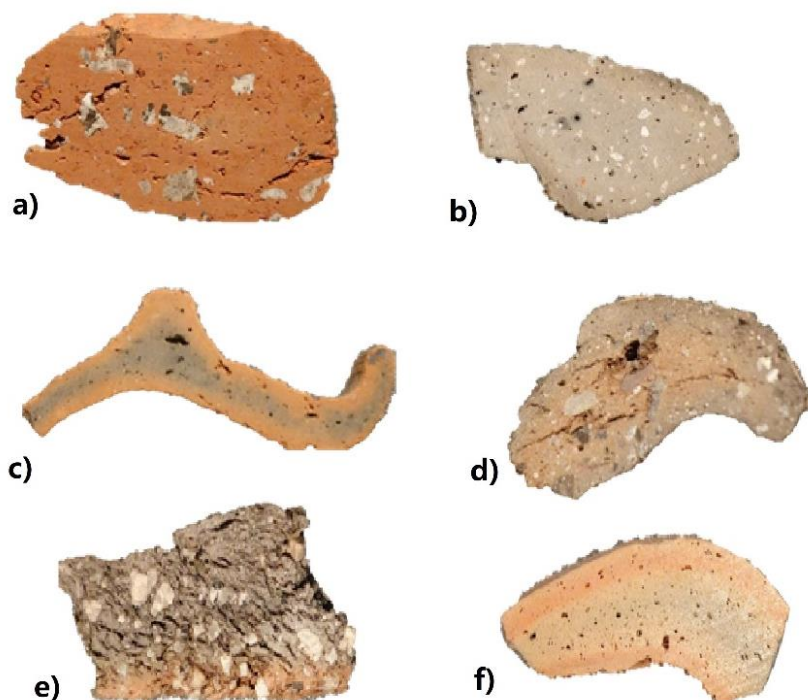


Fig. 5.86. Examples of firing patterns seen on selected sherd cross-sections from Majiayao: a) Oxidised, CNP35 b) Reduced, CNP34 c) Reduced core, oxidised margins, CNP43 d) Oxidised core, reduced margins, CNP21 e) Other firing pattern resulting in dark body colour on the outside, CNP18 f) Other firing pattern resulting in orange/ yellow body colour on the outside, CNP40.

5.1.2.1.4 Combination of decoration and fabric

Comparing the trends in combining a specific decoration type and fabric, two combinations stand out (Fig. 5.87). Most dominant is the pairing of painted decoration and fine fabric. Vessels made of fine clay have a more suitable surface for painting after burnishing or polishing than coarse fabrics. The paint sets in even layers and there is no risk of the brush getting caught on coarse inclusions. Fine fabrics are less porous and reduce the risk of the paint filling up the pores and cracks distorting the design. From this perspective, these types of decoration and fabric seem to have a practical and an aesthetic reason for being paired.

The second dominant combination is that of coarse fabric and impressed or impressed and appliqué decorations (Fig. 5.87). Impression only and impression plus appliqué is counted together in this summary and in summaries for other sites

because of impression and appliqué commonly appearing together. The appliqué on cord-impressed sherds appears not always throughout the whole body. Therefore, in some cases it is not clear which relief decoration covered the vessel body initially and it makes sense to summarise them for the trend analysis in this study. Coarse fabrics have large inclusions visibly protruding on the surface, and they are thus suitable for attaching three-dimensional decoration because they will connect well. The attachment will stick to the coarse surface and will not fall off. There are no coarse painted sherds among the samples from Majiayao (Fig. 5.87). Relief decoration has been identified on a few fine fabric sherds (Fig. 5.87). Based on the limited number of sherds sampled here, it cannot be said for certain whether fine fabrics are rarely combined with impression and/ or appliqué in general.

The decoration on coarse-fine-combination fabric reflects the above tendencies for the coarse and fine fabrics. The coarse part has relief decoration, and the fine part is painted, which is also the case for this type of fabrics from Luohantang, as will be discussed below. This supports the above suggestions for the possible preferences of prehistoric potters in combining specific types of decorations with certain fabrics because of their texture. The plain coarse-fine-combination sample (CNP36) was either thoroughly burnished so that no coarse inclusions can be seen on the outside or was coated with a slip made from the same fine clay to conceal the coarse texture.

Semi-coarse fabrics show no particular tendency to be paired with a decoration, though the sample size is too small for a proper interpretation.

Combination of decoration and fabric: Majiayao site

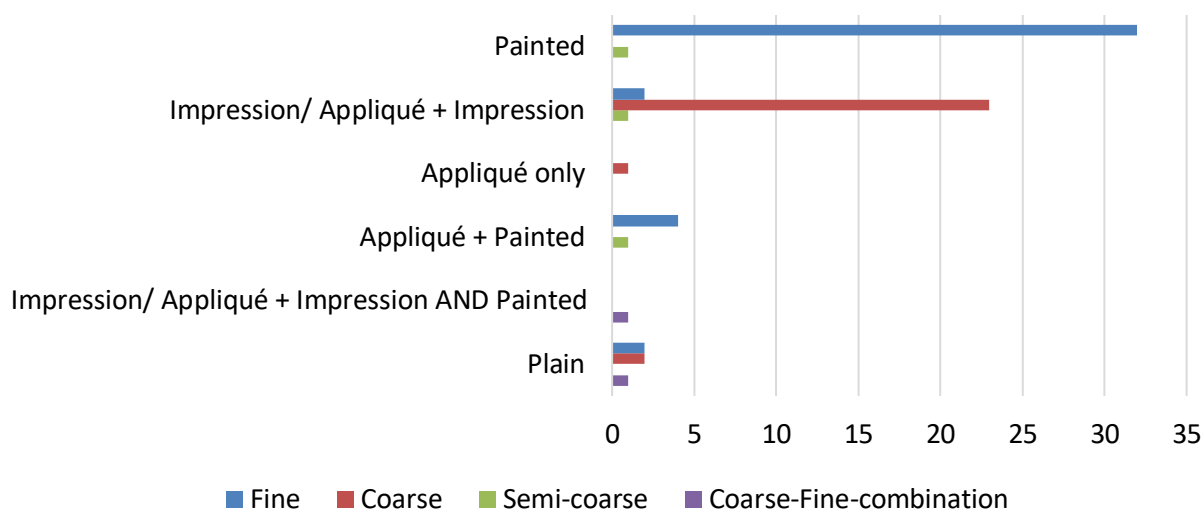


Fig. 5.87. Frequency of combinations of decoration and fabric on selected sherds from Majiayao; numbers represent the sherd number.

5.1.2.1.5 Combination of firing patten and decoration

To investigate the trends in firing and decoration combinations, the different firing patterns were summarised to their last firing atmosphere and the resulting vessel body surface colour. Thus, the variables for the firing are “orange/ yellow body colour” and “dark body colour” on the outside, “dark” implying shades of grey and black (Fig. 5.88).

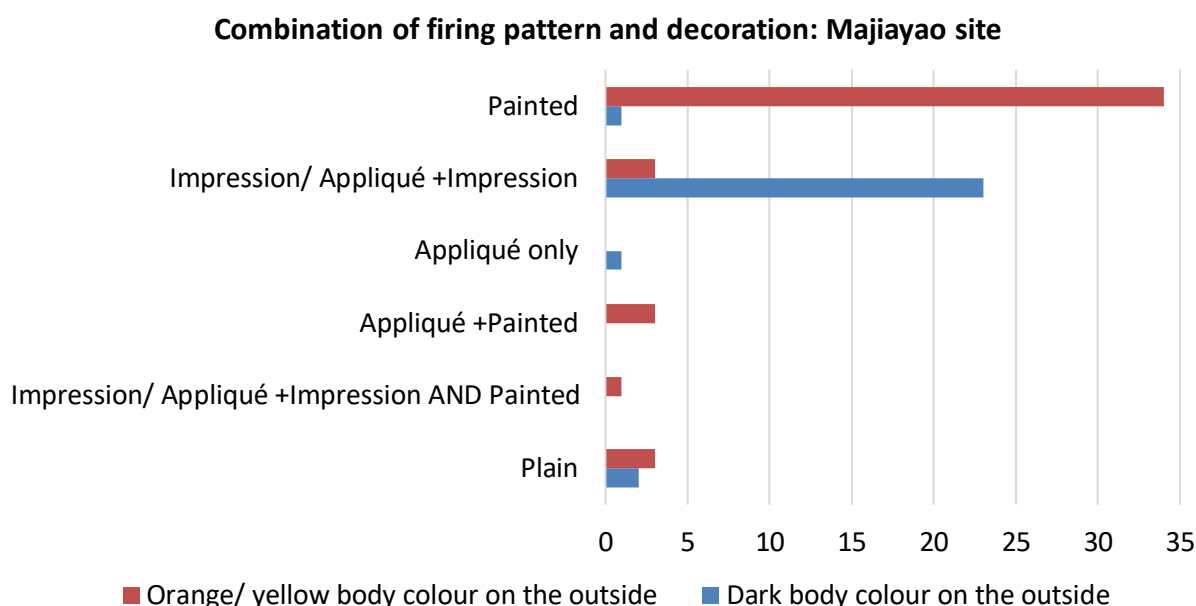


Fig. 5.88. Frequency of combinations of firing pattern and decoration on selected sherds from Majiayao; numbers represent the sherd number.

The dominant trend in this comparison is that all sherds that have paint as main or part of their decoration were last fired in the oxidising atmosphere and have a light yellow or orange body colour. In the previous discussion about firing (section 5.1.1.3), it was suggested that a light colour, particularly yellow, was a preferred background for painted designs. This might be the case for the painted pottery from the Majiayao site as the sample data indicates (Fig. 5.88). The light background was an aesthetic choice combined with the technological choice to fire the pottery in an oxidising atmosphere. One exception is CNP4 which has paint, probably black, on a dark greenish background. As observed under the petrographic microscope, CNP4 has an optically inactive vitrified matrix which means that it was fired above 1000° C. The greenish colour indicates that the temperature was high enough to cause the discolouration through chemical reactions of oxides and calcium in the clay paste.

The second evident trend is the combination of a dark body with a relief decoration. This pairing is difficult to explain from the technological perspective

since the colour of the body does not add any apparent visual effect to the three-dimensional decoration. However, it can be inferred from the cross-sections that the reducing atmosphere was a choice in firing e. g. in CNP21 or CNP18 (Fig. 5.86d-e) which were fired in oxidation first. At this point, this combination is only possible to explain from the aesthetic perspective that involved the extra step of creating reducing atmosphere in the kiln.

5.1.2.1.6 Combination of firing pattern and fabric

The data on the combination of a firing pattern and a fabric type mostly reflects the data on the combination of the decoration and firing pattern combination (Fig. 5.89). Sherds with fine fabrics were predominantly fired in oxidation as the last firing atmosphere, i. e. they have a yellow or orange surface colour. The situation is similar for the coarse fabrics which have the reduction as the last firing condition and a dark body colour. Sherds with semi-coarse fabrics all have oxidation as the last firing atmosphere, though here again, a small number of this fabric type has been identified in the present study. Both samples with coarse-fine-combination fabrics were fired in oxidation. CNP16 has painted decoration, which means that oxidising atmosphere was preferred here to produce the light background. CNP36 is plain, and no particular technical reason for the oxidation firing can be inferred from the sherd alone.

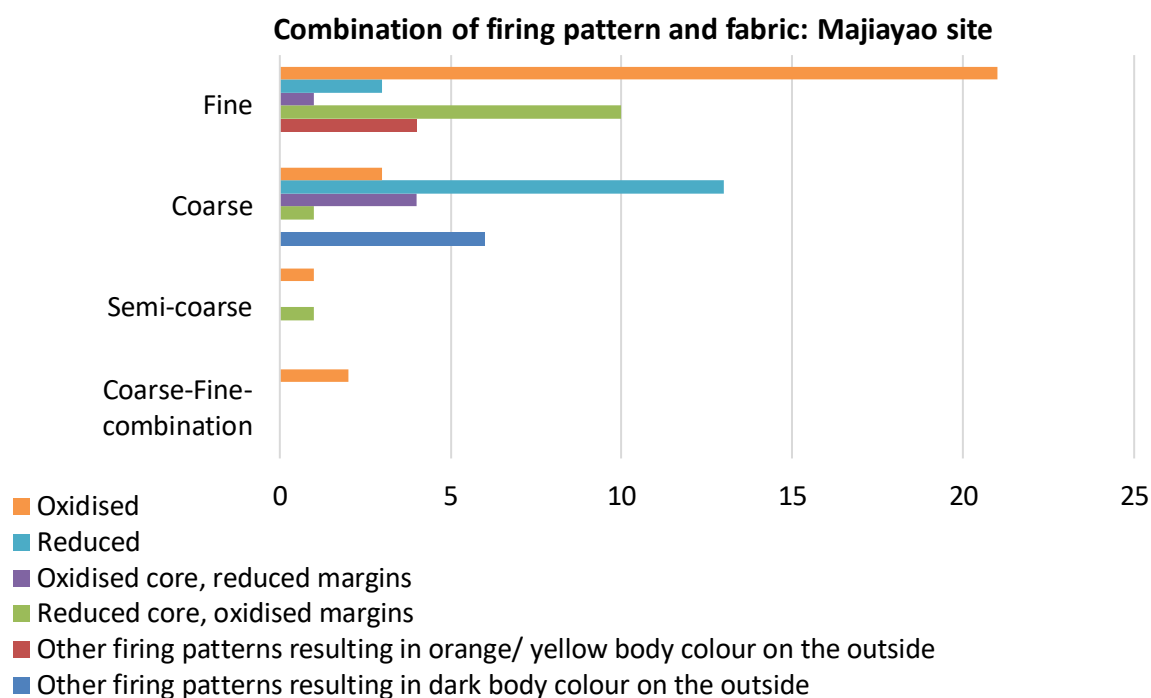


Fig. 5.89. Frequency of combinations of firing pattern and fabric on selected sherds from Majiayao; numbers represent the sherd number.

5.1.2.1.7 Summary: combination of fabric, decoration type, and firing pattern

Fine fabrics (40 samples)

Among the samples from the Majiayao site the fine fabrics show a clear tendency to be combined with painted decoration and be fired in oxidation as the last firing atmosphere (Fig. 5.90). This technological choice seems to happen for a practical reason of easier paint application and for an aesthetic reason to enhance painted design by creating a light-coloured background. If a fine fabric is paired with a relief decoration like in the case of CNP15 and CNP17, its last firing atmosphere will likely be reducing.

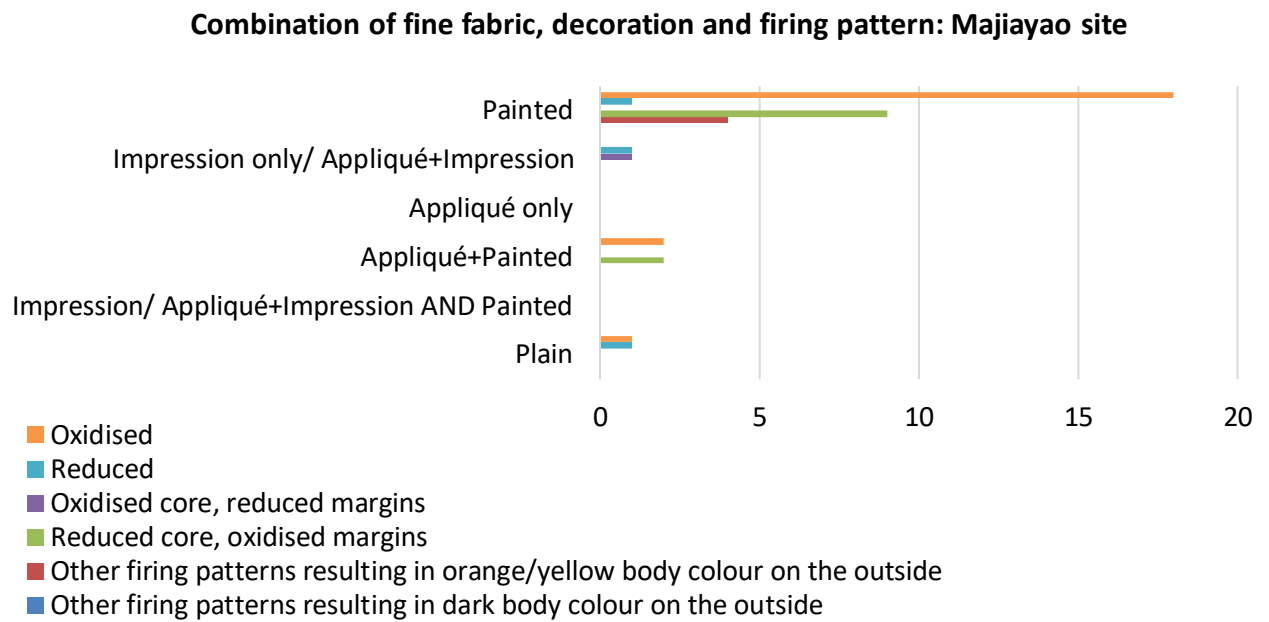


Fig. 5.90. Frequency of combinations of the fine fabric with different decoration and firing patterns on selected sherds from Majiayao; numbers represent the number of sherds.

Coarse fabrics (26 samples)

Among the samples from the Majiayao site, coarse fabrics tend to be combined with impression and appliqué decoration and fired in reduction as their last firing atmosphere, i. e. have a dark body colour (Fig. 5.91). There seems to be no practical explanation for this choice of body colour and decoration combination so far.

Combination of coarse fabric, decoration and firing pattern: Majiayao site

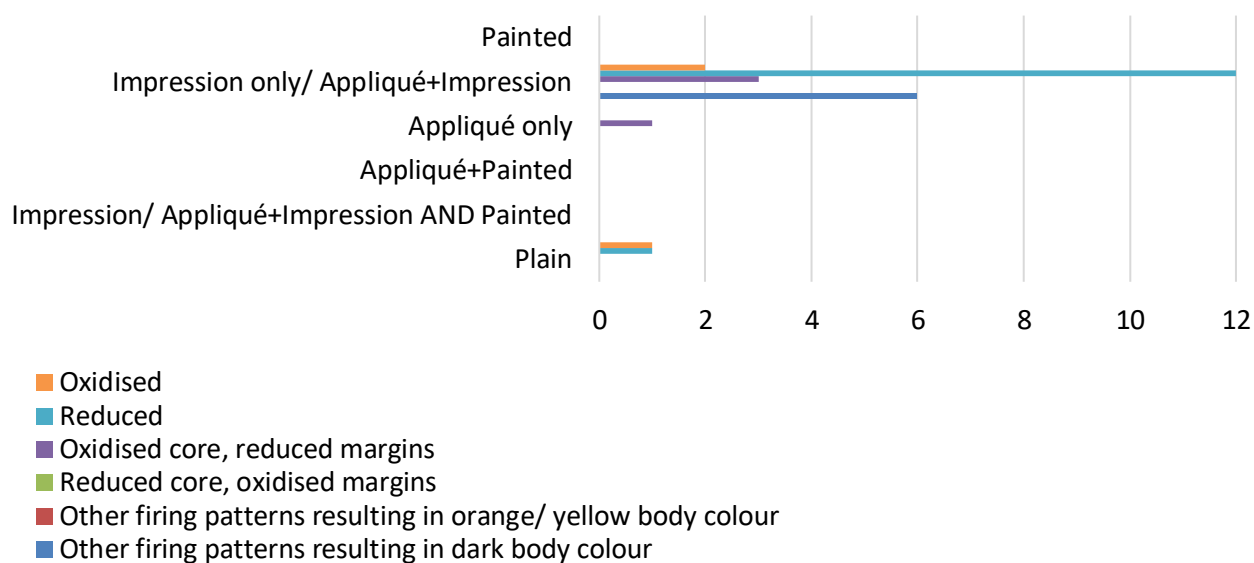


Fig. 5.91. Frequency of combinations of the coarse fabric with specific decoration and firing patterns on selected sherds from Majiayao; numbers represent the number of sherds.

Semi-coarse fabrics (3 samples)

As only three semi-coarse fabric samples were identified among the samples from Majiayao, no proper interpretation of data can be made. All three samples were fired in oxidation as the last firing atmosphere and can be painted as well as decorated with impression and appliqué (Fig. 5.92).

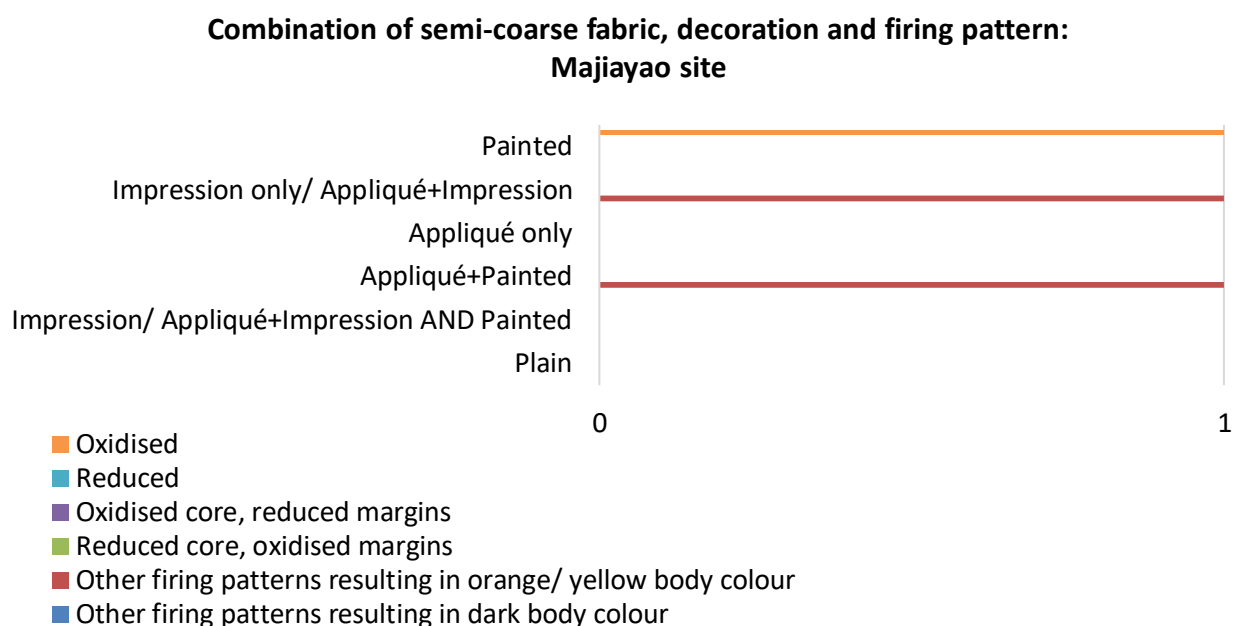


Fig. 5.92. Frequency of combinations of the semi-coarse fabric with different decoration types and firing patterns on selected sherds from Majiayao; numbers represent the number of sherds.

Coarse-Fine-combination fabrics (2 samples)

Among the samples from Majiayao, the coarse-fine combination fabric sherds were fired in oxidising atmosphere (Fig. 5.93). Only in the case of CNP16, which has painted decoration, the technological choice of the firing atmosphere seems appropriate. CNP36 is plain and does not provide enough clues to explain the firing. Perhaps it was fired together with vessels that were painted or with other coarse-fine-combination fabric vessels that also had paint decoration.

Combination of coarse-fine-combination fabric, decoration type and firing pattern: Majiayao site

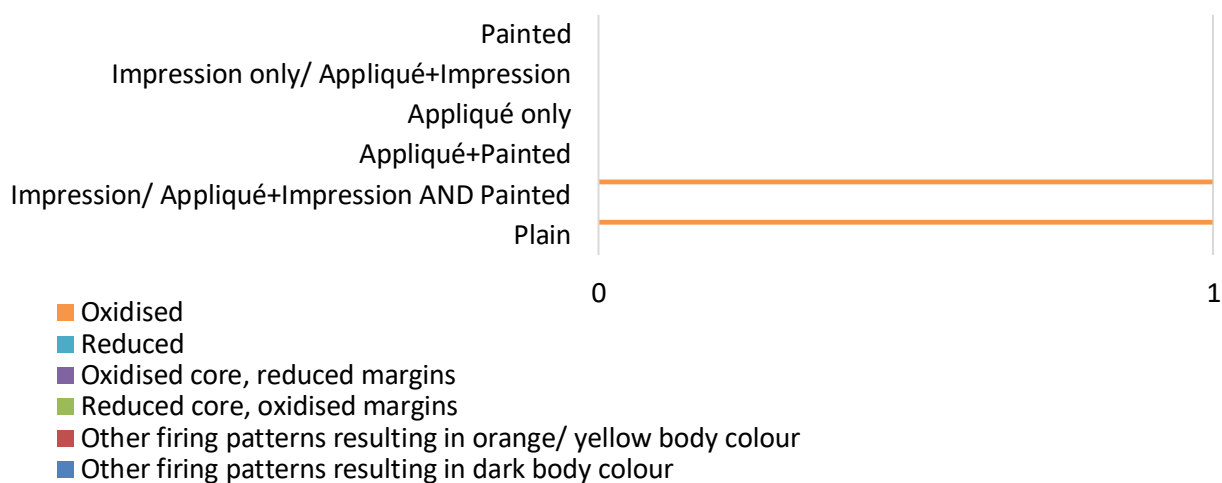


Fig. 5.93. Frequency of combinations of the coarse-fine-combination fabric with specific decoration type and a firing pattern on selected sherds from Majiayao; numbers represent the number of sherds.

5.1.2.2 Waguanzui (9 samples)

5.1.2.2.1 Fabrics

No coarse, semi-coarse or coarse-fine-combination fabrics have been identified on the selected samples from Waguanzui; all fabrics are fine (Table 5.4). The cross-sections show compact fine fabric with low porosity (Fig. 5.94).

Table 5.4. Fabric types identified in selected sherds from Waguanzui.

Fabric type	Number of sherds
Fine	9
Coarse	0
Semi-coarse	0
Coarse-Fine-combination	0



Fig. 5.94. Fine fabric example from Waguanzui, the large pores on the left and right of the cross-section likely indicate coil joining zones; CNP75.

5.1.2.2.2 Decoration

The main decoration type on the sherds from Waguanzui is black painting (Table 5.5). The designs are lines, curves, spiked lines and curves, as well as dots (Fig. 5.95). CNP78 is a plain sherd with a black and red brand mark (Fig. 5.96) similar to the ones on the painted vessels (cf. 5.1.1.2). Based on the study of the vessels, the location on a paint brand mark on a large plain sherd indicates that this sherd was a part of a lower body possibly of a large painted vessel.

Table 5.5. Decoration types identified on selected sherds from Waguanzui.

Decoration type	Number of sherds
Painted	7 in total
Painted outside + Painted in black	4
Painted outside + Painted in black + Painted in red	2
Painted outside + Painted inside + Painted in black + Painted in brown	1
Plain	2 in total



Fig. 5.95. Examples of decoration on selected sherds from the Waguanzui site. Left: black and dark red, CNP72; right: black, CNP79.



Fig. 5.96. CNP78 from Waguanzui with a faded black and red painted mark.

5.1.2.2.3 Firing patterns

All sherds from Waguanzui were fired in oxidation as the last firing atmosphere (Table 5.6). Cross-sections show that the temperature and oxygen distribution was not stable throughout the firing process which resulted in differently coloured core layers (Fig. 5.97a-c).

Table 5.6. Firing patterns identified on selected sherds from Waguanzui.

Firing pattern	Number of sherds
Oxidised	6
Reduced	0
Oxidised core, reduced margins	0
Reduced core, oxidised margins	2
Other firing patterns resulting in orange/yellow body colour on the outside	1
Other firing patterns resulting in dark body colour	0

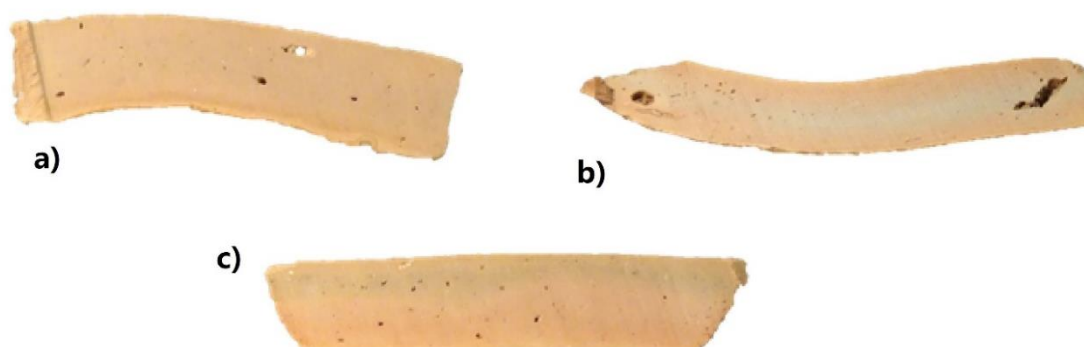


Fig. 5.97. Examples of firing patterns seen on selected sherd cross-sections from the Waguanzui site: a) Oxidised, CNP79 b) Reduced core, oxidised margins, CNP75 c) Other firing pattern resulting in orange/ yellow body colour on the outside – faint grey layer in the upper half of the cross-section, CNP80.

5.1.2.2.4 Combination of decoration and fabric

The combination of the painted decoration and fine fabric on the Waguanzui sherds can be interpreted similarly to the case of the painted fine sherds from Majiayao site (Fig. 5.98). The fine fabric provides a suitable surface for applying paint. As implied by the painted brand mark on the plain sample CNP78, it likely belongs to a painted vessel, therefore, it theoretically falls into the category “painted – fine”. The other plain sherd, CNP80, has parallel oriented scraping marks on its external surface. Based on the macroscopic analysis in section 5.1.1, these marks are found on lower bodies of large painted vessel. Therefore, CNP80 could be a part of a painted vessel and fall into the “painted – fine” category as well.

Combination of decoration and fabric: Waguanzui site

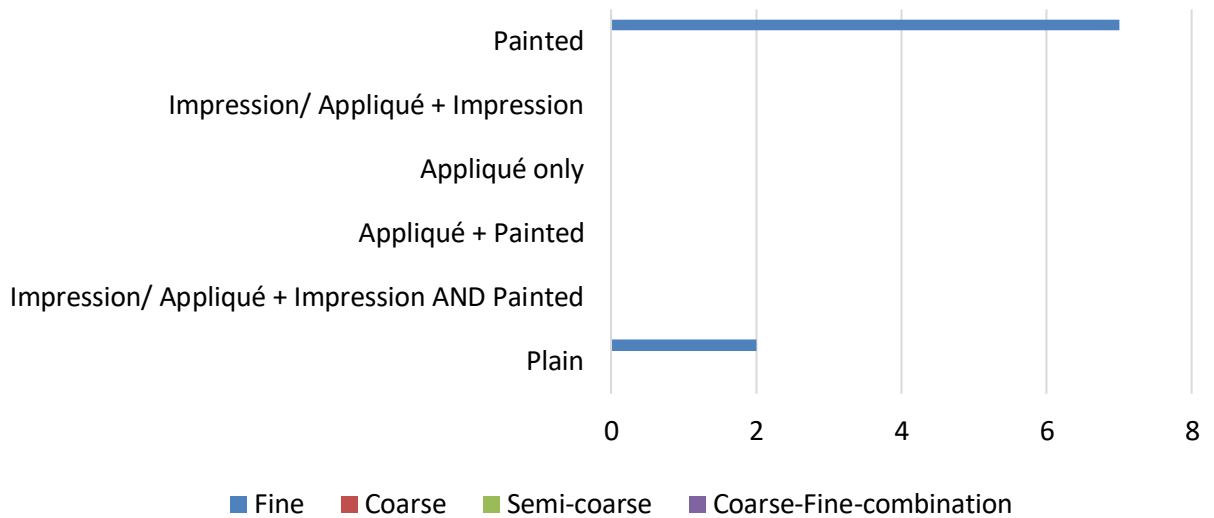


Fig. 5.98. Frequency of combinations of decoration and fabric on selected sherds from Waguanzui; numbers represent the number of sherds.

5.1.2.2.5 Combination of firing pattern and decoration

All the sherds were fired in oxidation as the last firing atmosphere (Fig. 5.99). Oxidation created a yellow body colour – a suitable background for applying painted decoration in darker colours.

Combination of firing pattern and decoration: Waguanzui site

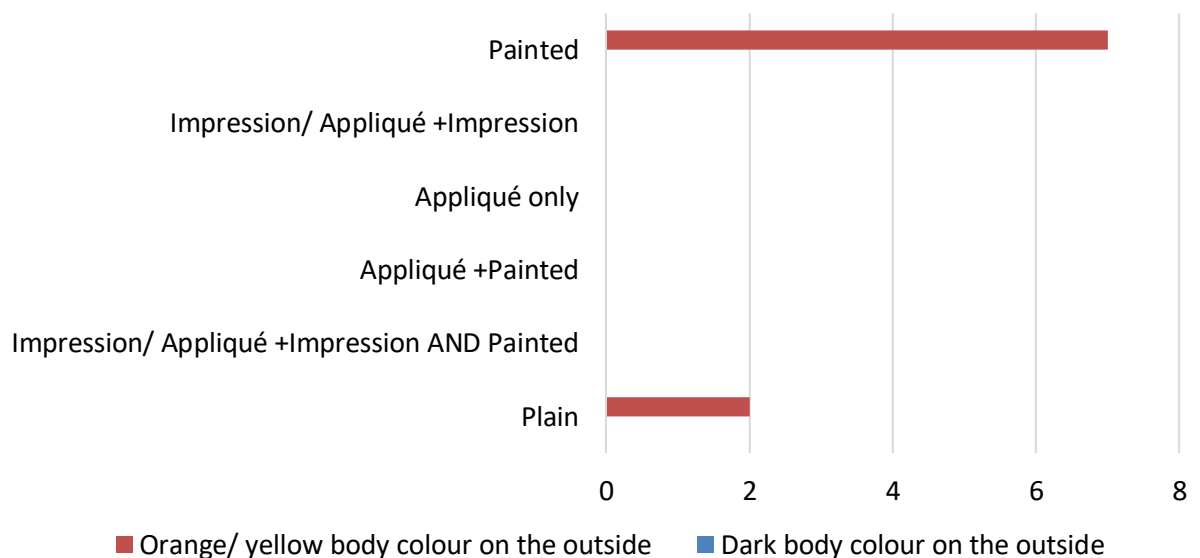


Fig. 5.99. Frequency of combinations of firing pattern and decoration on selected sherds from Waguanzui; numbers represent the number of sherds.

5.1.2.2.6 Combination of firing pattern and fabric

As became evident in the previous section, the fine fabric sherds were fired in oxidation as the last firing atmosphere (Fig. 5.100).

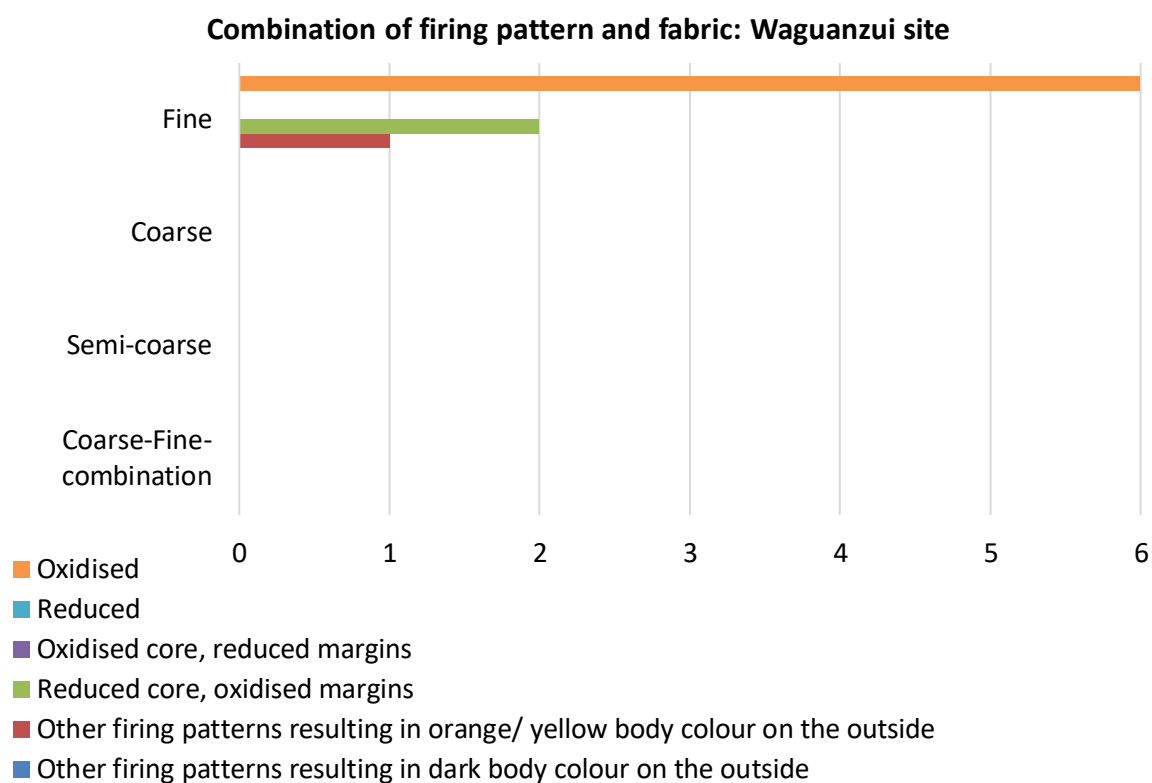


Fig. 5.100. Frequency of combinations of firing pattern and fabric on selected sherds from Waguanzui; numbers represent the number of sherds.

5.1.2.2.7 Summary: combination of fabric, decoration type, and firing pattern

Fine fabrics (9 samples)

In summary, the samples from Waguanzui support the trend observed among the Majiayao samples: fine sherds are commonly combined with painted decoration and oxidation as the last firing atmosphere (Fig. 5.101).

Combination of fine fabric, decoration, and firing pattern: Waguanzui site

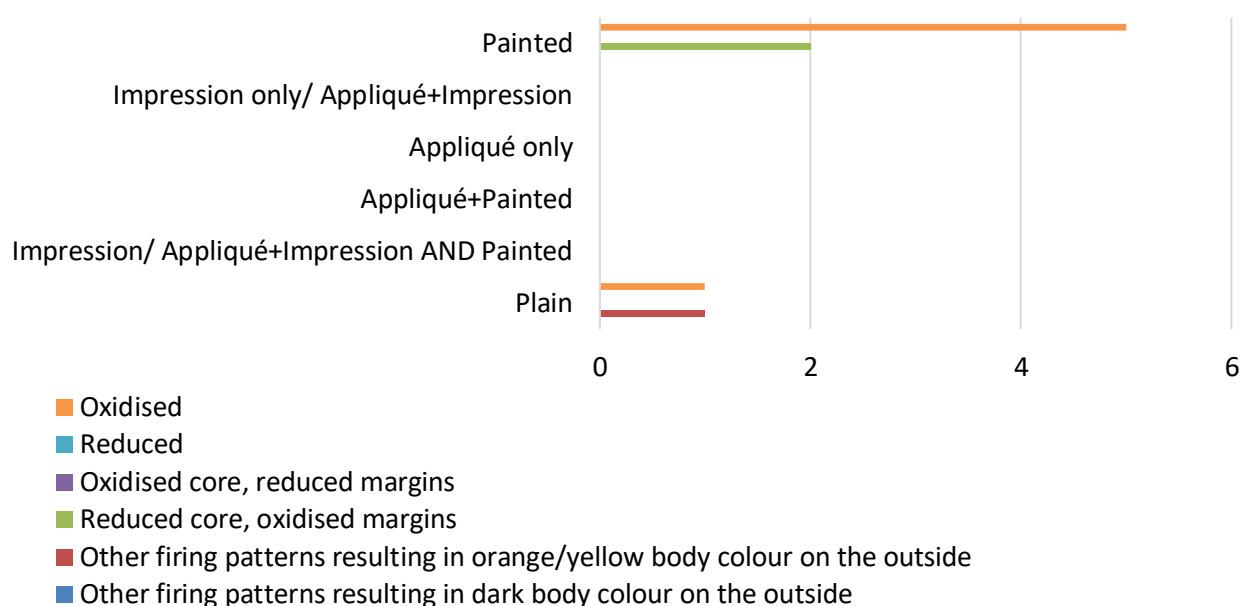


Fig. 5.101. Frequency of combinations of the fine fabric with decoration and firing pattern on selected sherds from Waguanzui; numbers represent the number of sherds.

5.1.2.3 Zhujiazhai (52 samples)

5.1.2.3.1 Fabrics

Sherds from Zhujiazhai have fine, coarse and semi-coarse fabrics. No coarse-fine-combination fabrics have been identified. The semi-coarse fabrics are not as common, similar to the Majiayao samples, but in relation to the sample size their number for Zhujiazhai is higher (Table 5.7). The cross-sections clearly show the difference between the three types of fabrics in the macroscopic visibility of non-plastic inclusions and their size (Fig. 5.102a-c).

Table 5.7. Fabric types identified in selected sherds from Zhujiazhai.

Fabric type	Number of sherds
Fine	25
Coarse	18
Semi-coarse	9
Coarse-Fine-combination	0

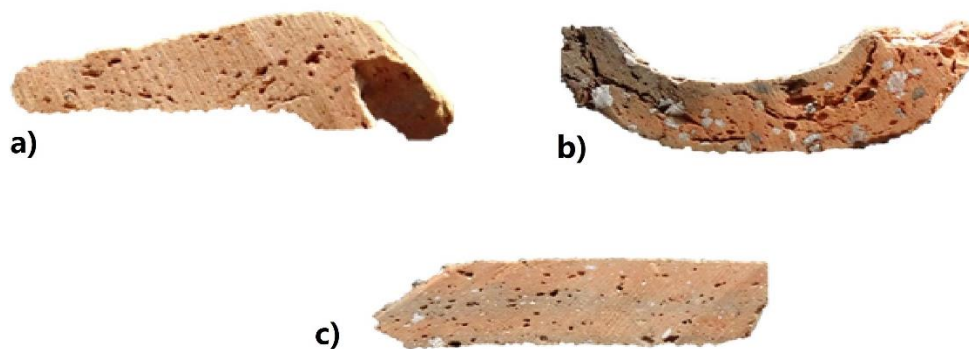


Fig. 5.102. Fabric type examples from Zhujiazhai: a) fine, CNP100 b) coarse, CNP106 c) semi-coarse, CNP109.

5.1.2.3.2 Decoration

The decoration types identified among samples from Zhujiazhai largely correspond to the variety of decoration on the Majiayao sherds and to the painted decoration on samples from Waguanzui (Table 5.8 and Fig. 5.103). Although painting is the most common decoration type, it needs to be emphasised here as well that this is mostly due to the sampling strategy. Zhujiazhai sherds show a brighter shade of red (Fig. 5.104a) than the brown shade from Majiayao, but this does not necessarily mean that bright red colour was not present among the pottery from the Tao River Valley. The red colour, as mentioned previously, indicates a later phase of the Majiayao-style pottery – Banshan or Machang. Vessels of this type were found at Waguanzui (e. g. K-05011). No complete vessels or sherds with bright red shade were collected by Andersson directly at the Majiayao site to the author's knowledge. The painted designs include straight lines, curves, lattice, spikey lines, and wavy lines. The relief decoration consists of variations of cord impression and appliqué (Fig. 5.104b-d). No combination of appliqué and painting has been observed on the sampled sherds from Zhujiazhai.

Table 5.8. Decoration types identified on selected sherds from Zhujiashai.

Decoration type	Number of sherds
Painted	36 in total
Painted outside + Painted in black	16
Painted outside + Painted in black + Painted in red	7
Painted inside + Painted in black + Painted in red	2
Painted outside + Painted in red	2
Painted outside + Painted inside + Painted in black + Painted in brown	2
Painted inside + Painted black	2
Painted outside + Painted brown	1
Painted outside + Painted in brown + Painted in white	1
Painted outside + Painted in black + Painted in brown	1
Painted outside + Painted inside + Painted in black + Painted in red + Painted in brown	1
Painted outside + Painted inside + Painted in brown	1
Impression only	4 in total
Cross-cord	2
Other impression	2
Appliqué + Impression	7 in total
Appliqué + Diagonal cord impression	1
Appliqué + Cross-cord impression	3
Appliqué + Vertical cord impression	1
Appliqué + Vertical cord + Cross-cord impression	1
Appliqué + Other impression	1
Appliqué only	2 in total
Plain	3 in total

Decoration types: Zhujiashai site

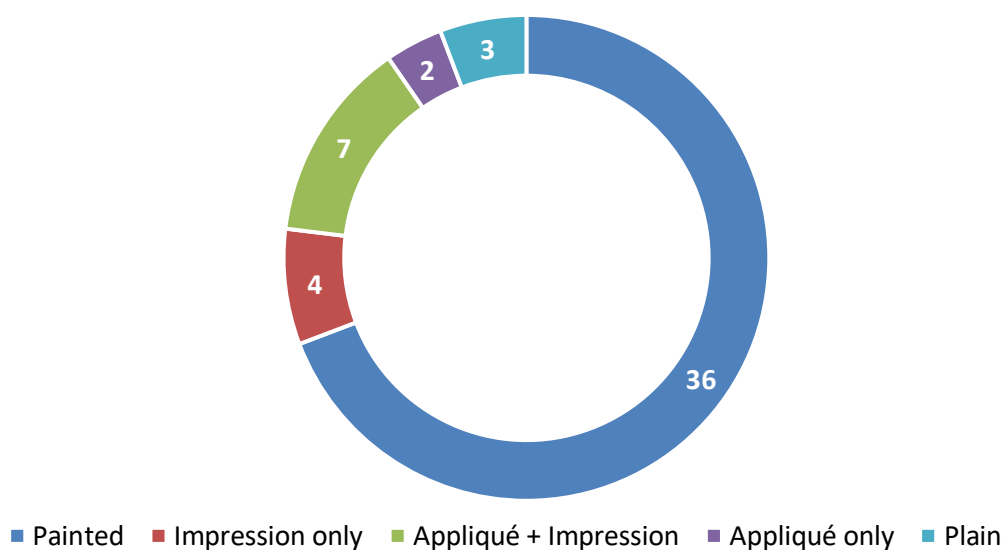


Fig. 5.103. Summary of the decoration types on selected sherds from Zhujiashai; numbers represent the number of sherds.

a) Painted



b) Impression and Appliqué



c) Impression and Appliqué



d) Impression and Appliqué

Fig. 5.104. Examples of decoration on selected sherds from Zhujiashai; a) CNP102 b) CNP105 c) CNP126 d) CNP82.

5.1.2.3.3 Firing patterns

Based on microscopic observations on the cross-sections, samples from Zhujiashan show a variety of firing patterns (Figs 5.105-106a-g). However, it appears that the firing in a fully reducing atmosphere was not as common as seen on the pottery samples from Majiayao. The data in Fig. 5.104. shows that only two samples were classified as fired in reducing atmosphere. These samples are CNP115 and CNP125 which are both painted rim sherds and they would be the only examples so far, where painting and reduction atmosphere were combined. However, the cores of these sherds might seem reduced at first (Fig. 5.106b), but they actually show a mix of beige, grey and yellow shades which are difficult to categorise. On the microscopic level, CNP115 shows a matrix with a moderate optical activity and CNP125 is optically inactive. This means that both sherds were fired at ca 1000° C or above. The unusual colouration in the core of CNP115 could be the result of a chemical alteration of iron oxides under high temperature. CNP115 fabric has coarse black opaque inclusions, possibly hematite, which reacted with potential calcite content forming calcium silicates and reduced the orange/ yellow hue. The calcite content could not be observed under petrographic microscope but might be detectable on the elemental level. The optically inactive matrix of CNP125 indicates that the starting vitrification could have contributed to the colour change in the fabric, possibly also combined with similar chemical processes as in CNP115.

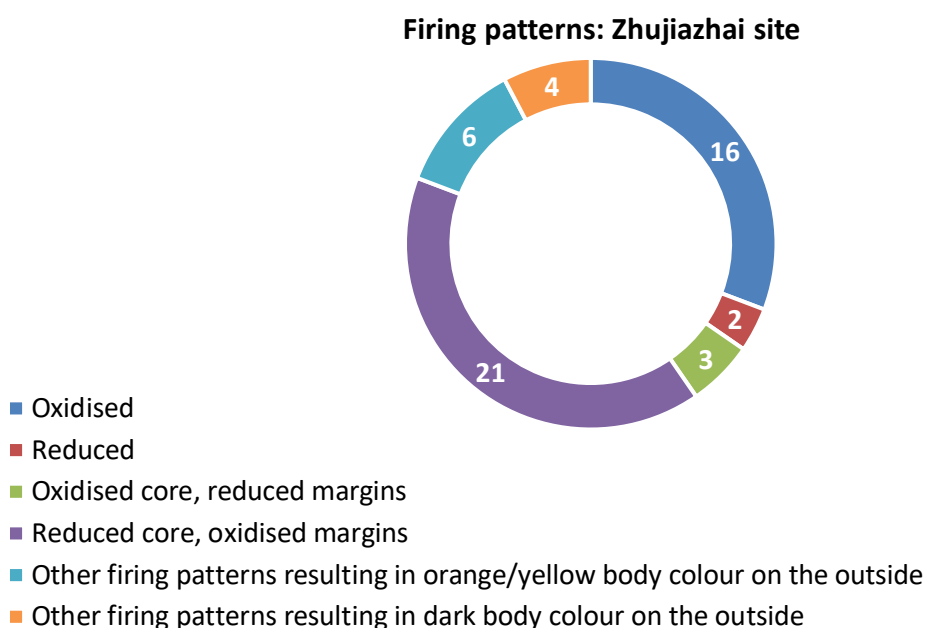


Fig. 5.105. Firing patterns identified on selected sherds from Zhujiazhai; numbers represent the number of sherds.

There are sherds which were fired in reduction as the last firing atmosphere, for example CNP89 and CNP103 and their cores or the inner core halves are red or orange (Fig. 5.106c, g). Sherds fired similarly to CNP89 only have a thin dark layer on the outer surfaces which are not clearly visible in the cross-section alone. It is possible that some kind of clay slip coating was applied to the exterior and interior of this vessel, though this also implies that the heat and/or oxygen levels needed to be regulated for the slip to achieve a dark colour. A chemical study of the surface would shed further light on this issue. Vessels K-06292 and K-06384 from Zhujiazhai show even grey colouration on the outside and inside. However, the K-06384 has a damaged area where the oxidised core is exposed. K-06292 has no damaged area that would allow to observe the inner core colours and this vessel could be an example of full reduction.

The firing of CNP103 and CNP127 presents an interesting case that has a counterpart among the Majiayao samples (CNP18, CNP23, CNP27, CNP28 and possibly CNP32). In the cross-section, the core has two layers: the upper including

the exterior surface is dark and the lower including the interior surface is orange (Fig. 5.104g). It appears that these sherds were first oxidised and then the oxygen supply was decreased. The reduction process seems not to have lasted long enough for the vessel wall to fully oxidise, as the sharp margin in the core indicates.

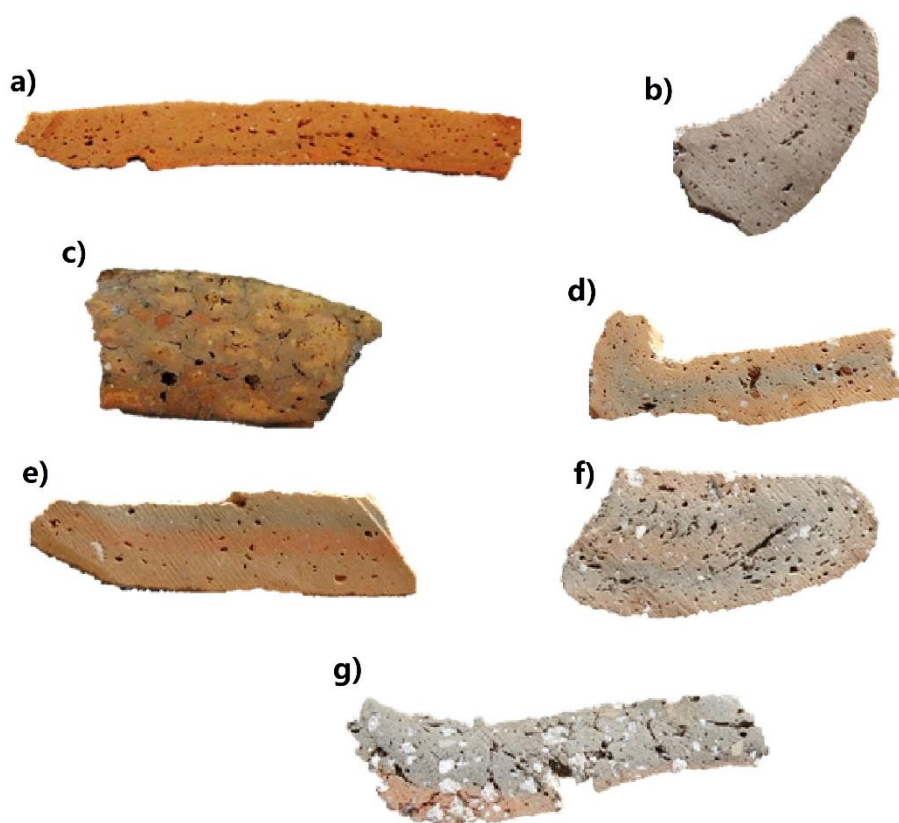


Fig. 5.106. Examples of firing patterns seen on selected sherd cross-sections from Zhujiashai: a) Oxidised, CNP112 b) Reduced? CNP125 c) Oxidised core, reduced margins, CNP89 d) Reduced core, oxidised margins, CNP96 e) Other firing pattern resulting in orange/ yellow body colour on the outside, CNP186 f) Other firing pattern resulting in orange/ yellow body colour on the outside, CNP110 g) Other firing pattern resulting in dark body colour on the outside, CNP103.

Similar firing pattern can be seen on coarse sherds from the Liuwan burial site which is also located in the Huangshui River Valley ca 50-60 km east from Zhujiashai along the river (Fig. 5.107).³⁸

³⁸ The staff of the Liuwan Painted Pottery Museum kindly allowed the author to view and take pictures of some of the excavated pottery material on which the conservators were working at that moment.

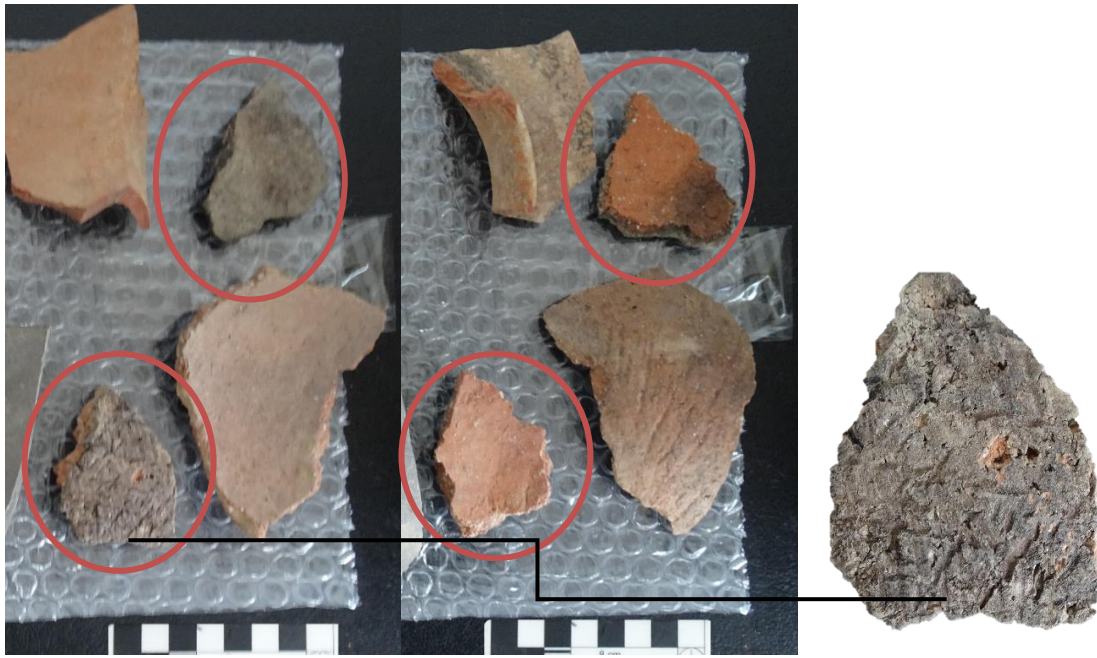


Fig. 5.107. Excavated Neolithic and Bronze Age sherds from the Liuwan burial site; red-circled are the coarse sherds with a firing pattern similar to CNP103 and CNP127. Left: exterior reduced surface up; middle – interior oxidised surface up. On the right – separate photo of one of the sherds showing cord-impressions; a small hole on the sherd surface shows how thin the reduced layer is.

The appearance of a similar firing pattern with reduction as the last firing atmosphere on pottery from different sites indicates how the reduction process might have been managed by the prehistoric potters. As the sherds fired in these conditions have coarse fabrics, their cores could have been already oxidised after a half an hour at 600-700° C (Rice 2015:280). The earliest time when the reduction atmosphere might have been created would be shortly after the heat reached that temperature.

CNP87 presents a reverse case where the interior half of the vessel is dark and the exterior half oxidised red. However, the layers in the cross-section are not as sharp as in the case of CNP103, CNP127, and similarly fired sherds from Majiayao.

Overall, a large proportion of the samples from Zhujiashai have a dark core and oxidised margins (Fig. 5.105, illustrated in 106d). This firing pattern is also common among the Majiayao and Waguanzui sherds and was discussed previously.

CNP186 and CNP110 (Fig. 5.106e-f) show irregularities in the firing conditions that are reflected in different coloured layering of the core.

5.1.2.3.4 Combination of decoration and fabric

Combinations of decoration and fabric types on samples from Zhujiashai show two clear trends (Fig. 5.108). The first one is the pairing of all fine fabric and semi-coarse fabric sherds with the painted decoration. The second trend is the combination of impression and appliqué decoration with coarse fabrics. The same trends were observed at Majiayao, and for the fine fabrics at Waguanzui. Additionally, Zhujiashai has coarse fabric sherds with painted decoration: CNP91, CNP182. Both sherds are painted red. Among the analysed vessels from Zhujiashai, K-06150, K-06144, K-06381 have coarse fabrics and are painted.

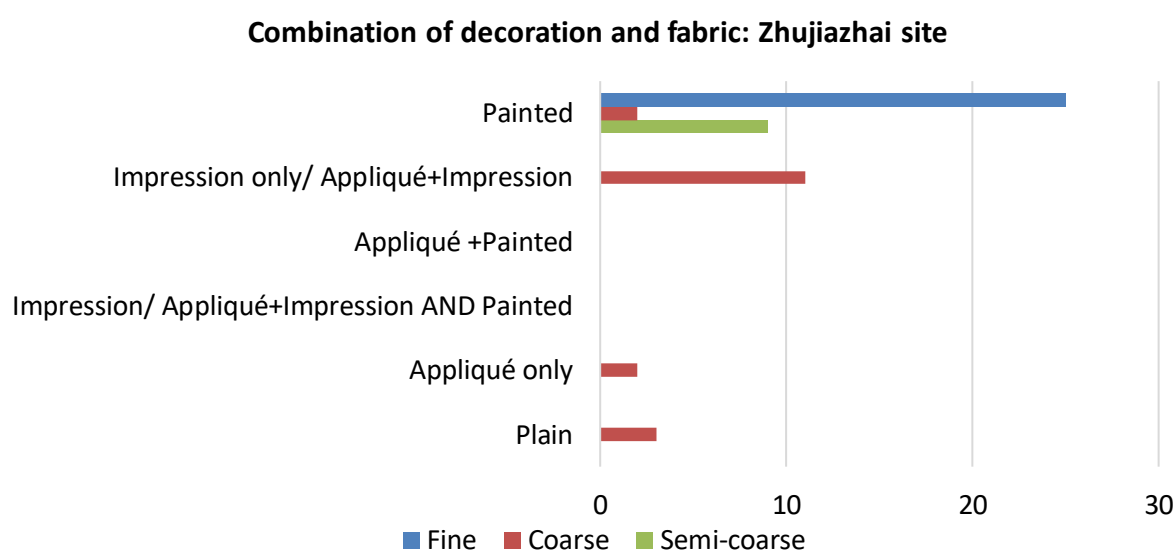


Fig. 5.108. Frequency of combinations of decoration and fabric on selected sherds from Zhujiashai; numbers represent the number of sherds.

5.1.2.3.5 Combination of firing pattern and a decoration

One clear trend among the Zhujiashai samples is the placement of painted decoration on the light background created by oxidation as the last firing atmosphere (Fig. 5.109). This combination is also dominant among the samples

from Majiayao and Waguanzui. A deviation from the trend involving relief decoration observed on the samples from Majiayao is that more Zhujiazhai sherds with impression and appliqué were last fired in oxidation than in reduction.

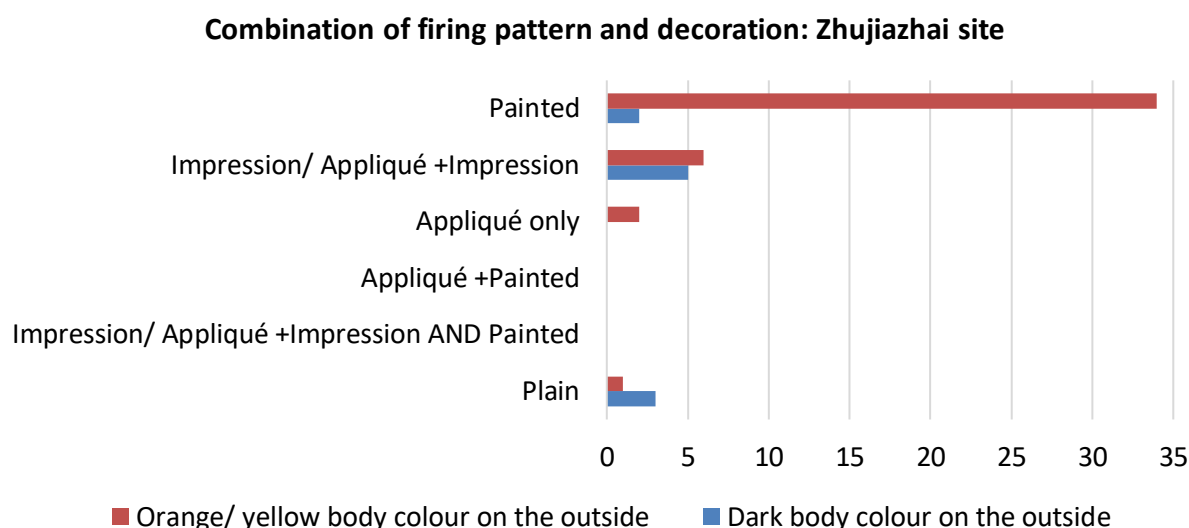


Fig. 5.109. Frequency of combinations of firing pattern and decoration on selected sherds from Zhujiazhai; numbers represent the number of sherds.

5.1.2.3.6 Combination of firing pattern and fabric

The combinations of specific firing patterns and fabric types on Zhujiazhai samples vary more than among the material from Majiayao and Waguanzui (Fig. 5.110). Nevertheless, the fine fabrics were fired in oxidation as the last firing atmosphere here as well. The one fine sample in the “Reduced” row is the previously discussed CNP125. Coarse fabrics seem to have no preferred firing pattern. The combination “coarse – reduction as the last firing atmosphere” has only slightly higher sample number than the combination “coarse – oxidation as the last firing atmosphere”. Semi-coarse fabrics were predominantly fired in oxidation. The one sample in the “Reduced” row is the previously discussed CNP115 with ambiguous core coloration.

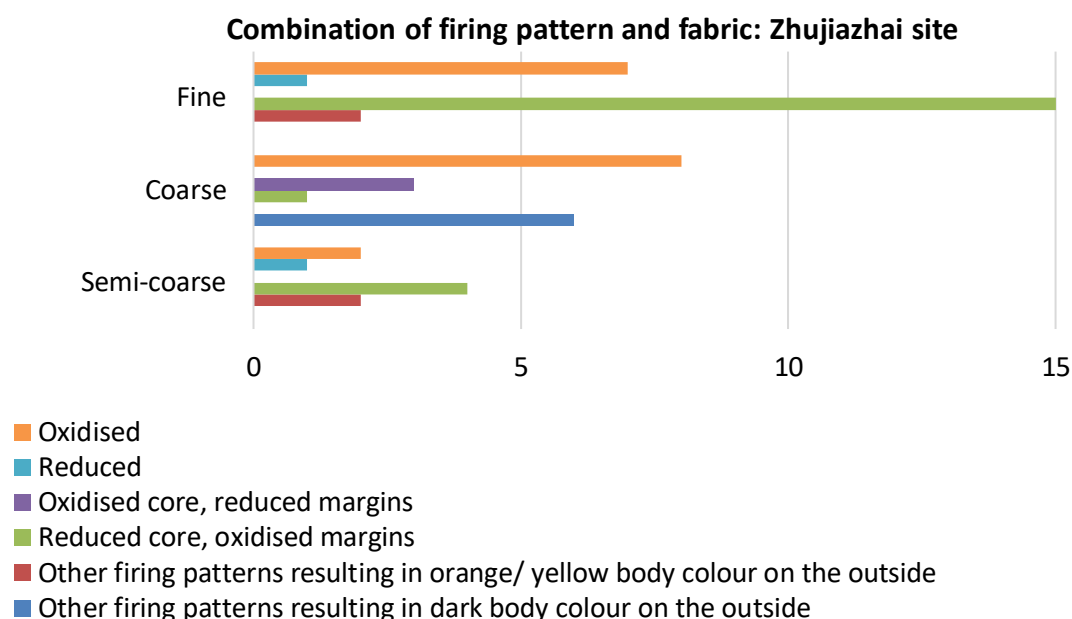


Fig. 5.110. Frequency of combinations of firing pattern and fabric on selected sherds from Zhujiashai; numbers represent the number of sherds.

5.1.2.3.7 Summary: combination of fabric, decoration, and firing pattern

Fine fabrics (25 samples)

Among the samples from Zhujiashai, the fine fabric shows a clear tendency to be combined with painted decoration and oxidation as the last firing atmosphere (Fig. 5.111).³⁹ Similar to the “fine – painted – oxidised” combination identified in the Majiayao and Waguanzui material, fine fabrics from Zhujiashai were preferentially used for painting. The oxidising atmosphere provided a light background to contrast with the dark paint.

³⁹ The one sample with in the “Reduced row” is CNP125 with ambiguous core coloration.

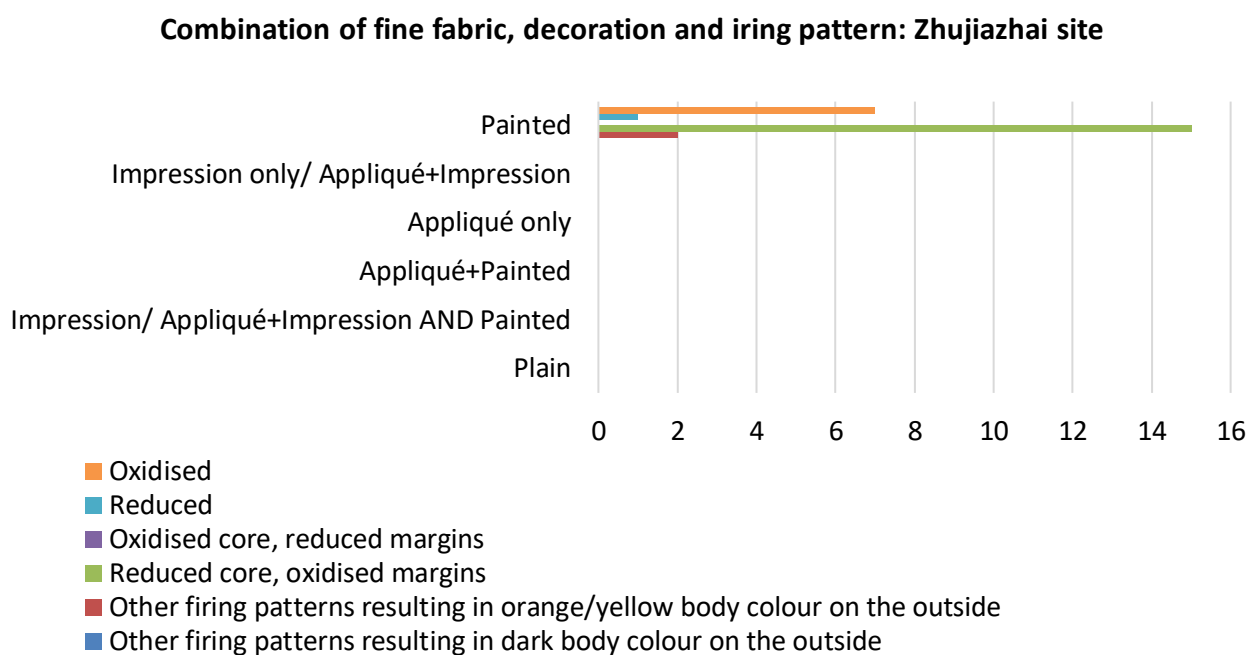


Fig. 5.111. Frequency of combinations of the fine fabric with a decoration type and a firing pattern on selected sherds from Zhujiashai; numbers represent the number of sherds.

Coarse fabrics (18 samples)

Among the samples from Zhujiashai, coarse fabrics show a tendency to be combined with impression and appliqué decoration (Fig. 5.112), which was also identified on the samples from Majiayao. The last firing atmosphere varies, but samples with oxidised exterior are the majority. There is no clear tendency like in the case with Majiayao, to combine coarse sherds decorated with impression and appliqué with reduction as the last firing atmosphere.

Combination of coarse fabric, decoration and firing pattern: Zhujiashai site

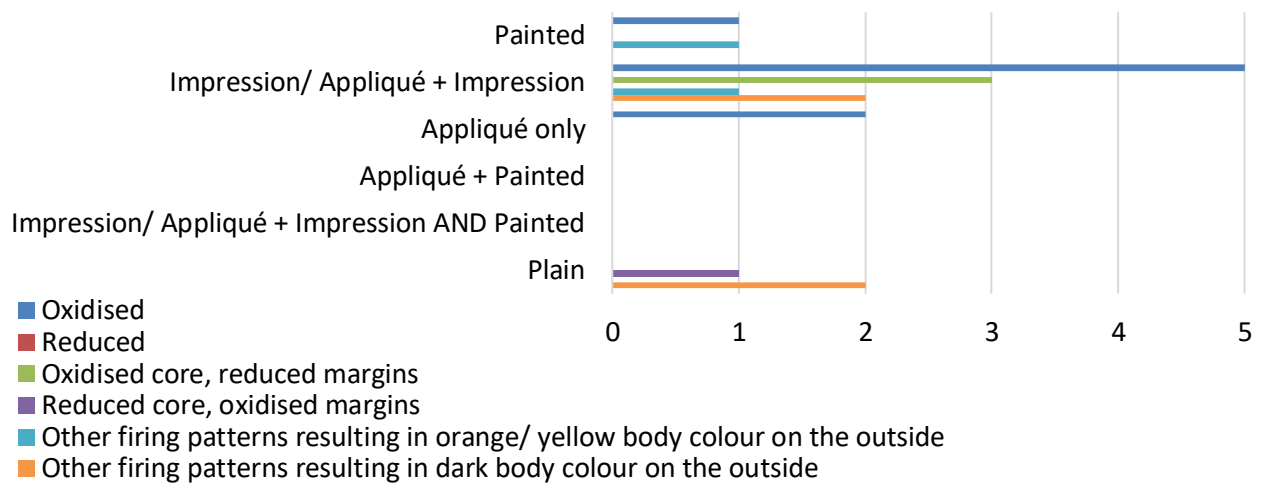


Fig. 5.112. Frequency of combinations of the coarse fabric with decoration and firing pattern on selected sherds from Zhujiashai; numbers represent the number of sherds.

Semi-coarse fabrics (9 samples)

Similar to the fine fabrics, the semi-coarse fabrics of samples sherds from Zhujiashai are combined with painted decoration and oxidising firing conditions as the last firing atmosphere (Fig. 5.113).⁴⁰ This raises the question whether semi-coarse was considered a different clay fabric by the prehistoric potters or not. Artificially classified as semi-coarse, this fabric type might as well have been non-levigated fine clay or a different clay raw material which was used.

⁴⁰ The one sample in the “Reduced” row is CNP115 which has ambiguous core coloration.

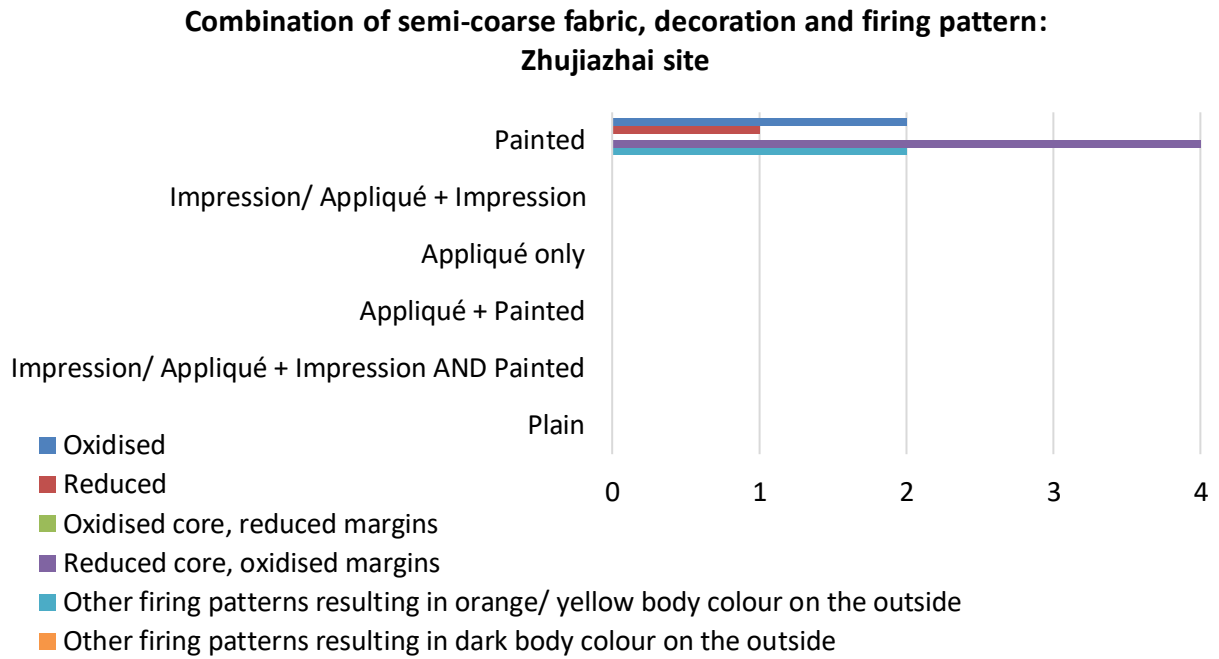


Fig. 5.113. Frequency of combinations of the semi-coarse fabric with decoration and firing pattern on selected sherds from Zhujiazhai; numbers represent the number of sherds.

In summary, the majority of the pottery samples from Zhujiazhai were fired in oxidising atmosphere or have oxidised exterior. The sample size and the scarce archaeological record of the habitation of the site do not allow for a proper discussion of this firing preference. However, it can be suggested that it could have had a technological – lack of technical knowledge and proper firing control, or an aesthetic reason.

5.1.2.4 Luohantang (55 samples)

5.1.2.4.1 Fabrics

The fabric types identified in the pottery samples from Luohantang include fine, coarse and coarse-fine-combinations (Table 5.9). No semi-coarse fabrics were identified. The fabric classification based on the non-plastic inclusion size was straightforward with the material from this site. Coarse grains are clearly identifiable in the cross-sections (Fig. 5.114a-c).

Table 5.9. Fabric types identified in selected sherds from Luohantang.

Fabric type	Number of sherds
Fine	24
Coarse	26
Semi-coarse	0
Coarse-Fine-combination	5

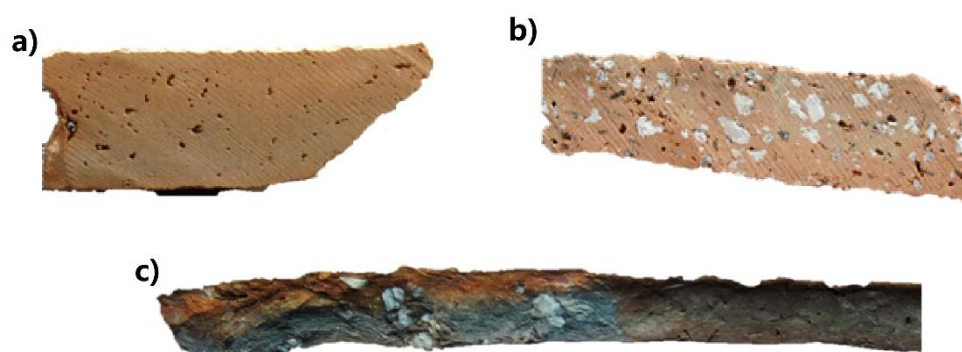


Fig. 5.114. Fabric type examples from Luohantang: a) Fine, CNP134 b) Coarse, CNP172 c) Coarse-fine-combination, CNP181.

5.1.2.4.2 Decoration

The decoration type variety on the samples from Luohantang is similar to the decorations (Table 5.10, Figs 5.115-116a-d). The painted decoration is the most common, which is largely influenced by the sampling strategy as mentioned before. The painted designs include straight lines, dots, curves, and spikey lines. Cord impression is the dominant relief decoration on this material like on the sherds from Majiayao and Zhujiazhai. A new decoration type only observed on the Luohantang sherds is the combination of impression with paint. The observed combinations of painted and relief decoration so far were appliqué and paint or impression plus appliqué and paint.

Plain sherds are also part of the material from Luohantang, as they are part of the material from the other sites. While plain sherds such as CNP159, CNP165, CNP168 and CNP171 might have belonged to painted pots because of their smooth

surfaces, CNP138, CNP142 and CNP167 have a rough surface unsuitable for painting in Majiayao style. Based on the observations in this study, impressed decoration was usually applied on the entire body surface, which is not the case with CNP138, CNP142 and CNP167. This means that likely not all pottery was decorated, and some vessels were left plain; however there is still the possibility of appliqué band decoration.

Table 5.10. Decoration types identified on selected sherds from Luohantang.

Decoration type	Number of sherds
Painted	24 in total
Painted outside + Painted in black	19
Painted outside + Painted inside + Painted in brown	1
Painted outside + Painted inside + Painted in black	2
Painted outside + Painted brown	1
Painted inside + Painted in red	1
Impression only	10 in total
Diagonal cord impression	6
Cross-cord impression	3
Vertical cord impression	1
Appliqué + impression	7 in total
Appliqué + Cross-cord impression	3
Appliqué + Vertical cord impression	3
Appliqué + Diagonal cord impression	1
Impression/ Appliqué + Impression AND Painted	7 in total
Diagonal cord impression + Painted outside + Painted in black	2
Applique + Cross-cord impression + Painted outside + Painted in black	2
Cross-cord impression + Painted outside + Painted in black	1
Applique + Cross-cord impression + Painted outside + Painted in brown	1
Vertical cord impression + Painted inside + Painted in red	1
Plain	7 in total

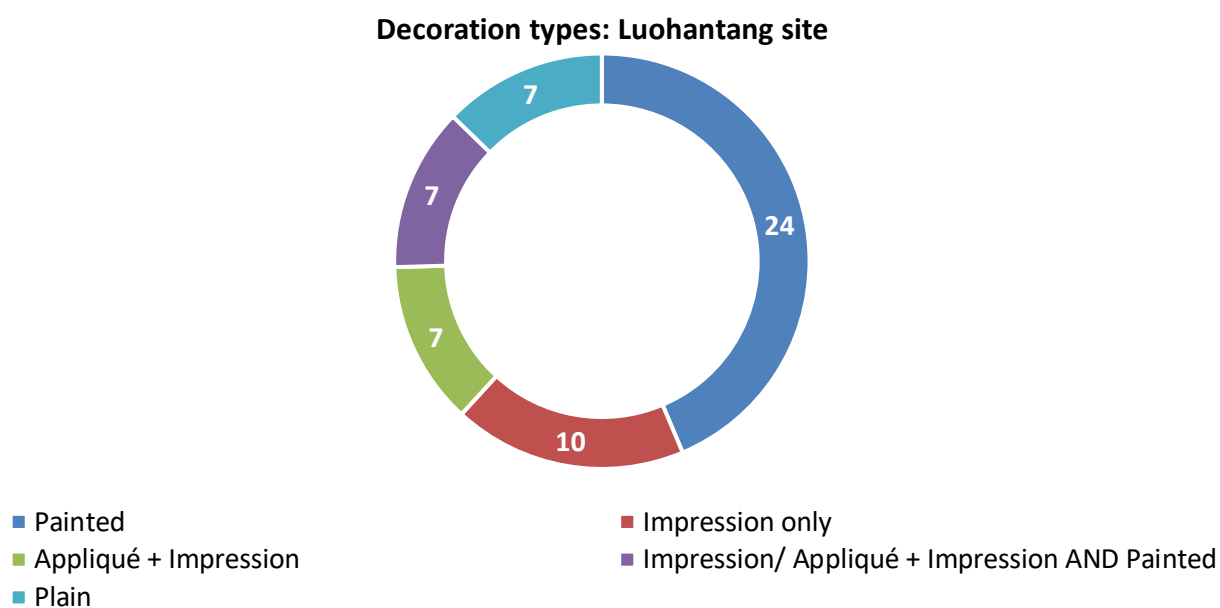


Fig. 5.115. Summary of the decoration types on selected sherds from Luohantang; numbers represent the number of sherds.

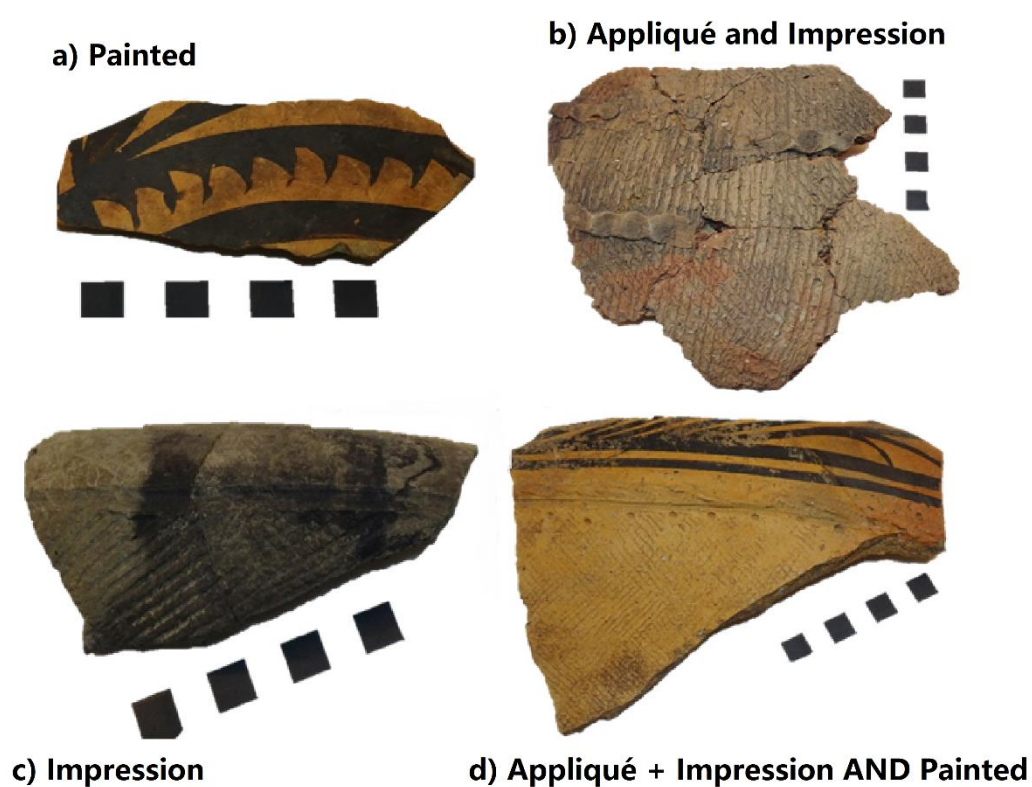


Fig. 5.116. Examples of decoration on selected sherds from Luohantang: a) CNP134 b) CNP137 c) CNP178 d) CNP187.

5.1.2.4.3 Firing patterns

A variety of firing patterns was observed in the cross-sections of sherds from Luohantang (Figs 5.117-118a-f). Oxidation firing is the most common (Fig. 5.118a). Sherds fired in reducing atmosphere are more than were identified in Zhujiashai material but less than in Majiayao material (Fig. 5.118b). However, as it will be discussed in the petrography section below, some of the reduction fired sherds have optically inactive or vitrified matrices, so that it is not certain if the dark colour of the body was intentional in those cases. There is only one example of the firing pattern “oxidised core, reduced margins” (Fig. 5.118c) among the samples, but the presence of this pattern can be considered generally low with regards to the total sample number from the study area.

The firing pattern “reduced core, oxidised margins” is common in the Luohantang material as well, as it has been in the sherds from each site. The development of this pattern can be influenced by the duration of the firing, temperature, or both. Such core layers were commonly seen in fine fabrics sherds from the other sites. CNP156 has a coarse fabric with a grey core (Fig. 5.118d). It has been noted previously that coarse fabrics usually oxidise faster than the fine fabrics due to their porosity, but it appears not to be the case with CNP156. This sample has an optically active matrix which suggests that the sherd was fired at a lower temperature and it could have been a short firing.

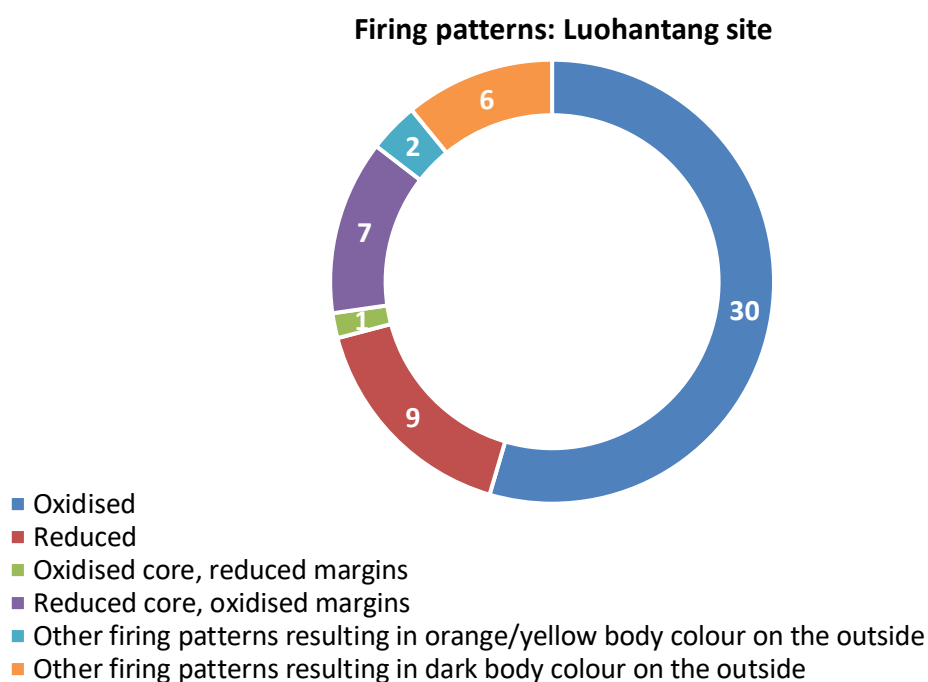


Fig. 5.117. Firing patterns identified on selected sherds from Luohantang; numbers represent the number of sherds.

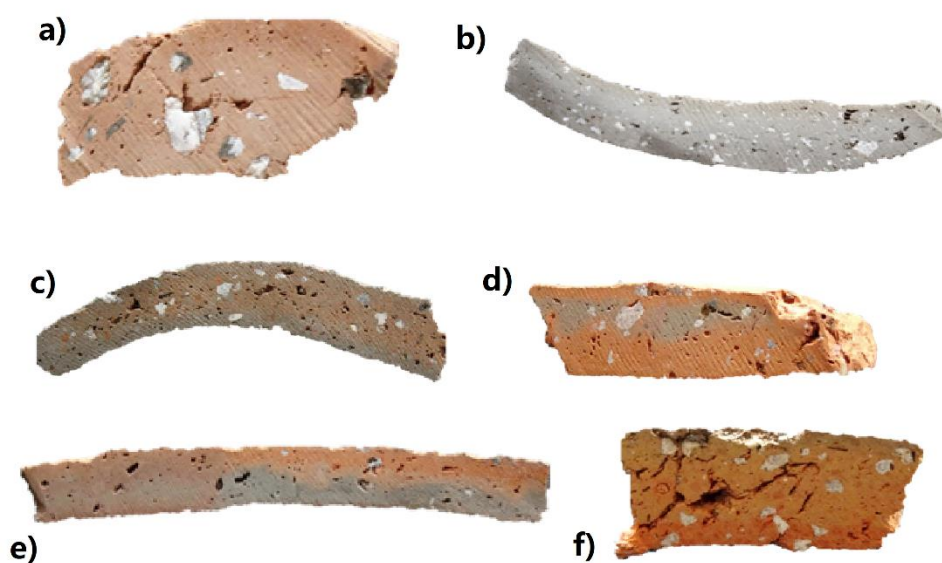


Fig. 5.118. Examples of firing patterns seen on selected sherd cross-sections from Luohantang: a) Oxidised, CNP142 b) Reduced, CNP170 c) Oxidised core, reduced margins CNP169 d) Reduced core, oxidised margins, CNP156 e) Other firing pattern resulting in orange/ yellow body colour on the outside, CNP181 f) Other firing pattern resulting in dark body colour on the outside, CNP175 (oxidised core and thin reduced layer on the outside).

Partially reassembled vessel K-12003-934⁴¹ (Fig. 5.119) shows a similar firing pattern to the sherds from Zhujiashai and Liuwan where the inside core and surface were not fully reduced.



Fig. 5.119. Partially reassembled vessel K-12003-934 from Luohantang showing a reduced surface and oxidised inside; photos taken from the MFEA online database.

CNP181, which is built from two different clays – coarse and fine, also shows two differently coloured cores in cross-section (Fig. 5.118e). Both clays were fired under the same conditions with oxidation as the last firing atmosphere. The fine part shows a faint grey core with brown margins and yellow exterior and interior surfaces. The coarse part has an orange upper layer with a bluish grey lower layer and yellow exterior and interior surfaces. It is obvious that the chemical composition of both clays has reacted differently to the heat and soaking time in the firing process. CNP187 sample would be an interesting refiring case, since it is possible that this sherd also has a slip coating. The homogeneous colour on the exterior and interior surfaces implies an additional technological choice either in paste preparation, surface treatment or firing process. That additional choice led to this surface colouration that contrasts with the colour of the thick margins in the cores.

⁴¹ Not analysed in this study as it was in conservation at the time of the research trip to MFEA in 2019.

5.1.2.4.4 Combination of decoration and fabric

The trends in combination of a decoration type and a fabric are similar to the trends observed in the material from the other three sites. Painted decoration is predominantly applied on the fine fabric pottery, and relief decoration is combined with coarse fabric pottery (Fig. 5.120).

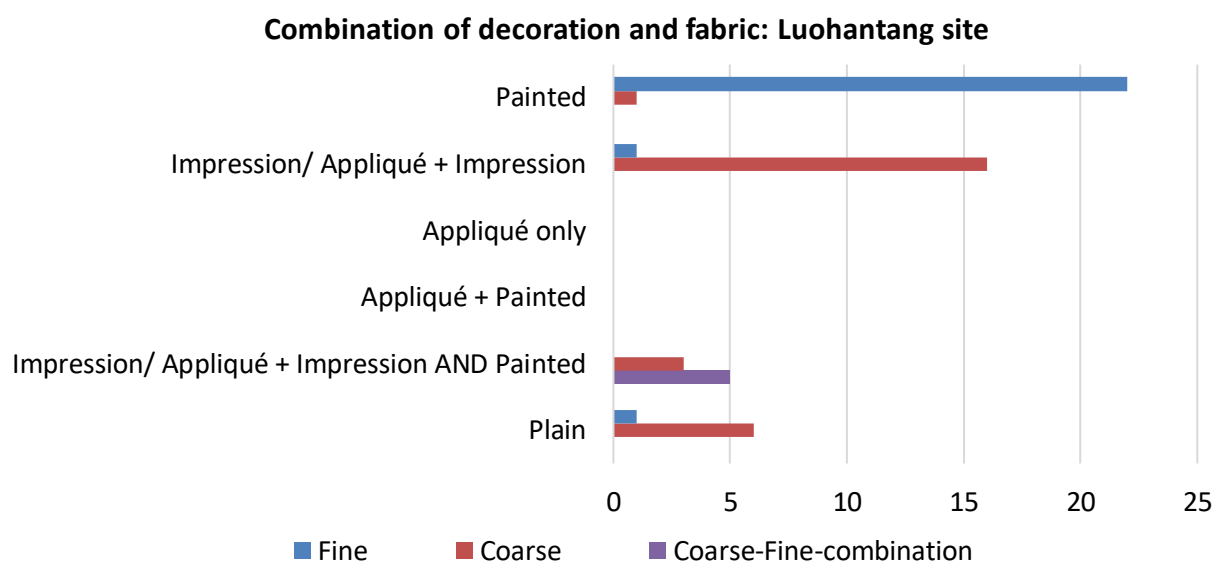


Fig. 5.120. Frequency of combinations of decoration and fabric on selected sherds from Luohantang; numbers represent the number of sherds.

Rare sherds with a coarse-fine-combination fabric have relief and painted decoration similar to the CNP16 from Majiayao. It has been suggested previously that this type of sherds might indicate the preferences in pottery production and design to combine certain fabrics with specific decorations.

5.1.2.4.5 Combination of firing pattern and decoration

In combining a firing pattern with a decoration type, samples from Luohantang show mostly the same trends as the material from the three other sites (Fig. 5.121). Every sample with painted decoration was fired in oxidation as the last firing atmosphere to provide a light background for the dark paint. The majority of the sampled sherds decorated with impression and appliqué were fired in reduction as

the last firing atmosphere, but there is also a number of this type of sherds having a light-coloured surface. The difference between the numbers of relief decorated sherds for the different firing conditions is greater in Majiayao material, and relatively small in Zhujiazhai sherds. It is thus difficult to identify a preferred combination in this case. Most sampled plain sherds from Luohantang were fired in oxidation as the last firing atmosphere. Here as well, the data shows different numbers for every site, so that no preference in firing condition for the plain sherds can be identified.

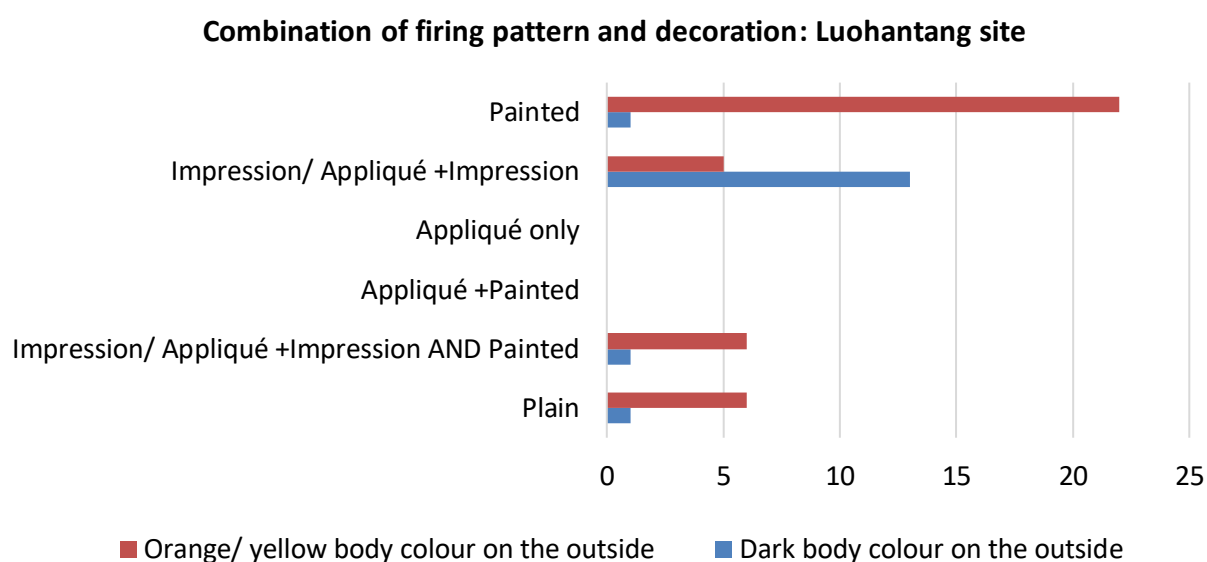


Fig. 5.121. Frequency of combinations of firing pattern and fabric on selected sherds from Luohantang; numbers represent the number of sherds.

5.1.2.4.6 Combination of a firing pattern and a fabric type

Fine sherds from Luohantang repeat the predominant trend in the material from the other sites of combination with oxidation and oxidation as the last firing atmosphere (Fig. 5.122).

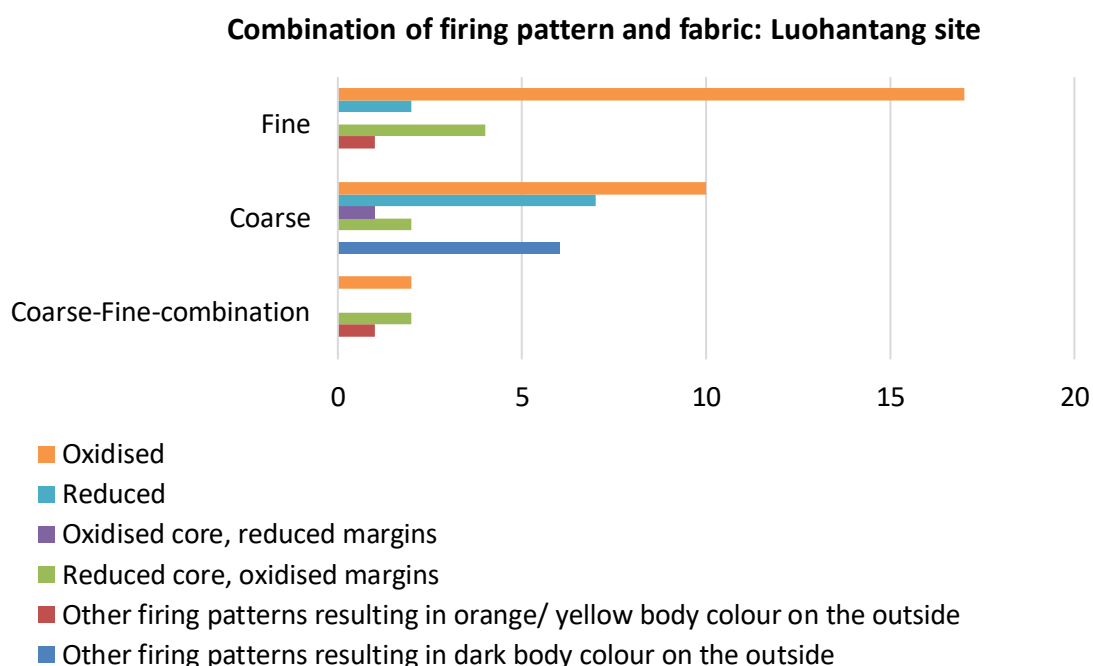


Fig. 5.122. Frequency of combinations of firing pattern and fabric on selected sherds from Luohantang; numbers represent the number of sherds.

The pairing of the coarse fabric with firing patterns resulting either in light or dark body colour is relatively even in numbers. These trends correspond more to the trends of pairings of coarse fabric and firing patterns in Zhujiashai, rather than to the trends in Majiyao.

Sherds with coarse-fine-combination fabrics show clear tendency to be fired in oxidation as the last firing atmosphere. Just like in the case of the fine fabrics, the firing conditions for these sherds were supposed to create a light-coloured background.

5.1.2.4.7 Summary: combination of fabric, decoration and firing pattern

Fine fabrics (24 samples)

A clear tendency to combine fine fabric, painted decoration and oxidation as the last firing atmosphere was observed among the sherds from Luohantang (Fig. 5.123). This is also the case for the material from the other three sites.

Combination of fine fabric, decoration and firing pattern: Luohantang site

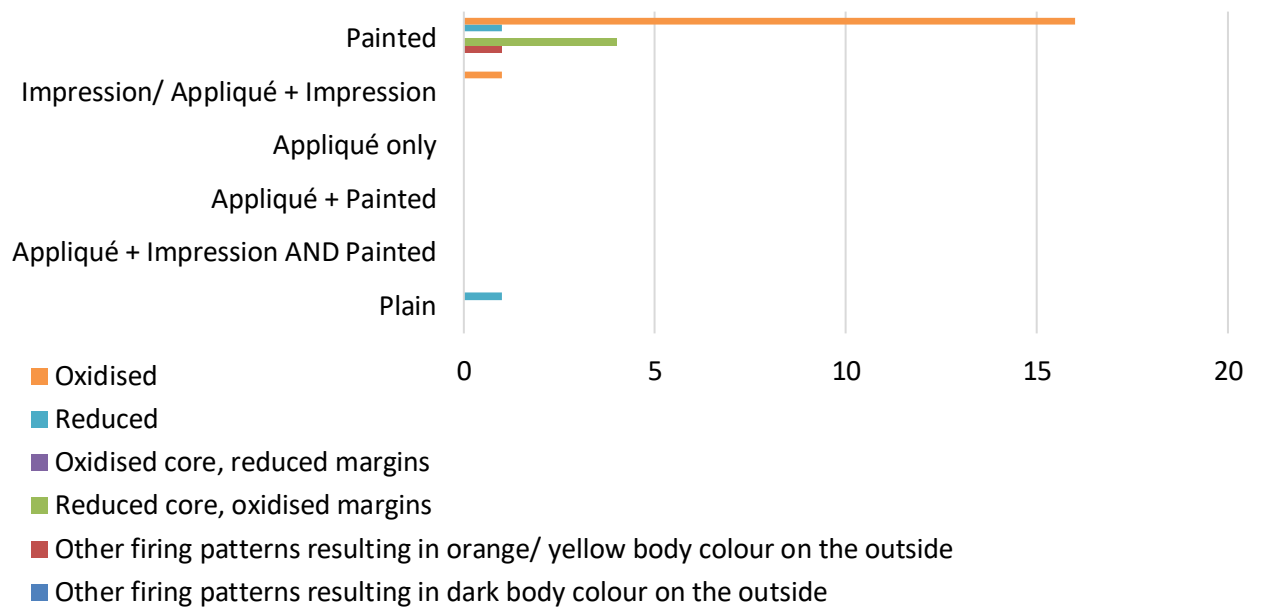


Fig. 5.123. Frequency of combinations of the fine fabric with decoration and firing pattern on selected sherds from Luohantang; numbers represent the number of sherds.

Coarse fabrics (26 samples)

Thirteen (50%) of the coarse fabric samples occur in combination with a relief decoration and a reduction as the last firing atmosphere, which matches the trend for the same combination in the Majiayao material and largely the in the Zhujiashai material (Fig. 5.124). However, the other half of the coarse samples from Luohantang shows combinations with different decorations and firing patterns. It can be tentatively suggested that the combination “coarse – relief decoration – dark body colour” has trend potential, though more samples are required to properly address this issue.

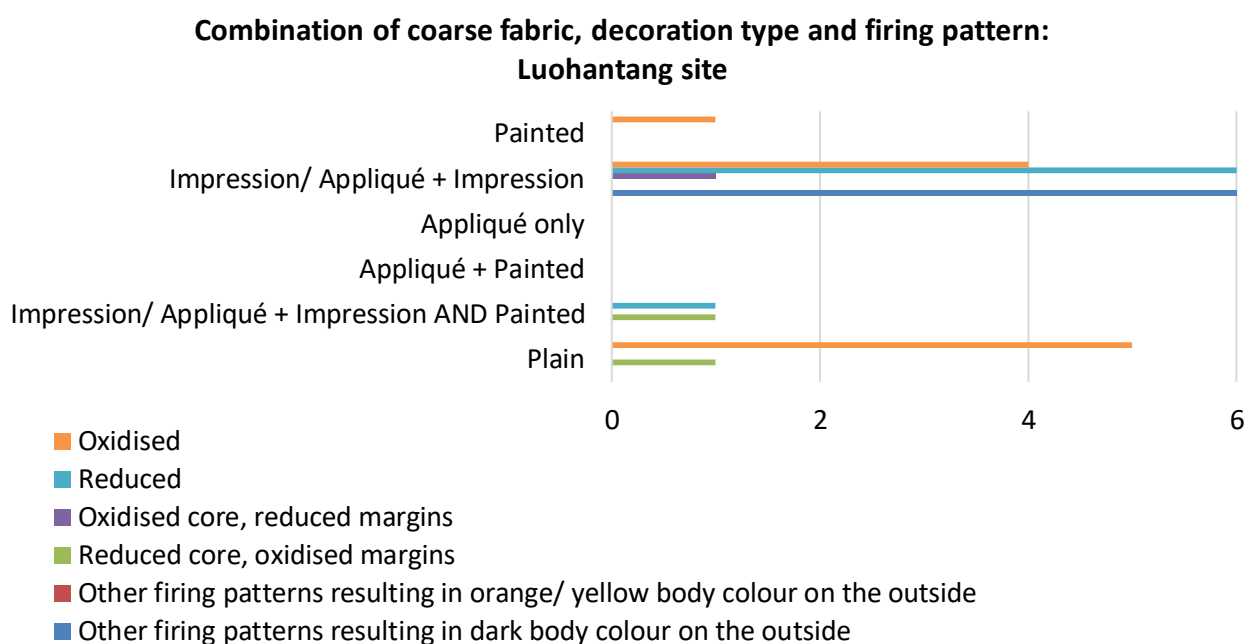


Fig. 5.124. Frequency of combinations of the coarse fabric with decoration and firing pattern on selected sherds from Luohantang; numbers represent the number of sherds.

Coarse-Fine-combination fabrics (5 samples)

Sherds with a coarse-fine-combination fabric show a clear tendency in being combined with oxidation as the last firing atmosphere and mostly impression and appliqué plus painted decoration (Fig. 5.125).

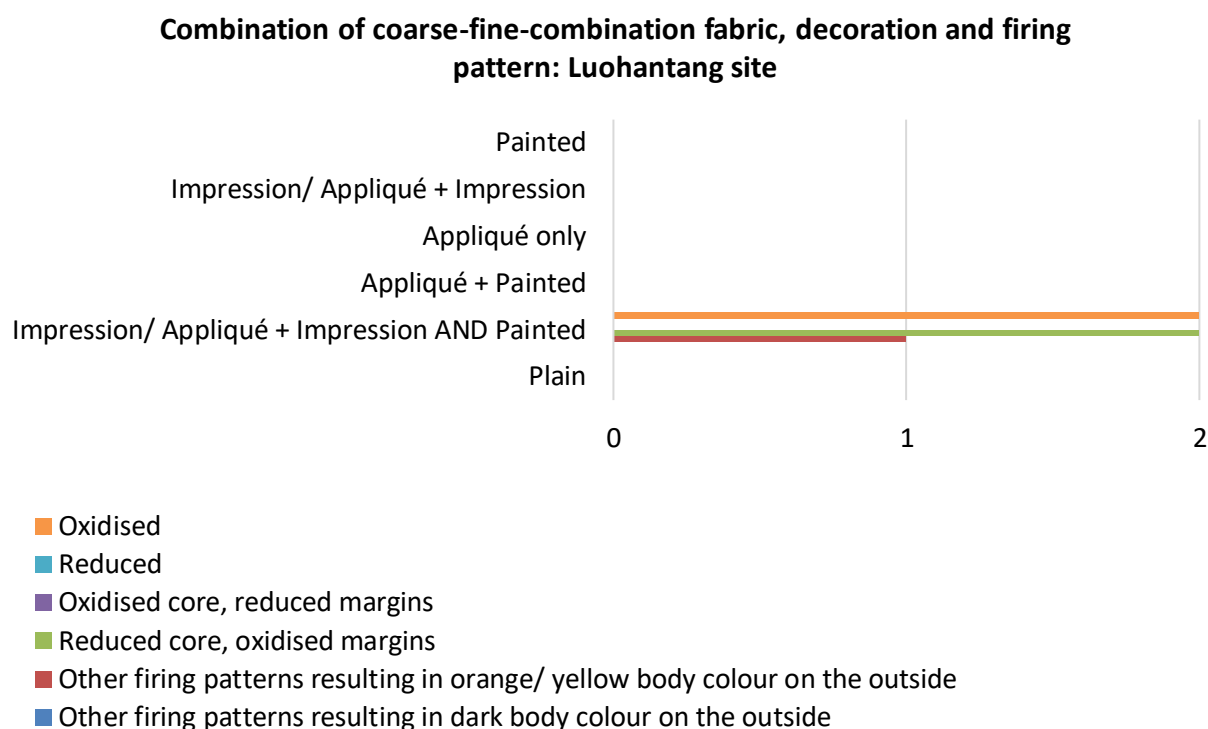


Fig. 5.125. Frequency of combinations of the coarse-fine combination fabric with a decoration type and a firing pattern on selected sherds from Luohantang; numbers represent the number of sherds.

5.1.2.5 Summary

5.1.2.5.1 Most frequent “Decoration – Fabric” combinations

The summaries of the data on “decoration type – fabric” pairing show that three types of combinations occur in more than 50% of the sampled sherds (Table 5.11). The most common pairing is painted decoration on fine fabric. Combining these two features is convenient for applying paint in even layers without distorting the design. The second most common pairing is relief decoration on coarse fabrics. It has been noted previously that the coarse surface might be more suitable for attaching appliqué. When burnished, coarse fabrics would not produce as smooth or as shiny surface as the fine fabrics do. Perhaps, relief decoration was another choice in design for the coarse fabrics as opposed to leaving them plain. Plain sherds are common among fine, coarse and coarse-fine-combination fabrics of the sampled sherds.

Coarse ware is commonly used for cooking because it is porous and therefore has the physical properties of thermal conductivity and resistance to thermal shock (Rice 2015:327-328; Hamer and Hamer 2015:372). At present, it is unclear what the Majiayao-style cooking pots might have looked like. Was the relief decorated coarse pottery used for cooking? The sampled rim sherds indicate that the shapes of the coarse pottery included jars of different sizes and bowls. Without proper use-wear study and residue analysis it is difficult to identify a cooking pot among the samples in this study.

Samples with a coarse-fine-combination fabric are a smaller number in comparison to the fine and coarse samples. Nevertheless, these show a trend in combination with relief and painted decoration. As has been pointed out previously, the decoration on the fine and painted parts of this type of sherds follows the above main trends for the “decoration – fabric” combinations and might be evidence for preferred design of the prehistoric potters. Based on his macroscopic and petrographic analysis, Womack (2017:143) also concluded that fine fabrics were combined with polished plain or painted surfaces and coarse fabrics with cord impressions.

Semi-coarse fabrics do not show any tendency to be combined with a particular decoration in comparison.

Table 5.11. Most frequent “Decoration – Fabric” combinations (all sites).

Combination	Sherd number in % and the amount in numbers out of all sherds with that type of “Decoration” or type of “Fabric”
Painted – Fine	86% by Decoration: 86/100 87.7% by Fabric: 86/98
Impression/ Appliqué+Impression – Coarse	92.6% by Decoration: 50/54 71.4% by Fabric: 50/70
Impression/ Appliqué+Impression AND Painted – Coarse-Fine-combination	75% by Decoration 6/8 85.7% by Fabric: 6/7

5.1.2.5.2 Most frequent “Firing pattern – Decoration” combinations

Two main trends can be identified among the “firing pattern – decoration” combination (Table 5.12). If a vessel has paint as the main or part of its decoration, then it usually has a yellow body fired in oxidation as the last firing atmosphere. Although very few sherds have been observed to have dark grey body colour and dark painting, it can be concluded that the painted decoration is best seen on a light-coloured background. Impressed and appliqué decoration mostly occurs on dark vessel surfaces. However, it has been shown above that this pairing is dominant only in the material from the Majiyao site. The data from Zhujiazhai and Luohantang shows that relief decoration and dark body is common combination but is not prevailing. This difference can be discussed from the technological and from the aesthetic points of view. In terms of technology, reduction firing might not have been as common practice at Luohantang and Zhujiazhai as it was in the Majiyao area. However, the sample size in this study is not sufficient to make such a broad statement. The data is likely further influenced by Andersson’s collecting practice and must be considered with caution.

From the aesthetic point of view, the light or dark body colours do not seem to enhance the decoration in any way as it is the case with the painting. Possibly, there was a preference to reduce the vessel surface with the relief décor, but this does not seem to be an essential technological choice as it was for the painted pottery in terms of providing an appropriate background colour. Purposeful reduction firing was observed on sherds fired mainly in oxidation and showing a thin dark layer on the exterior surface.

The last firing atmosphere of coarse-fine-combination sherds depends on the painted decoration which is oxidising. Except for CNP126, no sherds have been

identified among the samples which are decorated with impression and have the same creamy yellow coloured body as the background for painted pottery. Oxidised sherds of this type are more orange in colour. Relief decoration and yellow body colour combination is more common in coarse-fine-combination pottery because it has painted decoration.

Table 5.12. Most frequent “Firing pattern – Decoration” combinations (all sites).

Combination	Sherd number in % and the amount in numbers out of all sherds with that type of “Firing pattern” and “Decoration” type
Orange/yellow body colour on the outside – Painted + other decorations involving paint	78.6% by Firing pattern: 107/135 95.5 % by Decoration: 107/112
Dark body colour on the outside – Impression/ Appliqué+Impression	78.8 % by Firing pattern: 41/52 75.9% by Decoration: 41/54

To sum up, the combination of painting and oxidised exterior surface can be explained with practical and aesthetic reasons, but it is yet unclear why the pottery with relief decoration tends to be fired in reduction as the last firing atmosphere.

5.1.2.5.3 Most frequent “Fabric – Firing pattern” combinations

The majority of fine fabric samples and all of the coarse-fine-combination fabric samples were fired in an oxidising atmosphere as the last firing atmosphere for similar reasons discussed above for the “firing pattern and decoration” trends (Table 5.13). More than 60% of all coarse fabrics have a dark exterior surface. In the “fabric – firing pattern” combination the sherd percentage “by Firing pattern” is most interesting (Table 5.13). About 87% of all sherds fired in reducing atmosphere as the last firing atmosphere have coarse fabrics. This indicates that in the event of reduction firing, the kiln load is likely to be coarse pottery, and that the reduction atmosphere was specifically set up for this type of pottery. From this

perspective, combination of relief decoration and dark body colour discussed above seems to be a deliberate choice involving a different firing technique.

Table 5.13. Most frequent “Fabric – Firing pattern” combinations (all sites).

Combination	Sherd number in % and the amount in numbers out of all sherds with that type of “Fabric” and “Firing pattern”
Fine – Firing patterns resulting in orange/yellow body colour on the outside	91.8% by Fabric: 90/98 66.6% by Firing pattern: 90/135
Coarse – Firing patterns resulting in the dark body colour on the outside	62.8% by Fabric: 44/70 84.6% by Firing pattern: 44/52
Coarse-Fine-combination – Firing patterns resulting in orange/yellow body colour	100% by Fabric: 7/7 7.2% by Firing pattern: 7/97

5.1.2.5.4 Most frequent “Fabric – Decoration – Firing pattern” combinations

In sum, based on the data from pairings discussed above, three trends in tripartite “fabric – decoration – firing pattern” combinations were identified (Table 5.14):

1. Fine fabric – painted decoration - last firing atmosphere: oxidising.
2. Coarse fabric – impressed decoration (mostly cord) and appliqué – last firing atmosphere: reducing.
3. Coarse-fine-combination fabric – impressed decoration with or without appliqué – last firing atmosphere: oxidising.

Table 5.14. Most frequent “Fabric – Decoration – Firing pattern” combinations (all sites).

ID	Combination	Sherd number in % and the number of sherds out of the total number
1	Fine – Painted – Orange/yellow body colour on the outside	76.5% by Fabric: 75/98 75% by Decoration: 75/100 55.5% by Firing pattern: 75/135 30.1% by the total sherd number: 75/187
2	Coarse – Impression/ Appliqué+Impression – Dark body colour on the outside	55.7% by Fabric: 39/70 72.2% by Decoration: 39/54 75% by Firing pattern: 39/52 20.8% by the total sherd number: 39/187
3	Coarse-Fine-combination – Impression/ Appliqué+Impression AND Painted – Orange/yellow body colour	71.4% by Fabric: 5/7 62.5% by Decoration: 5/8 3.7% by Firing pattern: 5/135 2.6 % by the total sherd number: 5/187
Total number of tripartite combinations identified: 63.6% or 119/187		

Combinations 1 and 2 have a frequency of over 50% in all three categories: by fabric, by decoration, and by firing pattern. Combination 3 including the coarse-fine-combination fabric has a frequency over 50% only by fabric and by decoration. This is due to the oxidising firing pattern in this combination not being unique in contrast to the decoration and fabric type. Sherds with coarse-fine-combination fabrics are rare among the material from all sites considered here. This type of sherds seems to be absent from Zhujiashan, or at least from the MFEA collection material. Other examples of this fabric from sites in the Tao River Valley or in the vicinity seem to largely follow the combination 3 trend as well (Stilborg and Hein, forthcoming). Further examples can be found in publications by the Gansu Provincial Museum (Gansusheng Bowuguan 1960:4), as well as by Zhang (1990:Cat. num. 191), Ding (2010:45), and Ren (2016:63-65, 67-69, 183)⁴² who

⁴² One and probably more coarse-fine-combination vessel fragments (this is difficult to tell from drawings in Ren 2016:181-184) were found at from Donghuishan burial site (东灰山

shows the same examples as Zhang (1990) and Ding (2010), and additional ones. However, these types of vessels are not a focus of discussions in these publications. Three examples of coarse-fine-combination fabric vessels given in all four publications were found at the Linjia site 林家遗址. Linjia is located about 5-10 km west of from the modern Tao River riverbed and 20-30 km south west from the point where the Tao river flows into the Yellow River. Kilns have been excavated at Linjia (Womack et al. 2019b:2), meaning that pottery production took place there. The geographic location of the Linjia site suggests that it could have been connected with sites in the Tao River Valley as well as with sites in the Yellow River Valley. Four published coarse-fine-combination vessel fragments have been found at Xipogua 西坡圪遗址 and two published fragments of type have been found at Caojiazui 曹家嘴遗址. These sites are located near each other, in the vicinity of Lanzhou, and about 10 km south of the Yellow River. Remains of two kilns have been found at Xipogua (Gansusheng Bowuguan 1960:1), indicating pottery production activity at this site.

Hung (2011:49) has also observed pottery with coarse-fine-combination fabrics and appears to describe a vessel similar in shape to CNP143, which is a tall bottle-shaped vessel. Only the neck and rim were made of fine fabric and are painted. The shoulder and the rest of the body is coarse and decorated in cord markings. Hung does not specify the site, where the fragment she studied was found. This author

墓地). This site is located in Minle county, northern Gansu. It is more than 400 km away from Majiayao and Waguanzui and 200-250 km away from Zhujiazhai and Luohantang (both linear distances). This site is dated to Xia dynasty period according to Ren (2016). The occurrence of this type of vessels in that location and period raises many questions about knowledge transfer, which are out of scope of the present study. However, if the pottery from Donghuishan has indeed coarse-fine-combination fabrics, it could be another evidence of the degree of connectivity between sites in prehistory.

has observed that examples of this vessel type found during recent excavations at Majiayao, and CNP143 was found at Luohantang. It is safe to assume that this vessel type was known in different parts of the study area and probably beyond. Based on the samples analysed in this study, three other vessel shapes have been made with coarse-fine combination fabric:

1. Large vessel with globular body and small loop handles. Two fabrics are combined just below the middle section at the handle level. Upper fine part is painted and the lower has cord markings (CNP145, 155, 187).
2. Tall bottle-shaped vessel with a broad shoulder and possibly loop handles. Two fabrics are combined just above the middle section, similar to the vessel in the Qinghai Provincial Museum (Fig. 5.126, left) but probably smaller (CNP181).
3. Open small, spouted vessel. The coarse part starts at the lower edge of the round spout. The surface was left plain (CNP36).

Further shapes such as bowls and spouted basins were identified by Stilborg and Hein (forthcoming).

It seems unlikely that the position of coarse and fine fabrics in the vessel, lower and upper bodies respectively, indicates some kind of hierarchy of the fabrics. Such positioning could have been chosen due to practical construction reasons discussed in section 5.1.1: the coarse fabric with appliqué decorations is heavier and thicker, and the vessel would probably collapse in later stages of manufacturing process, if this fabric was used on the upper half. Such vessels that combine two fabrics and two types of decoration serve as evidence for accepted/assigned combinations between ceramic fabrics and vessel decoration.

Potential complete coarse-fine-combination vessels have been excavated at the Zongri site 宗日遗址 located in Qinghai near the Yellow River ca 130 km south west from Luohantang. (Lou and Yu 2013:29; Liu 2011:59; here Fig. 5.126). The long-necked vessel from Zongri (Fig. 5.126, left) looks similar in shape and decoration to the long-necked vessel from Linjia published by Zhang (1990:Cat. num. 191; here Fig. 5.127).



Fig. 5.126. Possible coarse-fine-combination fabric Majiayao-style pottery from Zongri in Qinghai; left: h 41.5 cm; right: h 41.5 cm; from Lou and Yu (2013:29), vessels now kept in the Qinghai Provincial Museum.



Fig. 5.127. Vessel from Linjia, Gansu showing two types of decoration, potentially made of coarse-fine-combination fabric, h 47 cm; from Zhang (1990: Cat. num. 191).

Zongri is classified as a separate archaeological culture with a distinct pottery type (Yan and Xu 2009; Hou et al. 2016) and is thought to have an extensive contact with the Majiayao culture which is also reflected in pottery decoration (Hong et al. 2012; Hou et al. 2016). Interestingly, some examples of Zongri pottery combine the painting and the cord-impression decoration in the manner similar to the Majiayao-style (Chen et al. 1998:15, Fig. 2) (Fig. 5.128).



Fig. 5.128. An example of Zongri pottery combining painted and cord-pattern decoration, h 27.8 cm; left from Hung (2011:264, Fig. 2.15:11), right from Qinghaisheng Wenwu Guanli Chu (1998: Pl.4,2).

The clay used to make this type of pottery with combined decoration is generally described as coarse (Chen et al. 1998:15; Hung 2011:67), and it is difficult to tell from the photos if two different fabrics were used. According to archaeological research (mostly study of burials, ceramic analysis), the area of contact between Zongri and Majiayao archaeological cultures is located in the Guide Basin, the area around the Luohantang site (Ren et al. 2020: Figure 1; here Fig. 5.129; Hong et al. 2011; Hou et al. 2016).

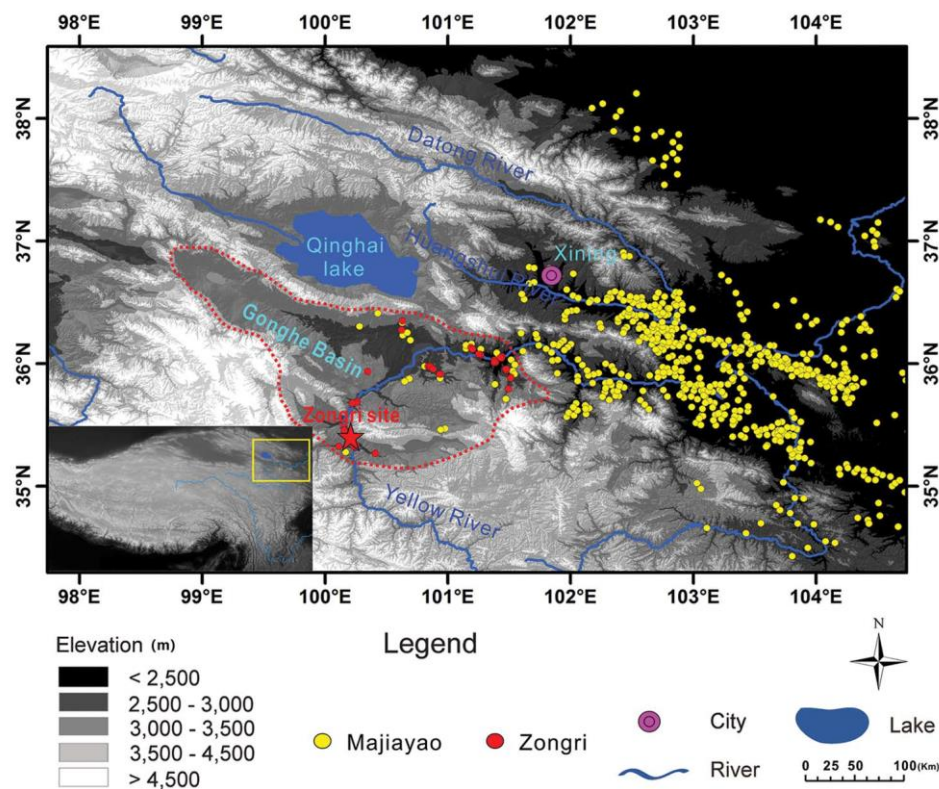


Fig. 5.129. Distribution of the Majiayao and Zongri period sites with contact area located in the Guide Basin, near Luohantang, Yellow River Valley; from Ren et al. (2020: Figure 1).

The pottery technology of Zongri pottery and its relation to Majiayao-style pottery technology is worth exploring in future studies. Such an investigation might provide insights into the coarse-fine-combination vessel building technology, as well as the function of those vessels. Further, investigating pottery from the Zongri-Majiayao contact area could shed light on the distribution of knowledge about the painted and relief decoration combination. At this stage of research with a limited sample number, it can be preliminary concluded that this type of pottery with combined decoration and/ or fabrics types could have been spread along the Yellow River and then into the Tao River Valley (Fig. 5.130). Hou et al (2016: Fig.4) came to the similar conclusion that the Yellow River could be one of the main routes of pottery distribution, after conducting a study on the potential pottery trade routes between Zongri and Majiayao cultures.



Fig. 5.130. Sites near the Yellow River and Tao River where coarse-fine-combination fabric pottery was found.

Samples with semi-coarse fabrics have shown no tendency to be combined with a particular type of decoration or firing pattern. As has been pointed out above, the semi-coarse fabric has not been identified on many samples and the prehistoric potters may have considered it being a fine clay. It might also have been a clay type that was used as is without levigation. Alternatively, semi-coarse clay could have been considered as a different type from fine since sherds with semi-coarse fabrics can be decorated with paint or relief decoration. However, due to their rare occurrence in the sherd samples, the questions about this type of fabric as technological choice remains open and will be further investigated by petrography in the following sections.

The total number of sherds with tripartite combinations (fabric + decoration + firing pattern) observed in the material from the study area is 119 or 63.6%, which is more than a half of all samples. Therefore, it can be tentatively suggested that the choices in Majiayao-style production technology and decoration were connected by a purpose which, especially in the case of dark fired coarse pottery, is still not entirely clear.

5.2 Thin-section petrography

This section provides an overview and summarised description of pottery fabrics identified in the samples from each site. For the detailed description of each fabric and associated samples numbers see Catalogue 1. The petrographic data is presented separately for each site first. A summary of the data for all sites is provided at the end of this section. The data analysis is structured as follows:

I. Fabric groups: the fabrics are split into four main types identical to the types in the macroscopic analysis section – fine, coarse, semi-coarse and coarse-fine-combination. As has been clarified in the section 5.1.2 the same classification is used for the fabrics in the macroscopic study. The fabric group names are based on the presence and amount of coarse non-plastic inclusions, between 0.2 – 6.3 mm in size.⁴³ The fabric groups are clustered according to these types in an overview table together with the sherd amount for each fabric. Further, a summary description for each fabric group is provided together with photomicrographs.

II. Summaries of fabric group compositions

This section provides charts and tables summarising the trends in the fabrics for each site in the three main areas: inclusions, matrix and porosity (voids).

IIa. Inclusions:

- Inclusion frequency and coarse fraction trends
- Maximum inclusion size in coarse and coarse-fine-combination fabrics
- Dominant inclusions in coarse fraction (beside quartz)
- Fine fraction characteristics

⁴³ According to ISO 2017 standard, see Table 1 in Catalogue 1.

I Ib. Matrix

- Clay pellet amount
- Optical activity

I Ic. Porosity

- Void amount

The summary section for all sites presents data following the structure of I Ia-c. Instead of showing the trends in inclusions, matrix and porosity for fabric types, the data in the summary section is grouped according to sites. Changing the resolution and looking at the data from the site perspective helps identify the similarities and differences in the petrographic fabric composition that are essential for the discussion of pottery technology. The key to the percentage estimations, abbreviations and vocabulary used for petrographic descriptions is provided in Table 1 in Catalogue 1.

5.2.1 Majiayao

5.2.1.1 Fabric groups

Seven main fabric groups were identified in the pottery samples from Majiayao (Table 5.15). It was possible to group all samples, and none has shown significant difference in the petrographic composition from the overall characteristics.

Table 5.15. List of fabrics identified in the sherd samples from Majiayao.

Fabrics	Number of sherds
Fine fabrics	
1 Fine, Mica-Quartz-Feldspar <i>CNP6, 8, 17, 38, 39, 40, 41, 42, 44, 50, 51, 54, 55, 57, 62, 63, 66, 67, 68, 70</i>	20/71
2A Fine, Mica-Quartz-Feldspar with lesser inclusion frequency than Fabric 6 <i>CNP2, 3, 4, 5, 7, 45, 46, 47, 48, 49, 56, 59, 60, 61, 65, 69</i>	16/71

2B Fine, Mica-Quartz-Feldspar with Calcite fraction <i>CNP43</i>	1/71
3 Fine, Quartz dominant <i>CNP15, 53, 64</i>	3/71
Coarse fabrics	
4A Coarse, Quartz-Feldspar and Granodiorite fragments <i>CNP12, 18, 20, 23, 24, 25, 27, 28, 30, 31, 32, 33, 52</i>	13/71
4B Coarse, Quartz-Feldspar and Granodiorite fragments - less porous and less inclusion frequency than Fabric group 4A <i>CNP9</i>	1/71
4C Coarse, Quartz and Granodiorite fragments with clay pellets <i>CNP35</i>	1/71
5A Coarse, Calcite and Quartz with Sedimentary rock fragments <i>CNP14, 19, 21, 22, 26, 29, 71</i>	7/71
5B Coarse, Calcite and Quartz with Sedimentary rock fragments - less coarse fraction and low porosity than Fabric group 5A <i>CNP34</i>	1/71
6A Coarse, Quartz and Sedimentary rock fragments <i>CNP10, 11</i>	2/71
6B Coarse, Quartz and Sedimentary rock fragments with Volcanic rock fraction <i>CNP13</i>	1/71
Semi-coarse fabrics	
7 Semi-coarse, Quartz dominant <i>CNP1, 37, 58</i>	3/71
Coarse-Fine-combination fabrics	
4D Coarse-Fine-combination fabric: coarse Quartz-Feldspar with Granodiorite fragments <i>CNP36</i>	1/71
4E Coarse-Fine-combination fabric: coarse Granodiorite fragments with Quartz and Feldspar <i>CNP16</i>	1/71

Coarse fabrics show a greater group variety than fine fabrics despite having a smaller sample number (Fig. 5.131). Each coarse-fine-combination fabric samples is treated as a single group because of its uniqueness. They can show similarities with the main coarse or fine fabrics but to incorporate the fine parts in to fine and the coarse parts into the coarse fabric groups would distort the statistics and analysis of the study. Keeping the coarse-fine-combination as its own fabric type contributed to the discussion in the macroscopic pottery analysis part of this

chapter and continuing so will subsequently contribute to the discussion in this section.

Main fabric groups overview: Majiayao site

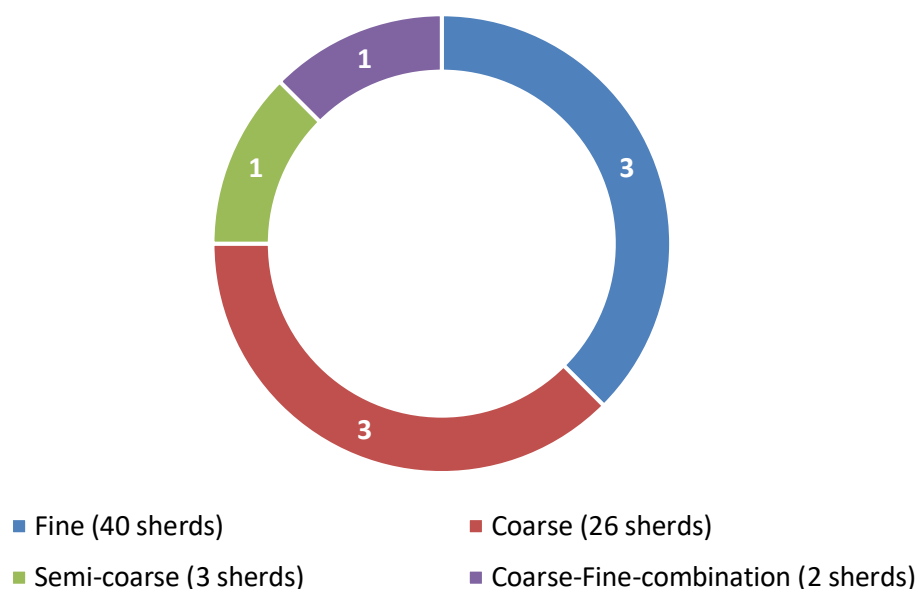


Fig. 5.131. Main fabric groups overview: Majiayao site; numbers represent the number of identified groups.

5.2.1.1.1 Fine fabrics

The fine fabrics are divided into four groups: three main groups, one having a sub-fabric (Table 5.16). Fabrics 1 and 2A show different amount of mica, quartz and feldspar inclusions than Fabric 3 (Fig. 5.132a, b, d).

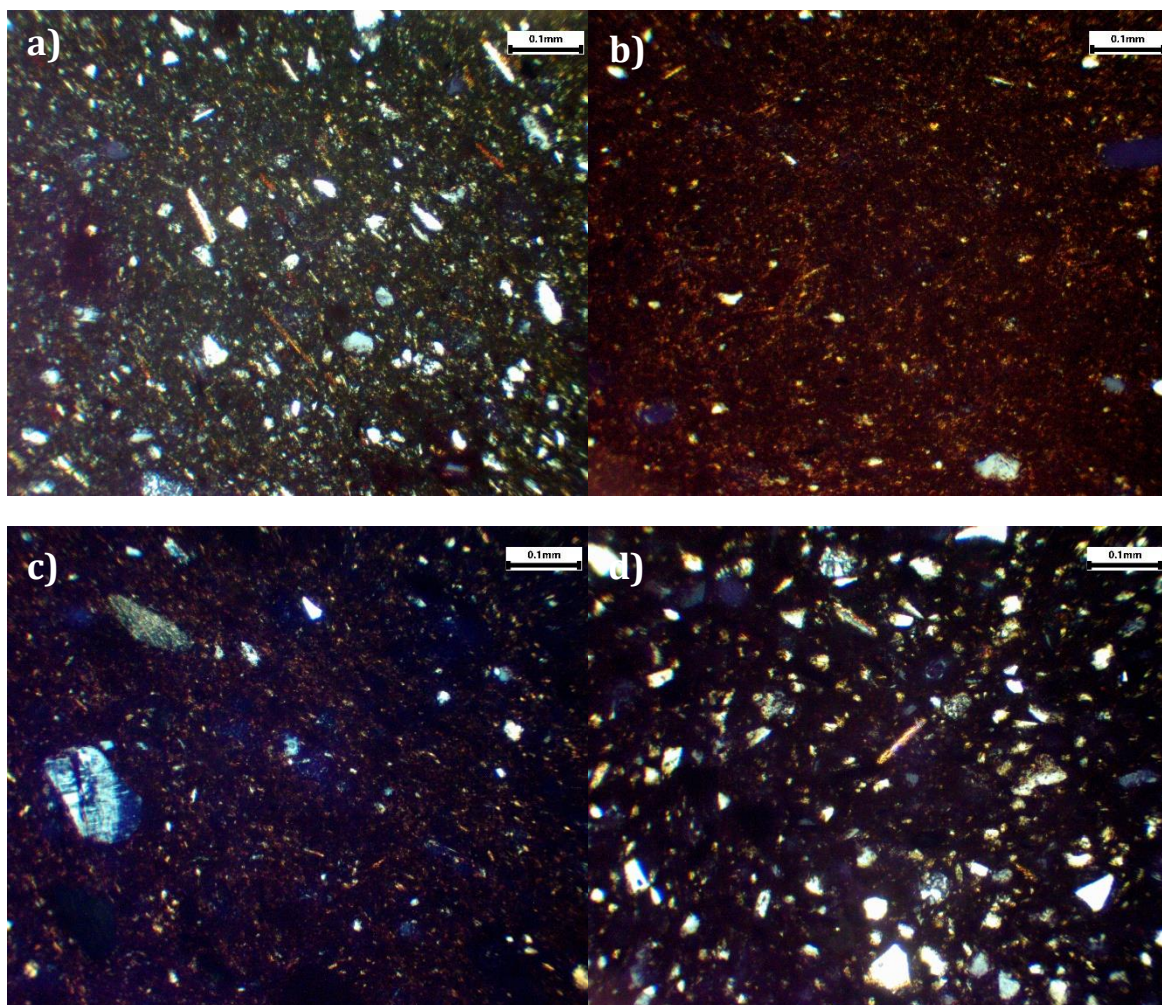


Fig. 5.132. Fine fabrics identified in selected sherds from Majiayao; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 1, CNP50 b) Fabric 2A, CNP69 c) Fabric 2B, CNP43 d) Fabric 3, CNP64.

Table 5.16. Petrographic description of fine fabric groups identified in selected sherds from Majiayao.

Fabric 1 Fig. 5.132a	Fabric 2A Fig. 5. 132b	Fabric 2B Fig. 5. 132c	Fabric 3 Fig. 5. 132d
Sorting	Sorting	Sorting	Sorting
mostly well	well	well	mostly well
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
20-30%	15%	10-20%	30%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
• mica 45.5 % • quartz 40% • feldspar 7% • micritic/crystalline calcite 4%	• mica 48% • quartz 46% • feldspar 5%	• quartz 35% • mica 35% • micritic calcite 25% • feldspar 5%	• quartz 60% • mica 32% • feldspar 8%
Matrix (average %)	Matrix (average %)	Matrix (average %)	Matrix (average %)
• 65-70% • micaceous • mostly homogeneous • mostly optically active	• 80-85% • micaceous • mostly homogeneous • mostly moderate optical activity	• 70-80% • micaceous • homogeneous • optically active	• 67% • micaceous • homogeneous • moderate optical activity
Voids (average %)	Voids (average %)	Voids (average %)	Voids (average %)
• 3-5% • macro/ meso vughs and vesicles	• 5% • meso vughs and vesicles	• 10% • macro/meso vughs	• 1-3% • macro/ meso vesicles
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
this fabric is similar to the groundmass of CNP16 (Fabric group 4E)	CNP69 has a MSi-sized fine fraction	It is not clear if the calcite inclusions are naturally present or post-depositional secondary accumulations	none

Fabric 3 has a higher quartz content and the highest inclusion frequency than 1 and 2A-B. Fabric 1 has a very similar groundmass (matrix and fine fraction) to the

fine part of the coarse-fine-combination sample CNP16 that is discussed in greater detail in subsection Id. The fine fraction in CNP69 is medium silt-sized or smaller which is rare but not uncommon among the fine fabrics from the study area. It might indicate that the clay was processed to make it as fine as possible. However, as the results of petrographic analysis of geological samples reveal below (section 6.2.1), there are natural clays with medium silt-sized or smaller fine fraction.

The sub-fabric 2B consists only of CNP43 which has a similar composition to the samples in 2A, but it also has 25% micritic calcite. It cannot be determined for certain under the petrographic microscope if the micritic calcite inclusions have accumulated post-deposition or were naturally present in the clay.

The sample matrices in groups 1, 2A, and 3 show predominantly moderate optical activity. This type of optical activity indicates that the sherds were fired at higher temperatures, possibly 900-1000° C because the clay matrix loses its birefringence when fired above 850° C (Quinn 2013:191), which would correspond to the analysis results published by Ma (2000) and other scholars. The matrix in CNP43 is optically active, and the sherd was probably fired at <900° C. The firing temperature estimation provides insights into the maximum heat that a vessel was subjected to and prompts to think with what technology this heat might have been achieved. Low temperature does not necessarily imply pit firing and temperature above 950° C does not necessarily imply kiln firing – both open firing and simple down/-updraft kilns can produce heat up to 950° C (Livingstone Smith 2001:998; Thér 2004:73). The maximum temperature under which a single vessel is fired largely depends on the vessels' position relative to the heat source and cannot be used to deduce the actual firing structure/ device and process (Gosselain 1992:256; Thér 2004:42).

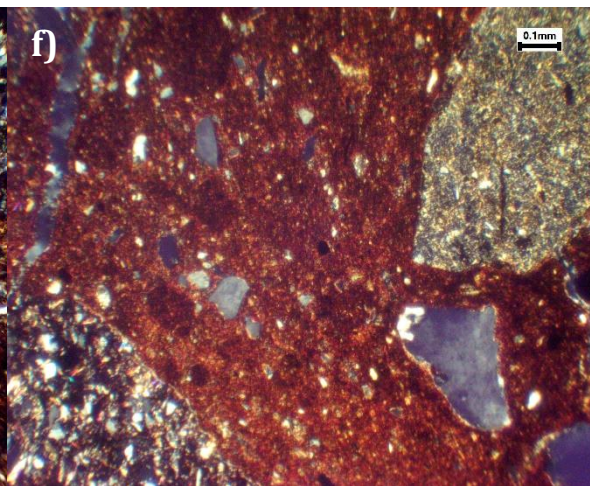
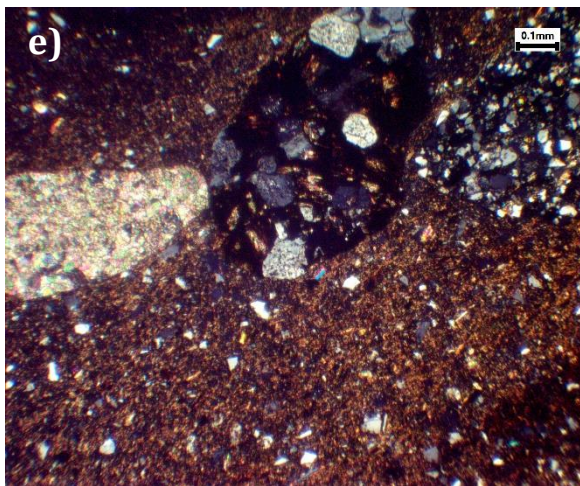
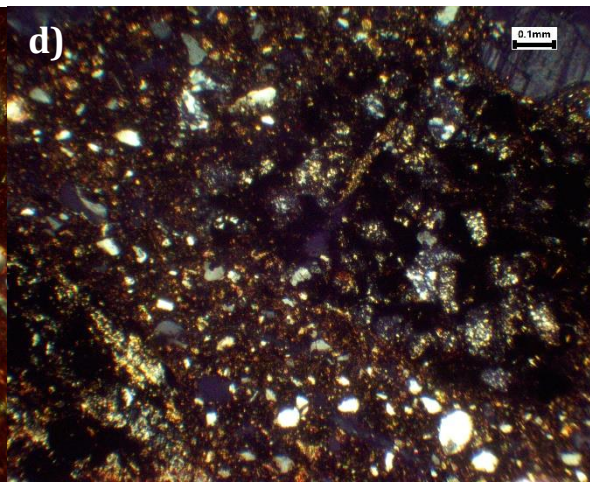
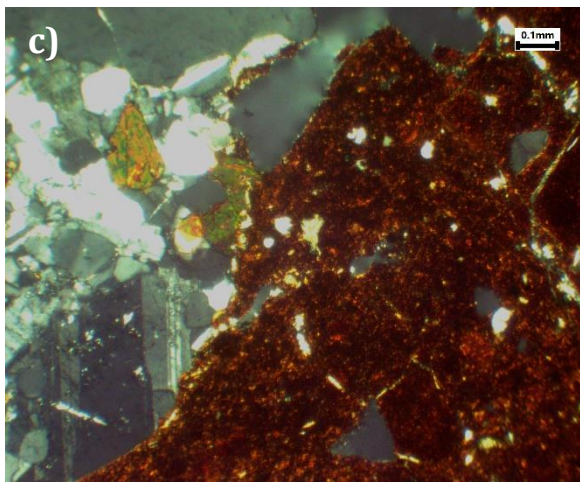
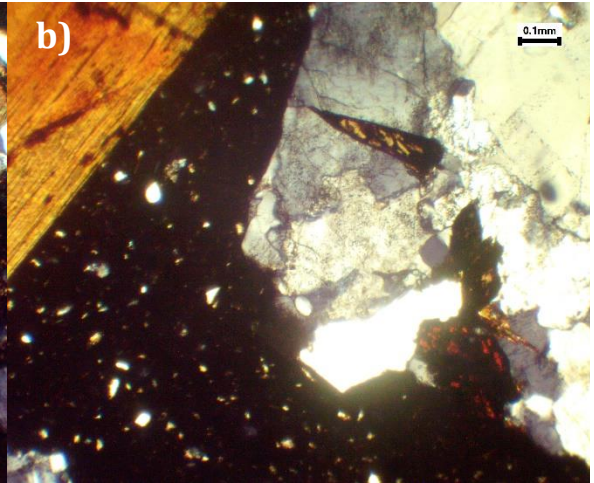
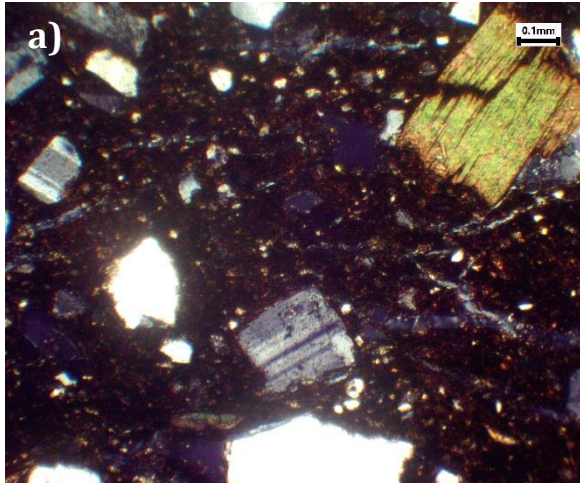
It further depends on the thermal conductivity of the clay and how different parts of the pottery body get heated during the firing process (Forget et al. 2015:86). Although kilns were found on several sites in the Tao River Valley and beyond and possible evidence for vessel stacking in a kiln has been discussed above, it is worth keeping in mind that the firing temperature deduced from the prehistoric pottery by itself is not a direct evidence for a particular firing technology. Despite the evidence for kiln usage in the Majiayao-style pottery production, it has been demonstrated in this study that several samples reflect irregularities in firing atmosphere and/ or temperature control in their core colours. Kiln firing as opposed to pit firing does not automatically produce stable firing conditions, and even firing can be created in pits as well (Maritan et al. 2006:13).

The void amount varies between the groups. Fabric 2B stands out being the most porous but the average porosity around 3-5% based on the data from all samples is generally low.

Despite the minor differences in matrix and porosity, fine fabrics are similar in terms of the inclusion type and size. It could be possible that the raw material came from the same clay bed. A thin section of manually worked clay offers only a minimal glimpse into the clay mineral composition which is a limitation of petrographic analysis of fine clays.

5.2.1.1.2 Coarse fabrics

The coarse fabrics are divided into seven groups: three main groups, each having up to two sub-fabrics (Tables 5.17-19). Overall, the coarse fabrics are dominated by granitic and sedimentary rock inclusions (Fig. 5.133).



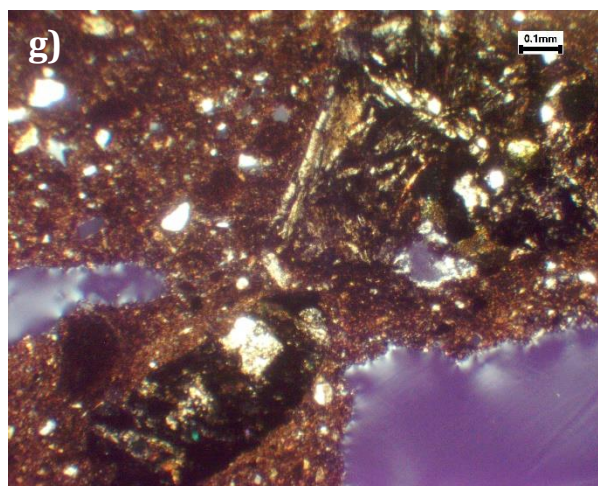


Fig. 5.133. Coarse fabrics identified in selected sherds from Majiayao; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 4A, CNP24 b) Fabric 4B, CNP9 c) Fabric 4C, CNP35 d) Fabric 5A, CNP22 e) Fabric 5B, CNP34 f) Fabric 6A, CNP10 g) Fabric 6B, CNP13.

The coarse fraction of Fabric 4A (Fig. 133a) consists of fine gravel-sized quartz, feldspar and granitic/ granodiorite rock fragments. On average, fine fraction is dominated by quartz and micritic calcite with low amounts of mica and feldspar. It is not clear from the petrographic analysis if the fine calcite was naturally present in the clay or formed in the post-depositional environment. The sample matrices in Fabric 4A and in the sub-fabrics 4B and 4C are mostly optically active, meaning that the pottery was not fired at a very high temperature, possibly at $<900^{\circ}\text{C}$. Due to its coarse texture the fabric is porous, with an average void amount of 10%. The sub-fabrics 4B and 4C (Fig. 5.133b-c) both show high amounts of coarse sand- to fine gravel-sized quartz, feldspar, and granitic/ granodiorite rock fragments. No feldspar was identified in the fine fractions of the sub-fabric. Sub-fabric 4B has the lowest porosity in comparison to sub-fabrics 4A and 4C, which is interesting from both the technological and usage perspective. Sub-fabric 4B is CNP9 which is possibly the coarse part of the coarse-fine-combination vessel fragment K.111998.19 analysed by Hein and Stilborg (2019:108; Stilborg and Hein forthcoming). If this is the case, then the low porosity implies that there was a shrinkage control of the coarse part. Usually, the clay would shrink around the

coarse non-plastic inclusions as it loses its water content during drying and firing (Quinn 2013:61). As observed in thin section (Fig. 5.133b), the coarse grains are mostly compactly embedded into the matrix without space at the edges. This texture suggests that the potter used a clay type with a low shrinkage rate during firing. Sub-fabric 4B/ CNP9 having low porosity and being a part of the coarse-fine-combination vessel further means that it was unlikely heated again and used as a cooking pot as it would have had low thermal conductivity. There are examples of differently tempered parts of the same pot in other parts of the world. Vessels with parts made of tempered and untempered clay are commonly identified among of sand tempered pottery from Crete (Broodbank and Kiriati 2007:254). This technique is also practiced among the modern potters on the island (Kiriati 2010:691). Another example from modern pottery making can be found in Pakistan, where the base of a cooking pot is tempered with grog to enhance its resistance to thermal shock, and the upper body is made from sand-tempered clay because this material is more suitable to apply impressed decoration (Spataro 2004:173). Roux and Courty (2019:35-36) describe cases from Africa and India, where modern potters mix temper of different size and type into clay to construct different parts of the vessel. However, they did not expand on the purpose of this practice.

The sub-fabric 4C has a heterogeneous matrix. Clay pellets are abundant in this fabric, so that the fine fraction is not evenly distributed throughout the sample. Womack (2017:139, 141) grouped twenty-four Majiayao period samples from his study area in the Tao River Valley into a Clay Pellet Fabric Group. This fabric contained clay pellets of similar size and amount as the present sub-fabric 4C. Womack (2017:139, 141) suggested two possible explanations for the clay pellets.

First, they might have been purposefully added. Second, they might have been naturally present, as there were clay pellets in some of his geological samples. Clay pellets form naturally in clays which need a long time to fully hydrate (Rye 1981:36). It seems unlikely that it is possible purposefully add clay pellets as a type of temper. Pellet formation as a result of clay mixing is difficult to investigate in the CNP samples by applying thin-section petrography only. The matrix of pellets and of the samples looks almost identical under the petrographic microscope. Clay pellets in this case are likely a result of poor hydration of the clay and insufficient wedging/ kneading during the making process (Spataro 2017:64).

Table 5.17. Petrographic description of the coarse fabrics identified in selected sherds from Majiayao (part 1).

Fabric 4A Fig. 5.133a	Fabric 4B Fig. 5.133b	Fabric 4C Fig. 5.133c
Sorting	Sorting	Sorting
poor	poor	poor
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
30-40%	20%	10-15%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 40%	Coarse fraction 20%	Coarse fraction 30%
- quartz (euhd, eq, el; ang – s-rnd; FSa-FGr) 36% - plagioclase/ microcline feldspar (euhd, eq, el; ang – s-rnd; FSa-FGr) 31% - granodiorite fragments – combination of quartz, plagioclase/ microcline feldspar, biotite and/ or muscovite and/or hornblende (eq; ang; CSa-FGr) 18% - micritic/ crystalline calcite (eq; rnd; MSa-CSa) 7% - biotite (lamellae, FSa-CSa) 4%	- quartz (euhd, eq; ang – s-rnd; CSa-FGr) 37% - plagioclase feldspar (euhd, eq; ang – s-rnd; CSa-FGr) 33% - granitic rock fragments – combination of quartz, plagioclase feldspar with/ without biotite and hornblende (eq, el; s-ang; CSa-FGr) 25% - biotite (lamellae; MSa-CSa) 5%	- quartz (eq, el; s-rnd; FSa-MSa) 59% - granitic/ metamorphic rock fragments – combination of quartz, plagioclase feldspar, biotite with/ without hornblende (eq; s-ang – s-rnd; CSa- FGr) 30% - plagioclase feldspar (eq, el; s-ang; FSa-CSa) 10% - biotite (lamellae, FSa-CSa) 1%

Fine fraction 60%	Fine fraction 80%	Fine fraction 70%
- quartz 41% - calcite/ micrite 40% - mica 15% - feldspar 4%	- quartz 60% - mica 40%	- quartz 90% - mica 10%
Matrix (average %)	Matrix (average %)	Matrix (average %)
50% - micaceous - mostly homogeneous - mostly optically active	77% - micaceous - homogeneous - moderately active	75-80% - micaceous - heterogeneous - optically active
Voids (average %)	Voids (average %)	Voids (average %)
10% - mega/macro/meso vughs, vesicles	3% - macro vesicles and vughs	10% - mega/macro vughs and channels
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
Not sure if the high amount calcite in the fine fraction are post-depositional secondary calcite accumulations or natural present inclusions.	Coarse but low porosity	MSa-CSa clay pellets taking up >10% of the matrix

Fabric 5A is characterised by coarse calcite, sedimentary rock, and feldspar inclusions. Micritic and crystalline calcite fragments are abundantly present in the coarse and fine fraction which indicates that it is not a secondary accumulation. The calcite could have been either naturally present in the raw material or added by the potter as a temper. The fine fraction is dominated by calcite and additionally has different amounts of quartz, mica and feldspar. The sample matrices of 5A are mostly optically active indicating that the pottery was probably fired at <900° C. Perhaps these samples were fired at a lower temperature to avoid the chemical alteration of calcite and expansion of its particles damaging the vessel. 5A has a lower porosity than Fabric 4A despite its coarse texture.

The sub-fabric 5B differs from 5A in its lack of coarse feldspar content. 5B has an even lower porosity than 5A which, similar to 4B might indicate its usage as a

coarse vessel. 5B is CNP34 which is a fragment of a spouted jar, a pouring vessel which might have not been exposed to fire heat to boil liquid.

Table 5.18. Petrographic description of the coarse fabrics identified in selected sherds from Majiayao (part 2).

Fabric 5A Fig. 5.133d	Fabric 5B Fig. 5.133e
Sorting	Sorting
mostly poor	poor
Average inclusion frequency %	Average inclusion frequency %
40%	30%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 35-45%	Coarse fraction 15-20%
- quartz (euhd, eq, el; ang – rnd; FSa-FGr) 34% - micritic and/ or crystalline calcite (euhd, eq; ang; FSa-CSa) 28% - sedimentary rock fragments – sandstone, siltstone (eq el; s-ang – rnd; FSa-FGr) 18% - plagioclase/ microcline feldspar (eq; ang – s-rnd; FSa-CSa) 11%	- quartz (eq, el; s-ang – s-rnd; FSa-CSa) 39% - micritic and crystalline calcite (eq; rnd; MSa-CSa) 30% - sedimentary rock fragments – sandstone, siltstone (eq; s-rnd; CSa) 25%
Fine fraction 55-56%	Fine fraction 80-85%
- calcite/ micrite 42% - quartz 31% - mica 19% - feldspar 8%	- calcite 35% - quartz 30% - mica 30% - feldspar 5%
Matrix (average %)	Matrix (average %)
50-60% - micaceous - homogeneous - mostly optically active	67% - micaceous - homogeneous - optically active
Voids (average %)	Voids (average %)
5% - macro/meso vughs, vesicles, channels	3% - macro/meso vesicles
Textural features/ Comments	Textural features/ Comments
This coarse fabric has less voids and cracks than Fabric group 4A.	coarse but low porosity

Fabric 6A is characterised by coarse quartz and sedimentary rock fragments. The fine fraction is dominated by calcite inclusions which appear to be naturally present in the clay. The average amount of fine quartz and mica seems to be the

same, feldspar is very low. The sample matrices of 6A are optically active, indicating firing at lower temperatures (600°-850° C). The porosity degree is similar to 5A. CNP10 further shows a high amount of clay pellets leading to an uneven distribution of fine fraction throughout the sample.

Besides quartz and sedimentary rock fragments the coarse fraction of the sub-fabric 6B consists of elongated/ acicular quartz and feldspar fragments in a black opaque matrix, described here as volcanic rock fragments. The fine fraction of 6B largely corresponds to the fine fraction in 6A but has a higher feldspar amount. The sample matrix is optically active and shows a high degree of porosity. 6B has a medium amount of clay pellets in the matrix.

Table 5.19. Petrographic description of the coarse fabrics identified in selected sherds from Majiayao (part 3).

Fabric 6A Fig. 5.133f	Fabric 6B Fig. 5.133g
Sorting	Sorting
poor	poor
Average inclusion frequency %	Average inclusion frequency %
20%	30%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction: CNP10 20%; CNP11 40-50%	Coarse fraction 40%
- quartz (euhd, eq, el; ang – s-rnd; FSa-MSa) 39% - sedimentary rock fragments – sandstone and siltstone (eq, el; s-rnd; CSa-FGr) 35%	- quartz (euhd, eq, el; ang – s-rnd; FSa-FGr) 30% - sedimentary rock fragments – sandstone or conglomerate? lithic grains in opaque matrix (el; s-rnd; CSa), siltstone (el; s-rnd; CSa-FGr), chert (eq; ang; CSa) 30% - volcanic rock fragments – elongated quartz, feldspar and olivine (?) with/without calcite in black opaque matrix (eq; s-rnd; CSa-FGr) 25%
Fine fraction: CNP10 80%; CNP11 50-60%	Fine fraction 60%
- calcite 42.5% - quartz 27.5% - mica 27.5% - feldspar 2.5%	- calcite 40% - quartz 30% - mica 20% - feldspar 10%
Matrix (average %)	Matrix (average %)
70% - micaceous - CNP10 heterogeneous, CNP11 homogeneous - optically active	60% - micaceous - homogeneous - optically active
Voids (average %)	Voids (average %)
5% - mega/macro planar voids, channels, vughs	10-15% - mega/macro channels
Textural features/ Comments	Textural features/ Comments
CNP10 has FSa-CSa clay pellets taking up >10% of the matrix.	FSa-CSa clay pellets taking up 5-10% of the matrix; mega channels at the coil join areas

5.2.1.1.3 Semi-coarse fabric

The semi-coarse fabric is defined by a smaller inclusion size (0.2-0.7 mm, MSa-CSa) in comparison to the coarse fabrics (see section 4.3.1). The non-plastic inclusions in this type of fabric are mostly fine and medium sand-sized and can have a few coarse sand-sized fragments. The coarse fraction of Fabric 7 is dominated by quartz with a small amount of calcite (Table 5.20, Fig. 5.134). CNP1 and CNP58 have medium to low amount of micritic calcite in coarse fraction, and CNP37 has clear secondary calcite accumulations. It could be possible that the calcite in CNP1 and CNP58 was naturally present. In this case CNP37 could be considered a sub-fabric or a different fabric. However, the origin of micritic calcite is difficult to determine petrographically from only one sample. No calcite has been identified in fine fraction, which has the common composition of quartz, mica and feldspar inclusions. The matrices in Fabric 7 are mostly optically active and have a low degree of porosity.

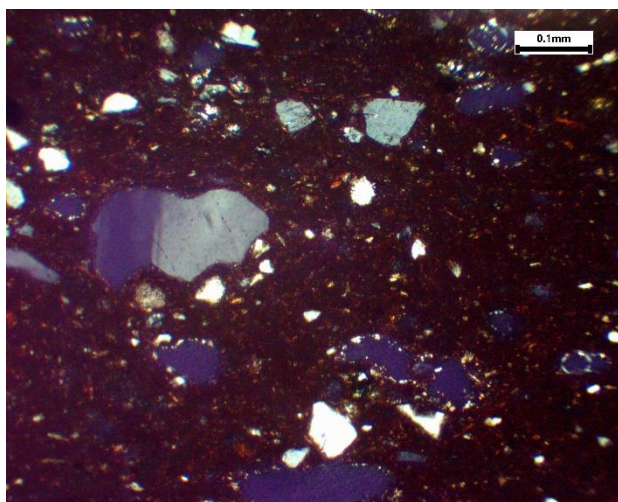


Fig. 5.134. Semi-coarse fabric identified in selected sherds from Majiayao; photomicrograph taken under XPL, scale size 0.1 mm; Fabric 7, CNP58.

Table 5.20. Petrographic description of the semi-coarse fabric identified in selected sherds from Majiayao.

Fabric 7 Fig. 5.134.
Sorting mostly poor
Average inclusion frequency % 20-30%
Dominant inclusions (average %) Coarse fraction 20% - quartz (eq, el; ang – s-rnd; FSa-CSa) 88% - micritic calcite (eq; ang – rnd; FSa-CSa) 8%
Fine fraction - quartz 48% - mica 43% - feldspar 8%
Matrix (average %) 65-75% - micaceous - mostly homogeneous - mostly moderate optical activity
Voids (average %) 5% - macro/ meso channels, vesicles
Textural features/ Comments It is unclear if the calcite inclusions are naturally present or post-depositional secondary accumulations.

5.2.1.1.4 Coarse-fine-combination fabrics

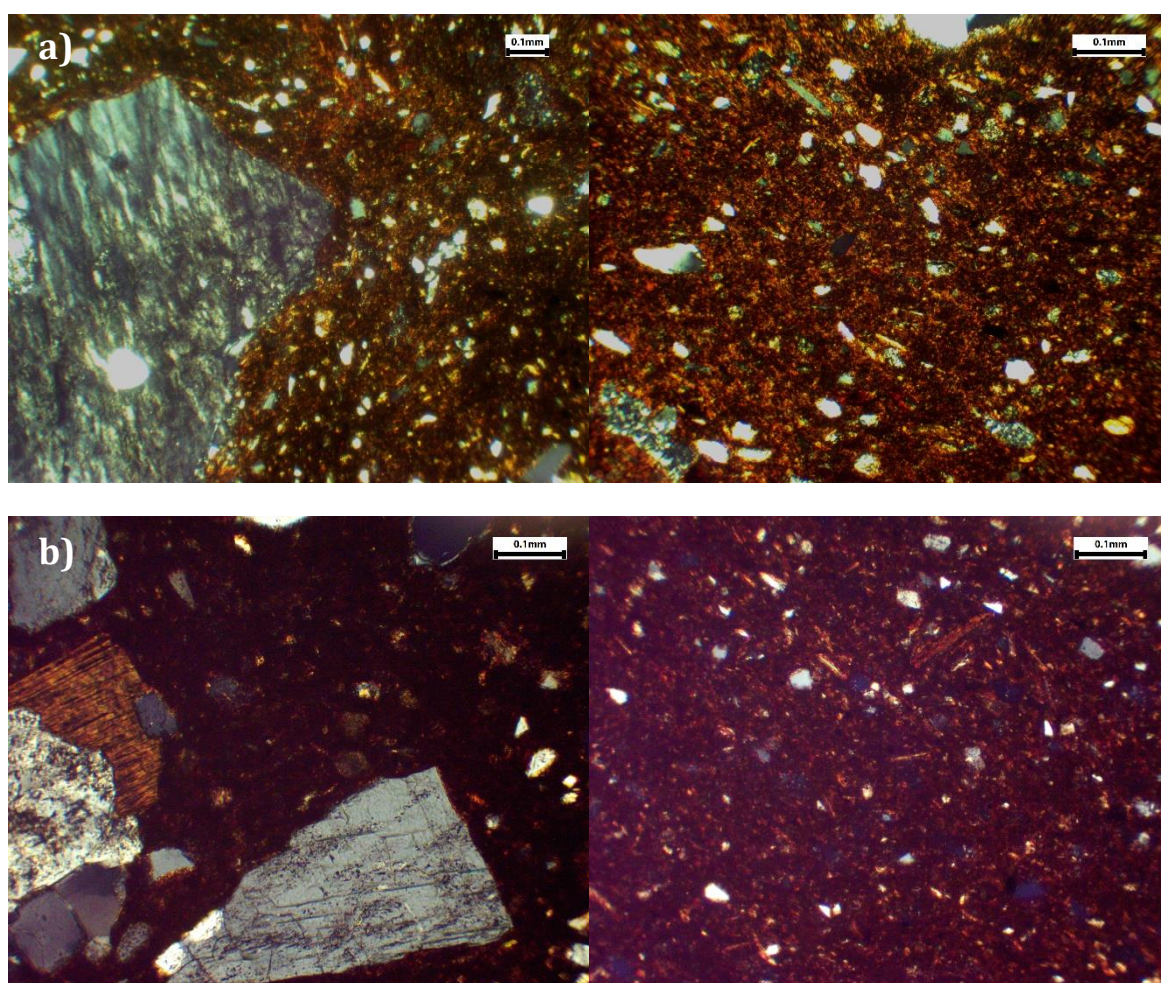


Fig. 5.135. coarse-fine-combination fabrics identified in selected sherds from Majiayao; photomicrographs taken under XPL, scale size 0.1 mm; left – coarse part, right – fine part a) Fabric 4D, CNP36 b) Fabric 4E, CNP16.

The coarse-fine-combination Fabrics 4D and 4E (Table 5.21, Fig. 5.135a-b) are sub-fabrics of Fabric 4A which is predominantly composed of coarse quartz, feldspar and granitic/ granodiorite rock fragments. Fabric 4D has larger non-plastic inclusions than 4E with a maximum of fine gravel size. The coarse and fine part of 4D have the same groundmass which indicates that the coarse granitic rock fragments were added into fine clay manually by the potter. No naturally present granitic rock fragments were identified in the fired geological samples during petrographic analysis (section 6.2.1). Macroscopic analysis of the fired samples has

shown that no coarse inclusions were visible in the cross-sections indicating that most clays in the surrounding of the Majiayao site are likely to be fine.

Sub-fabric 4E does not have fine gravel-sized coarse fraction, its maximum size is coarse sand. The coarse and fine parts of this sub-fabric have the same groundmass. Fine Fabric 1 has a similar texture and composition to the fine part of sub-fabric 4E, which supports the suggestion that the clay used a raw material was initially fine.

Sub-fabrics 4D and 4E have a low degree of porosity – coarse and fine parts combined. It is a similar case to the sub-fabric 4B/CNP9, which is the coarse part of another coarse-fine-combination vessel, in terms of technology and usage.

Because of its optically active matrix sub-fabric 4D appears to be lower fired than 4E, which has moderately active matrix. This difference could be due to the different technological choices in decoration of these sherds. 4E might have been fired at a higher temperature to achieve the light background colour for the painted part. However, as has been pointed out previously, the maximum heat that the vessel was exposed to depends on a number of different factors (Forget et al. 2015).

Table 5.21. Petrographic description of coarse-fine-combination fabrics identified in selected sherds from Majiayao.

Fabric 4D Fig. 5.135a	Fabric 4E Fig.135b
Sorting	Sorting
coarse part: poor; fine part: well-sorted	coarse part: poor; fine part: well-sorted
Average inclusion frequency %	Average inclusion frequency %
30-35%	25%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse part	Coarse part
Coarse fraction 10% - quartz and quartzite (eq, el; s-ang – s-rnd; CSa-FGr) 75% - plagioclase feldspar (eq; s-ang s-rnd; CSa) 20% - granitic rock fragments – combination of quartz, plagioclase feldspar, biotite (eq; s-ang; CSa-FGr) 5% Fine fraction 90% - quartz 55% - mica 40% - feldspar 5%	Coarse fraction 40% - granitic rock fragments – combination of quartz, feldspar, biotite, hornblende (eq, el; ang – s-rnd; MSa-CSa) 38% - quartz (eq, el; ang – rnd; FSa-CSa) 25% - plagioclase feldspar (eq; s-ang; MSa-CSa) 20% - biotite (lamellae; MSa-CSa) 15% Fine fraction 60% - mica 50% - quartz 40% - feldspar 10%
Fine part	Fine part
- quartz 55% - mica 40% - feldspar 5%	- mica 50% - quartz 40% - feldspar 10%
Matrix (average %)	Matrix (average %)
65% - micaceous - homogeneous - optically active	40-50% - micaceous - homogeneous - moderate optical activity
Voids (average %)	Voids (average %)
1-3% - mega/ macro vughs	3-5% - macro/meso vughs, vesicles
Textural features/ Comments	Textural features/ Comments
Coarse and fine parts have the same groundmass; low porosity; belongs to the same vessel as the sherds K.11999:470-471.	Coarse and fine parts have the same groundmass; porosity is low despite large coarse inclusions

5.2.1.2 Summary

Inclusions

The average inclusion frequency in all fabric types is 20-40% (Fig. 5.136). The fine fabrics analysed here do not tend to have an inclusion frequency above this margin. Coarse fabrics in contrast can have 40% or more non-plastic inclusions. Very coarse fabrics have 40-50% coarse inclusion frequency.

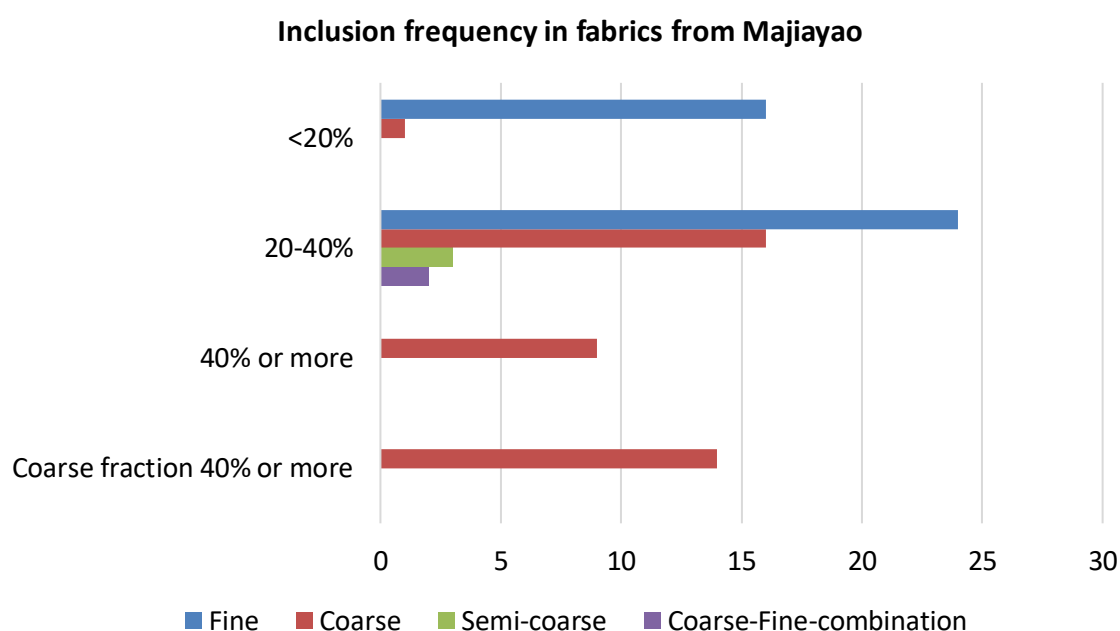


Fig. 5.136. Inclusion frequency and coarse fraction trends in fabrics identified in selected sheds from Majiayao; numbers represent the number of sherds.

The maximum coarse inclusion size in the samples from Majiayao is fine gravel (Fig. 5.137). According to ISO 2017, fine gravel size ranges between 2 – 6.3 mm. In the case of the Majiayao pottery fabrics, the average fine gravel size range is 2 – 2.5 mm. The macroscopic analysis of the fired geological samples has shown that only few naturally present non-plastic inclusions of this size can be found in the clay found in the surrounding of the Majiayao site area, as seen during the geological survey.

**Maximum inclusion size in coarse and coarse-fine-combination
sherds from Majiayao**

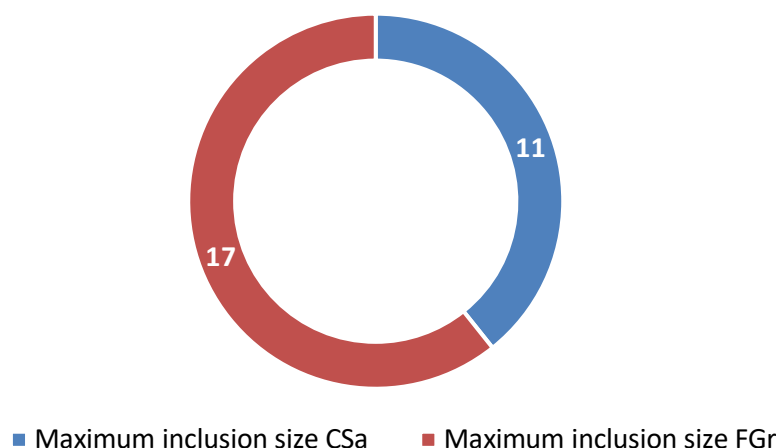


Fig. 5.137. Maximum inclusion size in coarse and coarse-fine-combination fabrics identified in selected sherds Majiayao; numbers represent the number of sherds.

For the evaluation of the most frequent non-plastic coarse inclusion type in the Majiayao fabrics quartz has been excluded from the dataset because of its constant occurrence in every sample. In thin section the sizes range from fine sand to fine gravel. The most occurring coarse inclusion type beside quartz is feldspar (Fig. 5.138). Feldspar is a natural component of residual clays (Shepard 1985:18) and is commonly present in coarse and fine fraction, as the results of the petrographic pottery analysis show. When added to the clay paste, coarse feldspar can act as fluxing agent and lower the melting points of clay (Shepard 1985:28; Rice 2015:108; Hamer and Hamer 2015:169).

The next most common non-plastic inclusion type is micritic and/ or crystalline calcite. The complication with identifying calcite as naturally present or secondary deposited has been already mentioned above. Calcite is naturally present in some types of clay in the study area at least on the elemental level, this became evident after conducting the firing experiment (section 6.2.1). Further, as discussed in the macroscopic analysis section, calcite can affect the colour of the pottery. Clays

containing calcite might have been specifically chosen by the prehistoric potters due to this property.

Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics from the Majiayao site

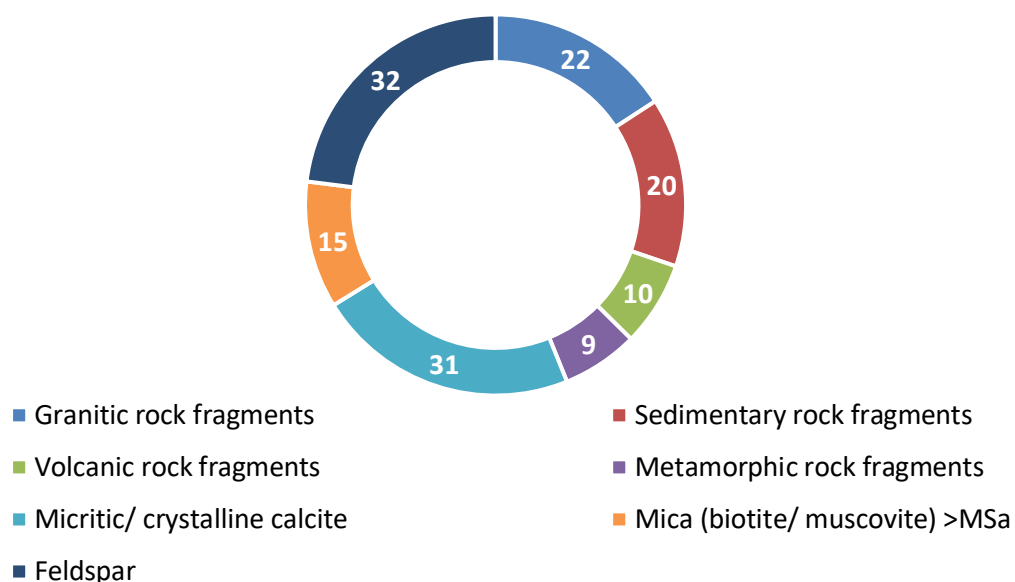


Fig. 5.138. Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics identified in the selected sherds from Majiayao. Numbers represent the number of sherds, but a sherd can have a combination of several inclusion types. This figure shows which inclusion types are most common. Although calcite is often present in sherds, it is unclear in some cases whether it was naturally present or is a secondary accumulation.

Granitic and sedimentary rock fragments occur with a similar frequency. Granitic fragments are usually large in size (FGr) and have angular to sub-rounded shapes. Fabrics 4A-E are characterised by this rock inclusion which was probably acting as temper. Granites are composed of feldspar, quartz and biotite so maybe they were added because of these minerals' properties (Hamer and Hamer 2015:169). Feldspar and quartz would act as flux lowering the vitrification point of the vessel bodies and adding granite would increase thermal conductivity which is essential for cooking purposes (Müller et al. 2007:148; Hein et al. 2007:17-18; Rice 2015:79, 108). If this refractory property of granite was known to the prehistoric potters,

then the granite tempered Majiayao-style pottery might have been used for cooking.

The angularity of the granitic inclusions indicates that they did not weather for a long time as sand particles in the river or sediment. No similar granitic/granodiorite rock fragments were petrographically identified in the collected sand sample (section 6.2.1). The granitic temper was probably freshly crushed from a rock by the potter.

In contrast to granite, sedimentary rock fragments show more rounded shapes (e.g. Fig. 5.133e). Fabrics 5A-B are characterised by coarse sedimentary rock, calcite and volcanic rock fragments. All three have been petrographically identified among the inclusions of the geological sand sample. The shapes and the type of the inclusions indicate that these might have come from widely available sand in the area. Based on his petrographic analysis of sherds and geological samples, Womack (2017:44, 138-139) similarly suggested that the coarse sherds from the Tao River Valley might have been tempered with river sand. Womack (2017:141) also identified a similar variety of mineral inclusions in the sherds sampled in his study. He analysed 116 thin sections among which feldspar, quartz and biotite dominated the coarse fabrics (Womack 2017:141). In contrast to the fabrics from Majiayao, only two Majiayao period samples from Womack's study area had calcium carbonate inclusions (Womack 2017:141). He suggested that the carbonate inclusions were naturally presented in the clay after comparison to a clay sample with high carbonate content from his study area (Womack 2017:140). The samples analysed in this study containing coarse calcite were grouped into one fabric and show difference in composition to the other coarse fabrics (Table 5.15). Considering Womack's observation, the calcite rich clay could have been a

distinct type of clay used in production which was different from the clays used for the other fabrics.

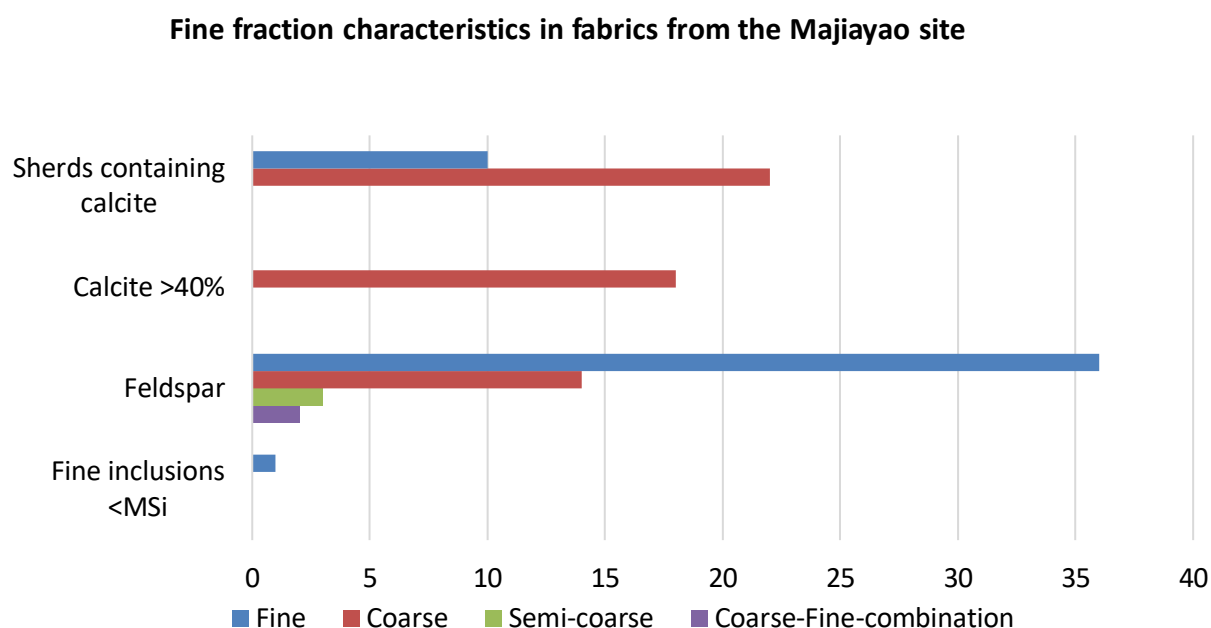


Fig. 5.139. Fine fraction characteristics in fabrics identified in selected sherds from Majiayao; numbers represent the number of sherds. It is unclear in some sherds whether calcite was naturally present or is a secondary accumulation.

Fine fraction data for all the fabrics show that calcite is mostly present in the coarse fabrics and in high amounts which reinforces the suggestion that there was a distinct clay type with this mineral naturally present (Fig. 5.139). The author did not include samples which had obvious accumulations of secondary calcite (e. g. around the void/ sample edges) in this dataset. Given that some fabrics might have been tempered with calcareous sand, the fine calcite in the dataset could be indeed a primary component.

All fabrics include a certain amount of feldspar in fine fraction. Almost all of the fine fabric samples have fine feldspar but it is present in only about a half of coarse fabrics. Either it was difficult to identify the fine inclusions petrographically or there could be some other reason for this. All geological samples analysed in thin section had feldspar in the fine fraction.

The fine fabric sample CNP69 has medium silt-sized fine fraction. Other fine and coarse fabrics have larger inclusions – coarse silt-sized – in fine fraction. CNP69 could be an example of specially processed and levigated clay. However, two of the geological clay samples (section 6.2.1) show the same fine fraction inclusion size, indicating that very fine clays were naturally available in the study area.

Matrix

Most of the fabrics from Majiayao have a well homogenised matrix, and only a few samples have a high clay pellet amount (Fig. 5.140). The presence of little to no clay pellets indicates that the clay was well hydrated and wedged. To increase plasticity and improve hydration, the clay material could have been also aged, but there is no evidence for that in the archaeological record of the study area.

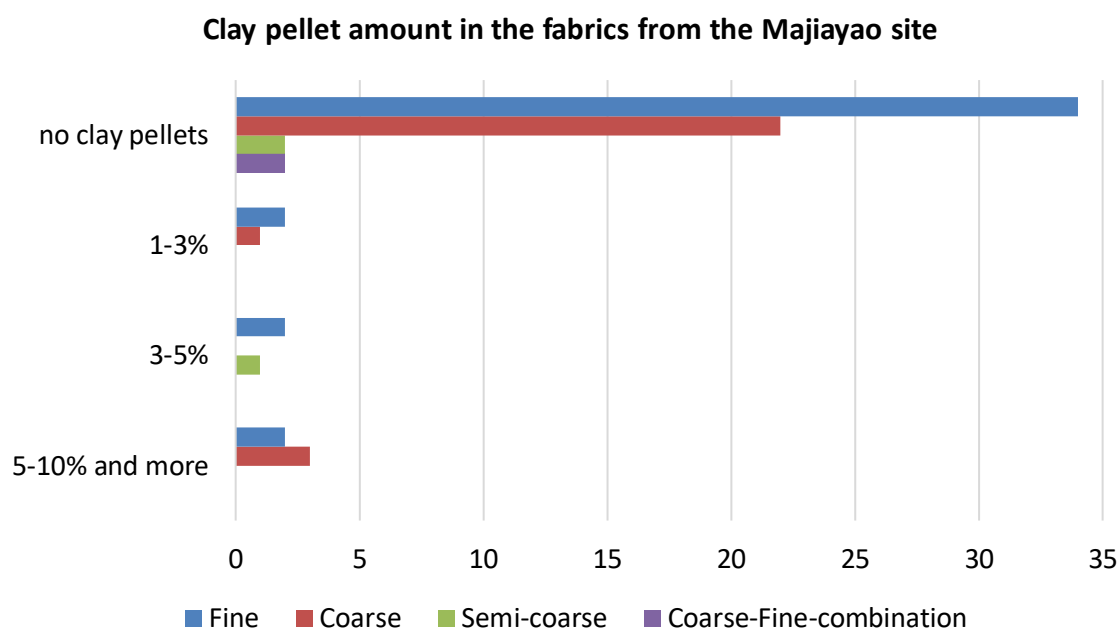


Fig. 5.140. Clay pellet amount in the fabrics identified in selected sherds from Majiayao; numbers represent the number of sherds.

The optical activity of the fabric matrices ranges mostly between active and moderately active (Fig. 5.141). This puts the overall firing temperature onto a scale from 700° to 1000° C (Quinn 2013:191). Based on their optically active matrices,

the majority of the coarse fabrics appears to be lower fired. No stark contrast in optical activity can be seen among the fine fabrics which could indicate that the varying firing temperature did not have a significant influence on the outcome of the firing. There are only three samples with optically inactive matrices out of seventy-one samples implying a careful firing control which did not result in burning or damaging the pottery.

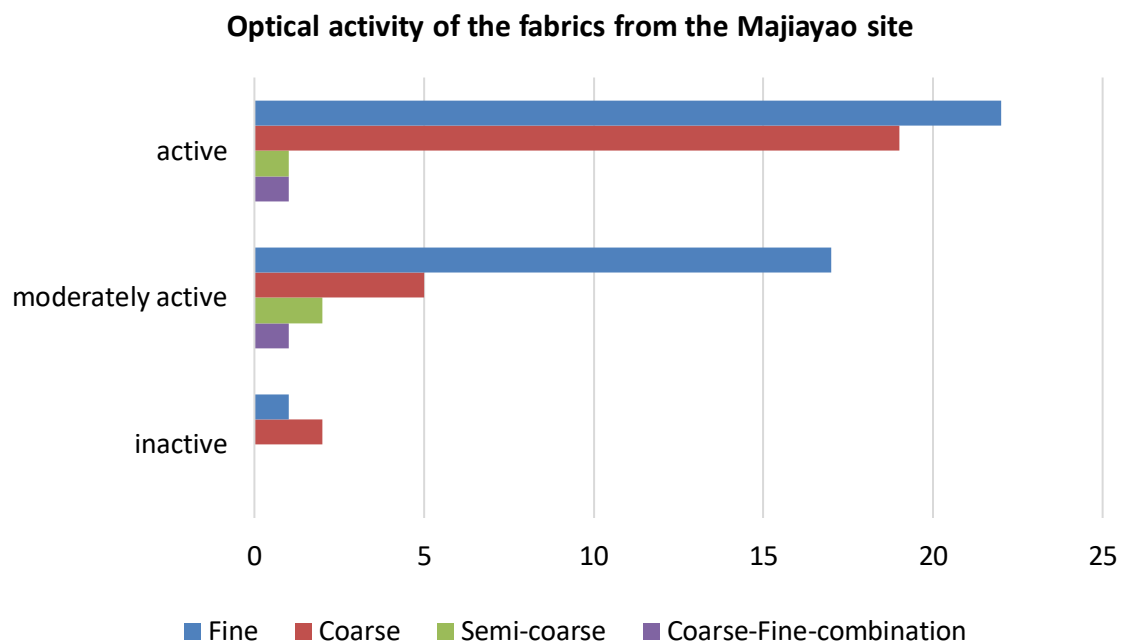


Fig. 5.141. Optical activity of the fabrics identified in selected sherds from Majiayao; numbers represent the number of sherds.

Porosity

The degree of porosity common to all fabrics is below 10% which is low to medium based on data from all sites in this study (Fig. 5.142). Due their different textures, fine fabrics are less porous, which also applies to the semi-coarse fabrics. Coarse fabrics can be highly porous but also show a small void amount like in the case of Fabrics 4B and 5B.

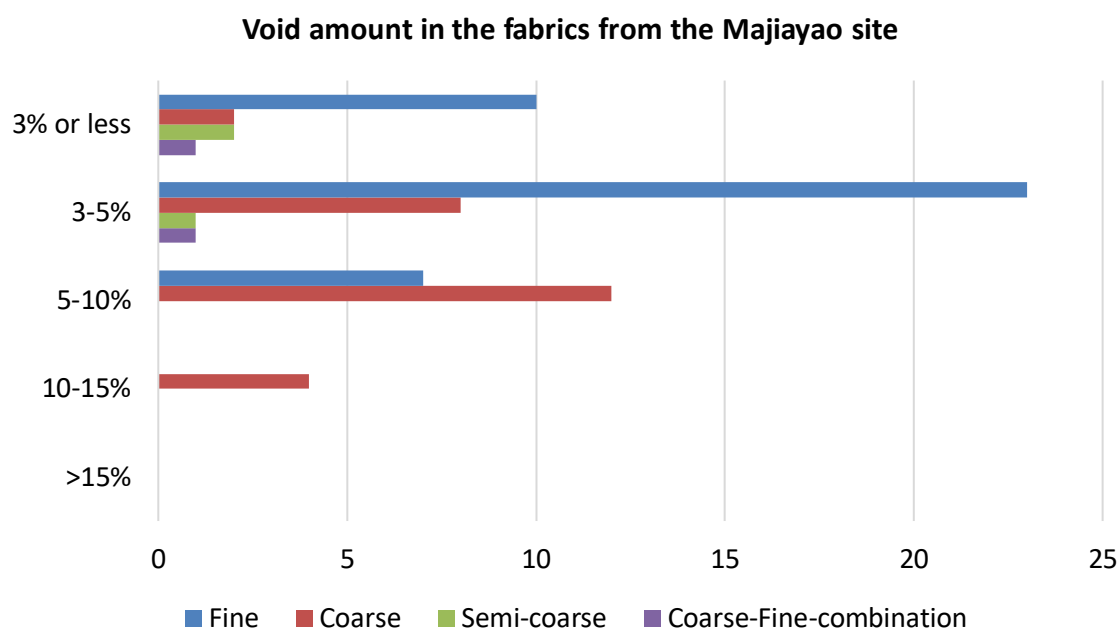


Fig. 5.142. Void amount in the fabrics identified in selected sherds from Majiayao; numbers represent the number of sherds.

5.2.2 Waguanzui

The thin sections made from the Waguanzui sherds are thicker than the standard thickness of 30 μm , so it was difficult to see the amount of inclusions and textural features such as clay pellets.⁴⁴

5.2.2.1 Fabric groups

All nine samples from Waguanzui have fine fabrics, which were divided in three different groups (Tables 5.22-23, Fig. 5.143a-c).

⁴⁴ The samples from the Waguanzui sherds were prepared as uncovered polished thin sections for the intended SEM-EDX analysis. The different preparation technique caused the difference in the thickness.

Table 5.22. List of fabrics identified in the sherd samples from Waguanzui.

Fabrics	Number of sherds
Fine fabrics	
1 Fine, Quartz-Mica-Feldspar <i>CNP72, 73, 74, 77, 78, 80</i>	6/9
2 Fine, Quartz dominant, inclusion frequency 1% <i>CNP76, 79</i>	2/9
3 Fine, Quartz dominant <i>CNP75</i>	1/9
Coarse fabrics	none
Semi-coarse fabrics	none
Coarse-Fine-combination	none

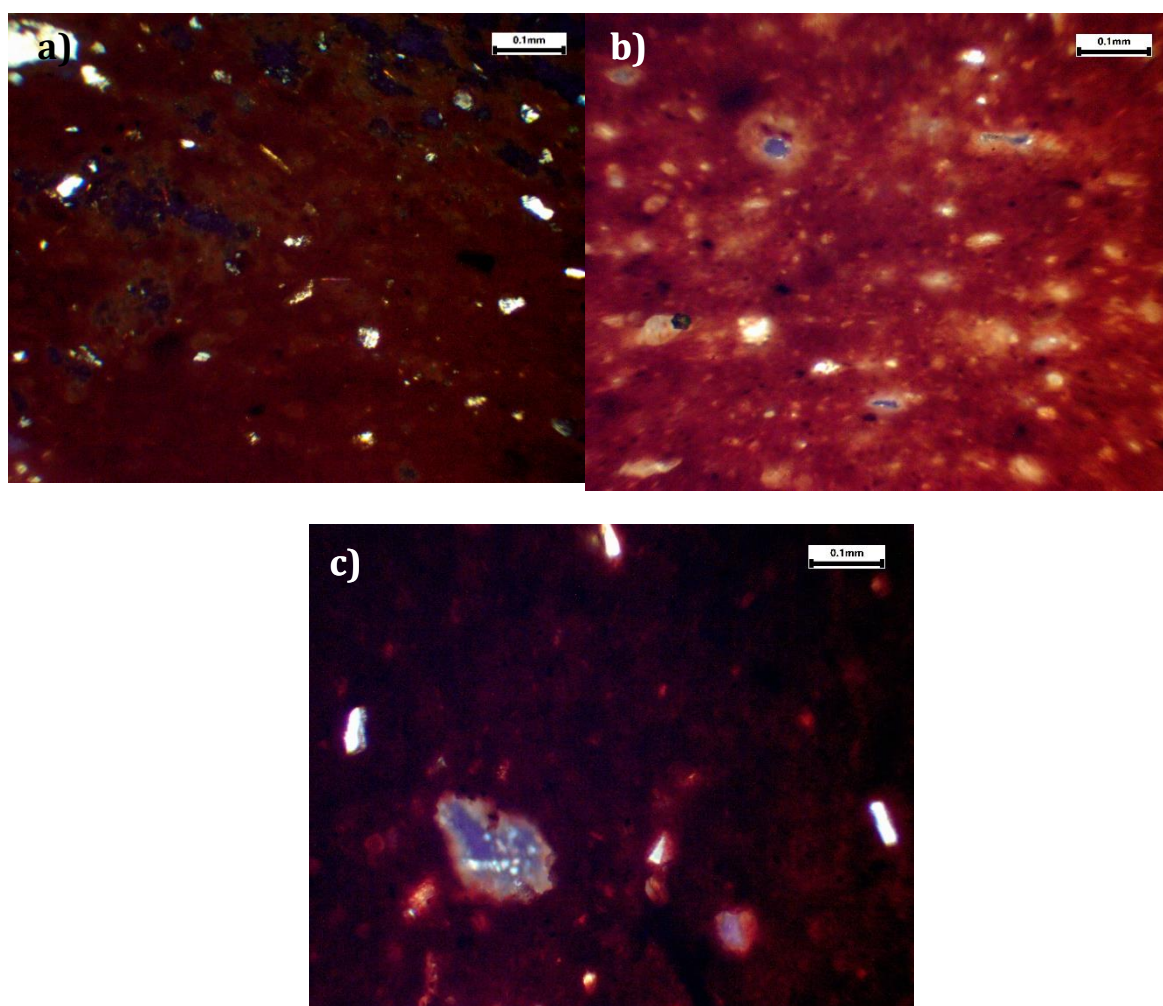


Fig. 5.143. Fine fabrics identified in selected sherds from Waguanzui; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 1, CNP74 b) Fabric 2, CNP76 c) Fabric 3, CNP75.

All fabrics have similar characteristics. Fabric 1 has the highest inclusion frequency and feldspar in fine fraction. Fabric 2 has the lowest inclusion frequency (1%) and highest porosity (5-10%) among the three groups. Fabrics 2 and 3 do not have feldspar in the fine fraction. All three fabrics have inactive matrices and appear to be highly fired. The petrographic data for these samples must be considered with caution as it is unclear to what extent the thickness of the thin sections has distorted the analysis of the fabrics' texture.

Table 5.23. Petrographic description of Fine fabric groups identified in selected sherds from Waguanzui.

Fabric 1 Fig. 5.143a	Fabric 2 Fig. 5.143b	Fabric 3 Fig. 5.143c
Sorting	Sorting	Sorting
well	well	well
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
10%	1%	5%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
- quartz 57% - mica 36% - feldspar 7%	- quartz 80% - mica 20%	- quartz 70% - mica 30%
Matrix (average %)	Matrix (average %)	Matrix (average %)
80% - micaceous - homogeneous - optically inactive	90% - micaceous - homogeneous - optically inactive	90% - micaceous - homogeneous - optically inactive
Voids (average %)	Voids (average %)	Voids (average %)
5% - macro/ meso vesicles, vughs, channels	5-10% - meso vesicles; vughs, channels	5% - macro/ meso vesicles, vughs, channels
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
none	none	none

5.2.2.2 Summary

Inclusions

All samples have less than 20% inclusion frequency (Table 5.24). No calcite has been identified in fine fraction. Fine feldspar was detected in six samples of Fabric 1.

Table 5.24. Inclusion frequency and fine fraction trends in fabrics identified in selected sherds from Waguanzui.

Characteristic	Number of sherds
Inclusion frequency	
< 20%	9
Fine fraction	
Sherds containing calcite	0
Calcite > 40%	0
Feldspar	6
Fine inclusions <MSi	0

Matrix

All fabrics appear to be well homogenised; no clay pellets were observed. Each sample has an optically inactive matrix which indicates a firing temperature around 1050° C and above.

Table 5.25. Clay pellet amount and optical activity in the fabrics identified in selected sherds from Waguanzui.

Characteristic	Number of sherds
Clay pellet amount	
no clay pellets	9
Optical activity	
active	0
moderately active	0
inactive	9

Porosity

The average porosity degree in samples from Waguanzui is similar to the porosity data of Majiayao fabrics (Table 5.26). Although these are fine fabrics with a very

low inclusion frequency, five samples have 5-10% voids. This could be the result of the vitrification process which led to vesicle formation as water or gasses escaped the clay under high temperature (Rice 2015:316).

Table 5.26. Void amount in the fabrics identified in selected sherds from Waguanzui.

Characteristic	Number of sherds
Void amount	
3% or less	0
3-5%	4
5-10%	5
10-15%	0
>15%	0

5.2.3 Zhujiazhai

5.2.3.1 Fabric groups

Seven main fabric groups were identified in the samples from Zhujiazhai (Table 5.27, Fig. 5.144). The semi-coarse fabrics are mostly sub-fabrics of the main fine and coarse fabrics. One fine and seven semi-coarse samples were classified as loners (fine CNP113, semi-coarse CNP81, CNP92, CNP93, CNP94, CNP102, CNP109, CNP115)⁴⁵, although their inclusion types do not differ significantly from the inclusions in other fabric groups. It was the overall different inclusion amount and size which made the grouping difficult.

Table 5.27. List of fabrics identified in the sherd samples from Zhujiazhai.

Fabrics	Number of sherds
Fine fabrics	
1 Fine, Mica dominant, mineral inclusions are MSi-sized and smaller <i>CNP114, 121</i>	2/52
2A Fine, Mica-Quartz-Feldspar <i>CNP95, 96, 97, 98, 99, 107, 117, 119, 120, 122, 123, 124, 184, 185, 186</i>	15/52
2B Fine, Mica-Quartz-Feldspar, higher inclusion frequency and coarse fraction than Fabric group 2A	1/52

⁴⁵ For the individual description of each sample see Catalogue 3.

<i>CNP100</i>	
3A Fine, Mica-Quartz-Feldspar, less inclusion frequency than Fabric group 2A <i>CNP108, 112, 116, 118, 125.</i>	5/52
Coarse fabrics	
4A Coarse, Quartz-Feldspar and Granodiorite fragments <i>CNP86,103 126</i>	3/52
4B Coarse Quartz-Feldspar and Granodiorite fragments with lower inclusion frequency than Fabric group 4A <i>CNP82, 83, 85, 87, 88, 127</i>	6/52
4C Coarse, Quartz-Granodiorite fragments <i>CNP105</i>	1/52
5A Coarse Quartz and Metamorphic rock fragments <i>CNP101, 106</i>	2/52
5B Coarse Quartz, Metamorphic and Sedimentary rock fragments <i>CNP183</i>	1/52
6 Coarse Grog <i>CNP84, 89, 90, 91, 104, 182</i>	6/52
Semi-coarse fabrics	
3B Semi-coarse, Quartz and Feldspar fragments, groundmass similar to 3A <i>CNP111</i>	1/52
4D Semi-coarse, Quartz-Feldspar with few Granodiorite rock fragments <i>CNP110</i>	1/52
Coarse-Fine-combination	none
Loners	
Fine, Quartz dominant <i>CNP113</i>	1/52
Semi-coarse, Quartz-Feldspar with Volcanic glass(?) fragments <i>CNP81</i>	1/52
Semi-coarse, Quartz-Feldspar with Metamorphic rock fragments <i>CNP92</i>	1/52
Semi-coarse, Quartz-Mica-Feldspar with rare Grog fragments <i>CNP93</i>	1/52
Semi-coarse, Quartz dominant with Feldspar fragments <i>CNP94</i>	1/52
Semi-coarse, Quartz and Grey Mudstone(?) fragments <i>CNP102</i>	1/52
Semi-coarse Quartz, Volcanic glass and Sedimentary rock fragments <i>CNP109</i>	1/52
Semi-coarse Sedimentary rock and Black opaque rock fragments <i>CNP115</i>	1/52

Main fabric groups overview: Zhujiashai site

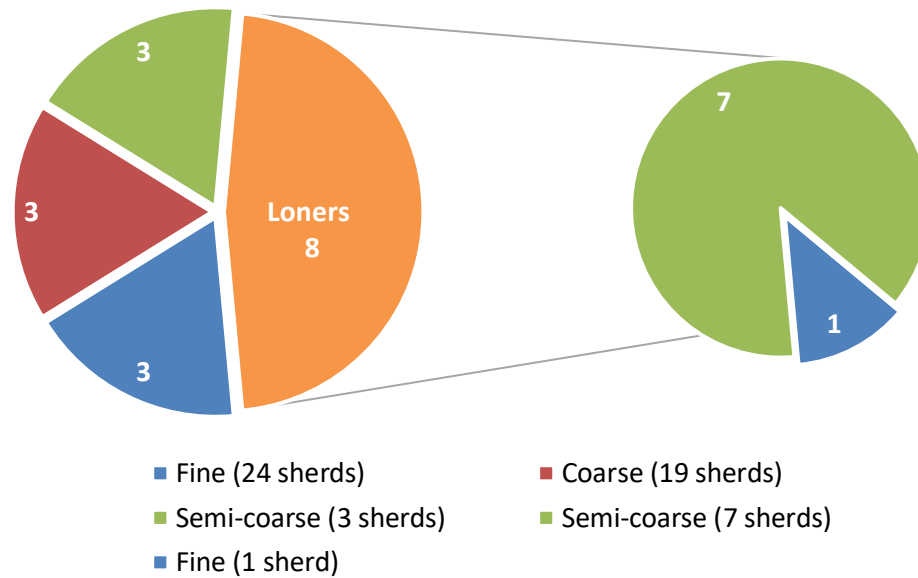


Fig. 5.144. Main fabric groups overview: Zhujiashai site; numbers represent the number of identified groups.

5.2.3.1.1 Fine fabrics

Similar to the fine fabrics from Majiayao, the fine fabrics from Zhujiashai all have different amounts of quartz, mica and feldspar (Table 5.28, Fig. 5.145a-d). Three main groups have been identified, with one having a fine sub-fabric and one having a semi-coarse sub-fabric. All the fabric groups appear to be very micaceous.

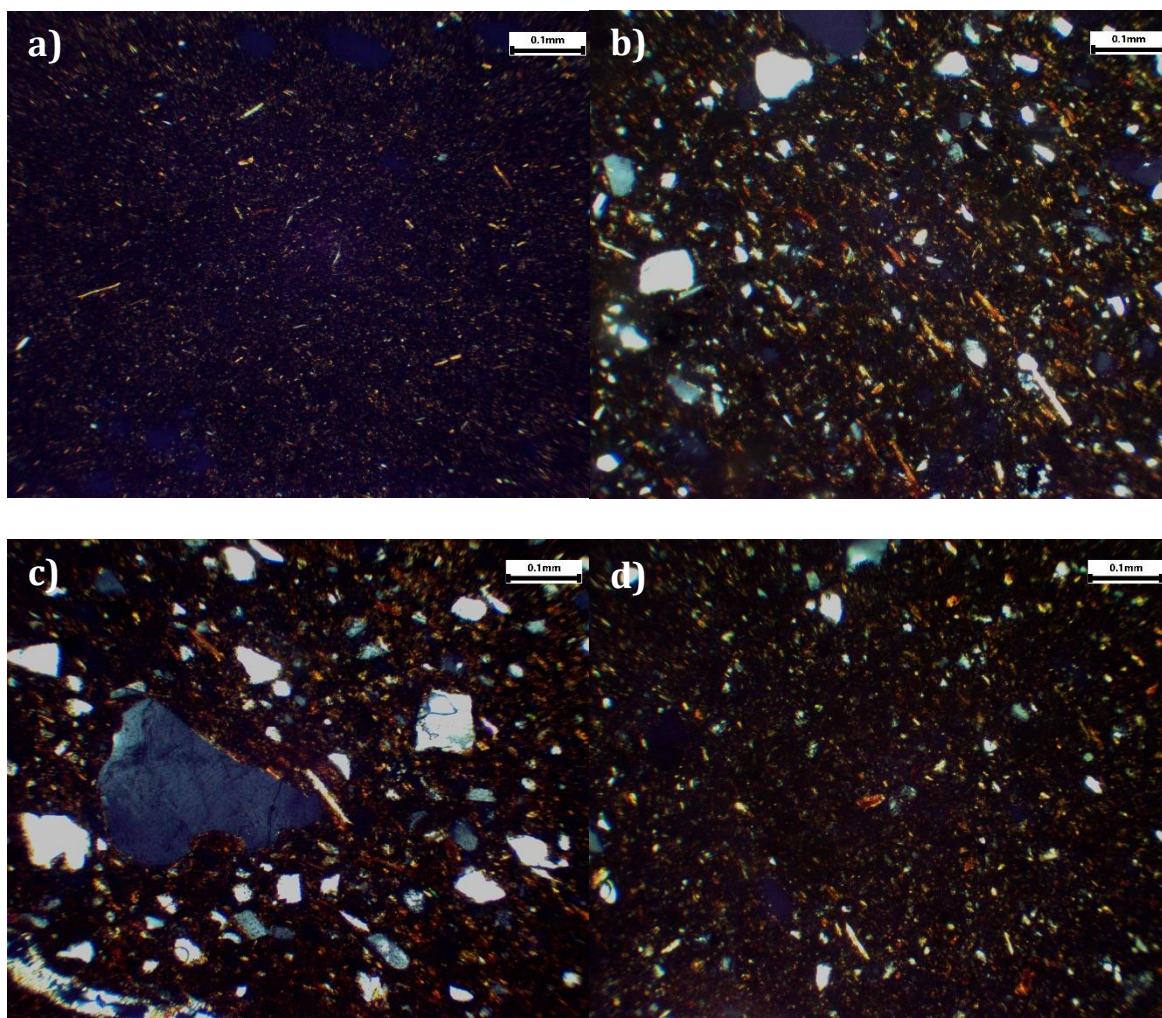


Fig. 5.145. Fine fabrics identified in selected sherds from Zhujiazhai; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 1, CNP121 b) Fabric 2A, CNP117 c) Fabric 2B, CNP117 d) Fabric 3A, CNP116.

Fabric 1 is a mica-dominant fabric and has medium silt-sized mineral inclusions, similar to CNP69 from Majiayao. It has dominant mica and a low amount of quartz that was possible to identify under the petrographic microscope. No feldspar inclusions were observed in this fabric. The sample matrices of Fabric 1 are optically active. The porosity is very low (3%), possibly due to the small mineral inclusion size.

Fabric 2A has on average small amounts of feldspar and calcite but the numbers can vary among the individual samples in this group. Calcite inclusions appear to be naturally present in this fabric. The sample matrices are mostly optically active,

and the average porosity is low (5%). The sub-fabric Fabric 2B has a small coarse fraction (5-10%) which consists of mainly fine sand-sized quartz and feldspar. Theoretically, because there is a coarse fraction, 2B which is CNP100 could be classified as a semi-coarse fabric. However, because most of the inclusions in the coarse fraction are fine sand-sized it is still considered a fine fabric in the present study. The matrix in 2B is optically active and has higher porosity than 2A showing mega planar voids. These are not part of the texture characteristics but are due to the sherd area where the sample was cut from: shoulder and neck join area. The elongated voids show that the coils of the neck were not attached very well to shoulder and have slightly disconnected as the clay shrank.

Fabric 3A consists of less amounts of mica, quartz, feldspar than Fabrics 2A-B. The sample matrices are mostly optically active and show low porosity.

The sample CNP113 classified as a loner has a higher amount of feldspar (10%) than the other groups. This sample has an optically inactive vitrified matrix which conceals any distinct textural features; therefore, it was difficult to assign this sample to any of the existing fabric groups.

Table 5.28. Petrographic description of Fine fabric groups identified in selected sherds from Zhujiashai.

Fabric 1 Fig. 5.145a	Fabric 2A Fig. 5.145b	Fabric 2B Fig. 5.145c	3A Fig. 5.145d
Sorting	Sorting	Sorting	Sorting
well	mostly well-sorted	moderate	mostly well-sorted
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
10%	20%	30%	15%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
• mica 75% • quartz 25%	• mica 55% • quartz 38% • feldspar 4% • calcite 3%	• mica 50% • quartz 40% • calcite 5% • feldspar 5%	• mica 55% • quartz 25% • feldspar 4%
Matrix (average %)	Matrix (average %)	Matrix (average %)	Matrix (average %)
• 85-87% • micaceous • homogeneous • optically active	• 65-70% • micaceous • homogeneous • mostly optically active	• 60-65% • micaceous • homogeneous • optically active	• 75-80% • micaceous • homogeneous • mostly optically active
Voids (average %)	Voids (average %)	Voids (average %)	Voids (average %)
• 3% • macro/ meso vughs and vesicles	• 5% • macro/ meso vughs and vesicles	• 5-10% • mega planar voids, macro/meso vughs	• 3% • macro/ meso vughs and vesicles
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
Mineral inclusions are MSi-sized and smaller.	none	accumulations of secondary calcite on sherd margins	none

5.2.3.1.2 Coarse fabrics

Three main coarse fabrics were identified, one having two sub-fabrics and another one having one sub-fabric (Tables 5.29-31, Fig. 5.146a-f). Similar to the coarse fabrics from Majiayao, coarse fabrics from Zhujiashai are characterised by granitic rock inclusions. There are less sedimentary rock fragments and more metamorphic

rock fragments. Unique to the material from Zhujiashai, one fabric group is characterised by coarse grog inclusions (Fig 5.146f).

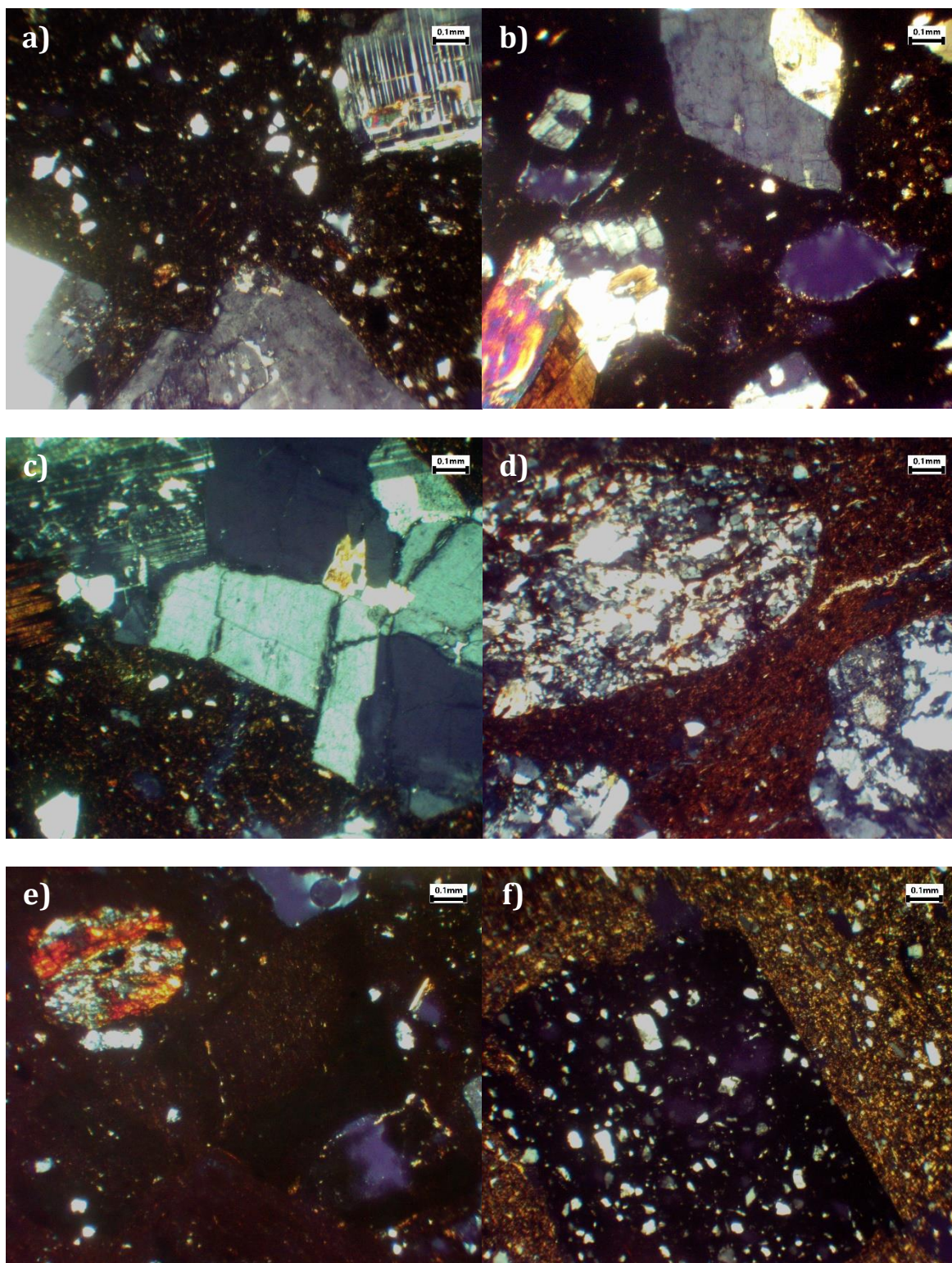


Fig. 5.146. Coarse fabrics identified in selected sherds from Zhujiashai; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 4A, CNP103 b) Fabric 4B, CNP87 c) Fabric 4C, CNP105 d) Fabric 5A, CNP106 e) Fabric 5B, CNP183 f) Fabric 6, CNP104.

Fabric 4A is dominated by coarse sand-/ fine gravel-sized quartz, feldspar, and granitic rock fragments. Fine fraction consists predominantly of quartz and mica. The average fine feldspar amount is very low (2%). The sample matrices are mostly optically active and show on average very low porosity (3%). The texture with low porosity in 4A is similar to the sub-fabric 4B/CNP9 and the coarse part of sub-fabric 4E/CNP16 from Majiayao, where the coarse inclusions were inclusions are matrix supported without any space in between the grain and the groundmass. The sub-fabric 4B has coarse biotite inclusions, which are possibly detached particles from the granite rock fragments, and a lower fine fraction content than Fabric 4A. The sample matrices are mostly optically active and have a medium degree of porosity (5-10%).

The sub-fabric 4C has a higher inclusion frequency and higher granitic rock content than 4A and 4B, but its coarse feldspar content is lower. Fine fraction has a higher mica content and possibly a higher feldspar content than sub-fabrics 4A and 4B. The sample matrix is optically active, and the porosity is very low (1-3%). The optically active matrix implies that the sherds were fired <900° C. The matrix in 4C further contains a small amount of clay pellets which the 4A and 4B do not.

Similar to the granitic/ granodiorite inclusions in the coarse fabrics from Majiayao, granite in the Zhujiazhai fabrics appears to be manually added crushed rock. However, it was not possible to collect geological samples in the site area and assess the type of naturally present coarse inclusions.

Table 5.29. Petrographic description of the coarse fabrics identified in selected sherds from Zhujiashai (part 1).

Fabric 4A Fig. 5.146a	Fabric 4B Fig. 5.146b	Fabric 4C Fig. 5.146c
Sorting	Sorting	Sorting
mostly poor	mostly poor	poor
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
25%	20%	30%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 20%	Coarse fraction 40%	Coarse fraction 30%
- quartz (eq, el; s-ang – s-rnd; FSa-FGr) 43% - plagioclase/ microcline feldspar (eq; s-ang – s-rnd; FSa-CSa) 32% - granitic rock fragments – combination of quartz, plagioclase/ microcline feldspar and biotite and/ or muscovite (eq; ang – s-ang; FSa-CSa) 22%	- quartz (eq, el; ang – s-rnd; CSa-FGr) 45% - plagioclase/ microcline feldspar (eq, el; ang – s-ang; FSa-CSa) 29% - granitic rock fragments – combination of quartz, plagioclase/ microcline feldspar, biotite and/ or muscovite (eq, el; ang – s-rnd; CSa-FGr) 23% - biotite/ muscovite (lamellae; MSa-CSa) 6%	- quartz (eq, el; ang – rnd; FSa-MSa) 55% - granitic rock fragments – combination of quartz, plagioclase/ microcline feldspar, biotite, muscovite (eq, el; s-ang; CSa-FGr) 40% (ortho-?)/ plagioclase feldspar (eq; ang; FSa) 5%
Fine fraction 80%	Fine fraction 60%	Fine fraction 70%
- quartz 65% - mica 33% - feldspar 2%	- quartz 63% - mica 36.5% - feldspar 0.5%	- mica 55% - quartz 40% - feldspar 1-5%
Matrix (average %)	Matrix (average %)	Matrix (average %)
65-70% - micaceous - homogeneous - mostly optically active	70% - micaceous - homogeneous - mostly optically active	65-70% - micaceous - homogeneous - optically active
Voids (average %)	Voids (average %)	Voids (average %)
3% - macro/ meso vughs, channels	5-10% - macro/ meso channels, vughs	1-3% - macro/ meso vughs, channels, vesicles
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
none	The fine fraction content is lower than in Fabric groups 4A and 4C; CNP85 fine fraction <MSi	FSa-MSa clay pellets taking up 3-5% of the matrix; coarse but low porosity; higher mica content than in Fabric groups 4A and 4B.

Fabric 5A is dominated by coarse sand-sized quartz and metamorphic rock fragments, which appear to be shist. The fine fraction has dominant mica and less quartz; no fine feldspar was identified. The sample matrices are optically active and have on average a very low porosity (1-3%) which appears to be common among the coarse fabrics from Zhujiashai. The fabric has a small amount of clay pellets.

In addition to medium sand-sized quartz and metamorphic rock fragments, sub-fabric 5B has a high amount of coarse sand-sized opaque inclusions of uncertain origin. They have a greenish grey colour in plain polarised light and appear to be either highly fired mudstone or vitrified clay pellets. These inclusions are black under crossed polarised light and do not contain any detectable minerals; some of them have voids. The fine fraction has a small amount of feldspar beside mica and quartz. 5B matrix seems to be optically inactive but not as vitrified as the black inclusions. The porosity is high (15%) which is likely the result of firing under a high temperature causing the black inclusions create voids. The fact that the black inclusions can create voids implies that they could be of argillaceous nature, such as from a different type of clay with a lower sintering point than the clay matrix of the sample.

Table 5.30. Petrographic description of the coarse fabrics identified in selected sherds from Zhujiazhai (part 2).

Fabric 5A Fig. 5.146d	Fabric 5B Fig. 5.146e
Sorting	Sorting
poor	poor
Average inclusion frequency %	Average inclusion frequency %
20%	20%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 10-15%	Coarse fraction 40%
- quartz (eq, el; ang – rnd; FSa-CSa) 45% - metamorphic rock fragments – quartz mica schist (eq, el; s-ang – s-rnd; MSa-CSa) 43.5%	- quartz (eq, el; s-ang – rnd; FSa-MSa) 47% - grey overfired mudstone(?) (eq; el; s-rnd – rnd; MSa-CSa) 30% - metamorphic rock fragments – quartz mica schist (eq, el; ang – s-rnd; MSa) 11% - sandstone (eq; s-ang; MSa) 10%
Fine fraction 85-90%	Fine fraction 60%
- mica 65% - quartz 35%	- mica 60% - quartz 35% - feldspar 5%
Matrix (average %)	Matrix (average %)
77-79% - micaceous - homogeneous - optically active	65% - micaceous - heterogeneous(?) - optically inactive
Voids (average %)	Voids (average %)
1-3% - macro vughs	15% - mega/macro/meso channels, macro/meso vughs and vesicles
Textural features/ Comments	Textural features/ Comments
FSa-CSa clay pellets taking up 1-3% of the matrix.	Unclear if greyish green overfired mudstone inclusions are indeed vitrified mudstone or different clay material.

Fabric 6 is characterised by fine gravel-sized grog inclusions. Grog material is crushed pottery, which makes clear that it was a part of the clay recipe and added manually by the potter. In Fabric 6 grog has mostly a vitrified fabric. It is sometimes difficult to identify in some samples either under plain or cross polarised light because the grog matrix is too similar to the sample matrix and the

inclusions blend in and can be only distinguished after a closer examination in both microscope modes. CNP84 possibly has grog-in-grog inclusions implying a continuing practice of using grog as an additive to the pottery paste. The average fine fraction is dominated by mica and quartz with small amounts of calcite and feldspar.

Not all matrices of the samples in Fabric 6 seem to be homogeneous. It is possible that some of the fine grog inclusions were mistaken for clay pellets by the author since the grog inclusions sometimes blended in with the sample matrix. The optical activity varies from active to inactive implying different firing conditions. The average porosity of the matrix is 4% which seems to be a general trend among coarse fabrics from Zhujiashai.

Table 5.31. Petrographic description of the coarse fabrics identified in selected sherds from Zhujiashai (part 3).

Fabric 6
Fig. 5.146f
Sorting
mostly poor
Average inclusion frequency %
20-25%
Dominant inclusions (average %)
Coarse fraction 30%
• grog (eq, el; ang – s-rnd; MSa-FGr) 55% • quartz (eq, el; ang – s-rnd; FSa-MSa) 36%
Fine fraction 70%
• mica 48% • quartz 41.5% • calcite 7.5% • feldspar 3%
Matrix (average %)
• 73% • micaceous • CNP89, 90, 104 homogeneous; CNP84, 91, 182 heterogeneous • optical activity: CNP84, 104 active; CNP89, 90, 91 moderate; CNP182 inactive
Voids (average %)
• 4% • macro/ meso vughs and channels
Textural features/ Comments
Grog is mostly vitrified ceramic fabric; CNP84 appears to have grog-in-grog inclusions.

5.2.3.1.3 Semi-coarse fabrics

Two of the semi-coarse fabrics are sub-fabrics of the Fabrics 3A and 4A (Table 5.32, Fig. 5.147a-b).

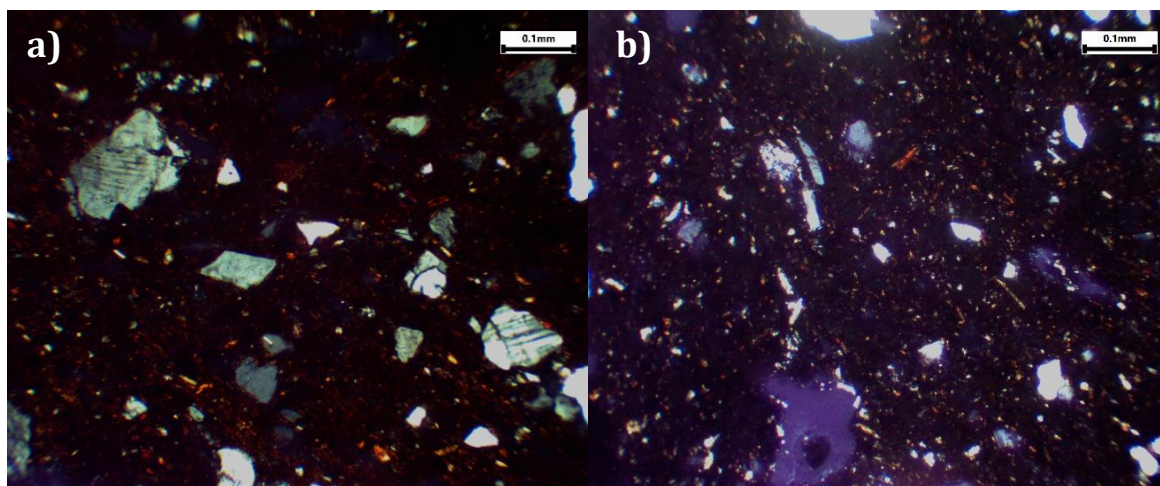


Fig. 5.147. Semi-coarse fabrics identified in selected sherds from Zhujiazhai; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 3B, CNP111 b) Fabric 4D, CNP110.

The sub-fabric 3B has medium sand-sized quartz and feldspar inclusions but the fine fraction seems very similar to Fabric 3A. It has dominant mica, less quartz and almost no feldspar. The sample matrix shows moderate optical activity and is not well homogenised. It has a high amount of clay pellets ranging from fine sand- to fine gravel size. Due to the clay pellets the fabric shows higher porosity (5-10%) than Fabric 3A.

The sub-fabric 4D has dominant coarse sand-sized quartz and feldspar and medium sand-sized granitic rock fragments. The fine fraction contains mica and quartz. No fine feldspar was identified – Fabrics 4A-C generally have a very low feldspar content. The clay matrix shows a moderate optical activity and very low porosity (3%).

Table 5.32. Petrographic description of the semi-coarse fabrics identified in selected sherds from Zhujiashai.

Fabric 3B Fig. 5.147a	Fabric 4D Fig. 5.147b
Sorting	Sorting
poor	poor
Average inclusion frequency %	Average inclusion frequency %
20%	25%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 30%	Coarse fraction 20%
- quartz (eq, el; ang – s-rnd; FSa-MSa) 70% - feldspar (eq; s-ang; FSa-MSa) 30%	- quartz (eq, el; ang – rnd; CSa) 55% - plagioclase feldspar (eq; ang – s-ang; FSa-CSa) 40% - granitic rock fragments - quartz, plagioclase, biotite (eq; s-rnd; MSa) 5%
Fine fraction 70%	Fine fraction 80%
- mica 70% - quartz 29% - feldspar <1%	- mica 60% - quartz 40%
Matrix (average %)	Matrix (average %)
70-75% - micaceous - heterogeneous - moderate optical activity	75-80% - micaceous - homogeneous - moderate optical activity
Voids (average %)	Voids (average %)
5-10% - macro/ meso vughs and channels, meso vesicles	3% - macro/ meso channels
Textural features/ Comments	Textural features/ Comments
FSa-FGr clay pellets taking up >10% of the matrix.	Channel voids are aligned parallel to the long edge of the sample.

The semi-coarse loners show a mixture of non-plastic inclusions in coarse fraction. They have different amounts of biotite/ muscovite, possibly volcanic glass, and small amounts of feldspar and metamorphic rock fragments. At least two coarse sand-sized grog inclusions containing mica-quartz-inclusions have been identified in CNP93. However, these grog inclusions did not show enough similarities in composition or texture for CNP93 to be classified as sub-fabric for Fabric 6. CNP102 has similar vitrified greenish grey inclusions as sub-fabric 5B. CNP115 is dominated by coarse siltstone and black haematite. Such diversity among non-

plastic inclusions and also their mostly sub-angular to rounded shapes indicate that either these inclusions were naturally present in the clay, or an amount of sand was added to the clay paste.

5.2.3.2 Summary

Inclusions

The average inclusion frequency in the fabrics from Zhujiashai is 20-40%, similar to the average inclusion frequency in the Majiayao material (Fig. 5.148). None of the fabrics have the inclusion frequency over 40%.

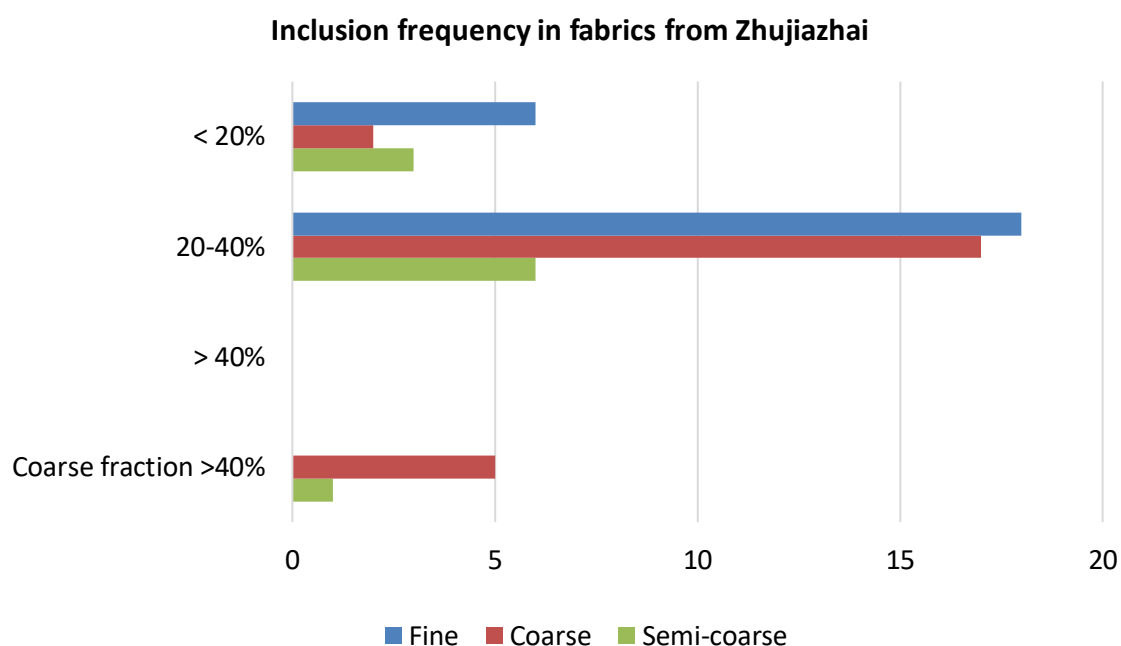


Fig. 5.148. Inclusion frequency and coarse fraction trends in fabrics identified in selected sherds from Zhujiashai; numbers represent the number of sherds.

The maximum non-plastic inclusion size is coarse sand, but the coarse sand and fine gravel sizes occur in relative equal amounts (Fig. 5.149). Similar to the data from Majiayao, the maximum fine gravel size in Zhujiashai samples is 2 – 2.5 mm; only grog and granitic rock inclusions fall into this category. Grog is added material, and its size depends on the requirements of the potter who crushed it. Based on their angularity in shape and large size, it is possible that the granitic rock

fragments were also manually added. This would be a parallel to the coarse fabric groups from Majiayao, where granitic rock inclusions have the similar size and shape and were likely used as tempering material.

The coarse sand-sized and inclusions have less angular shapes. They come from different rock and mineral types. It is likely that the coarse fraction with diverse inclusion types was either naturally present in the clay or comes from sand temper, which is a possible case with the Majiayao material as well.

Maximum inclusion size in coarse fabrics from Zhujiashai

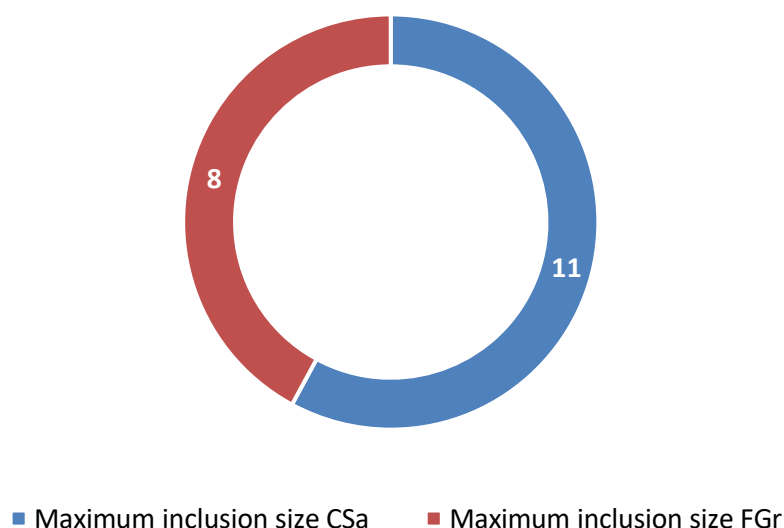


Fig. 5.149. Maximum inclusion size in coarse fabrics identified in selected sherds from Zhujiashai; numbers represent the number of sherds.

The most common coarse inclusion type beside quartz is feldspar, which is also the case in the coarse Majiayao material (Fig. 5.150). Possibly here as well feldspar was added alongside quartz because of its physical properties to act as flux. Next in line are sedimentary rock fragments, coarse mica, and granitic rock fragments that occur in less than half the amount of feldspar. Coarse mica is likely a mineral fragment from crushed granite since they mostly occur together in a fabric. Sedimentary rock fragments together with the metamorphics, less common

volcanics and calcite could be either naturally present or added by tempering with loose sand.

Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics from Zhujiashai

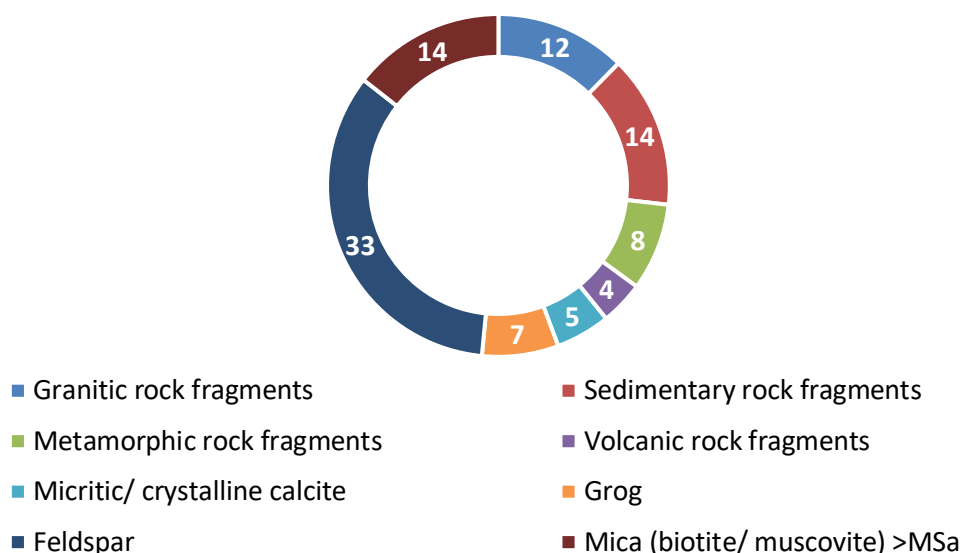


Fig. 5.150. Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics identified in the selected sherds from Zhujiashai. Numbers represent the number of sherds, but a sherd can have a combination of several inclusion types. This figure shows which inclusion types are most common. Although calcite is often present in sherds, it is unclear in some cases whether it was naturally present or is post-depositional.

Fine fraction in the fabrics from Zhujiashai shows significantly less amount of calcite than the fine fraction in the Majiayao fabrics (Fig. 5.151). The majority of sherds has fine felspar. Four samples from Zhujiashai have medium silt-sized or smaller fine inclusions, which include coarse and semi-coarse fabrics.

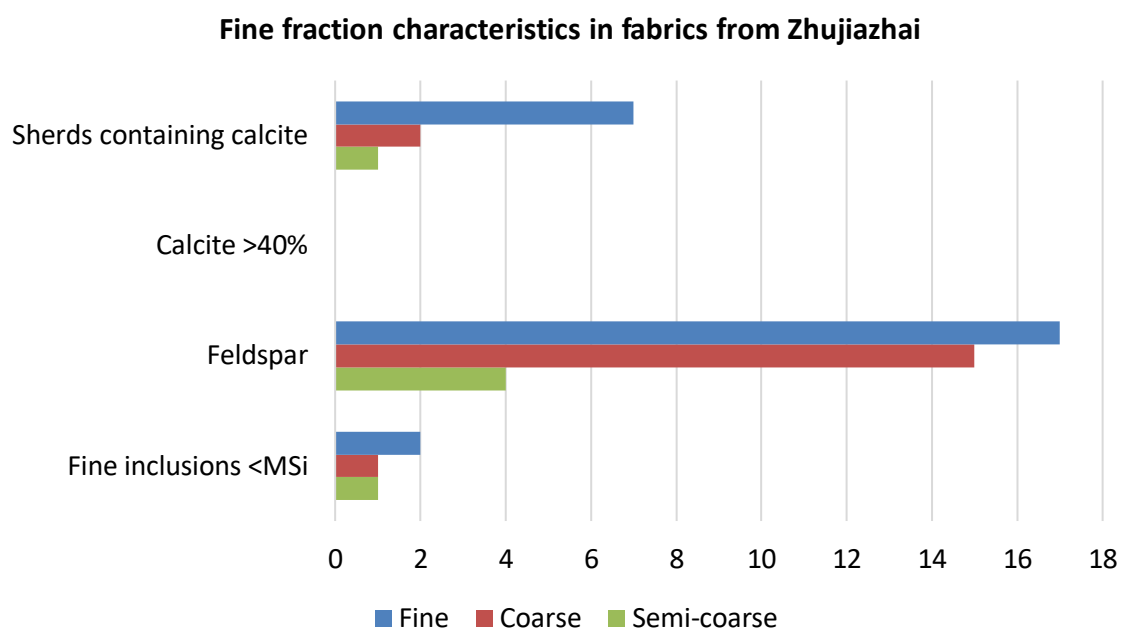


Fig. 5.151. Fine fraction characteristics in fabrics identified in selected sherds from Zhujiashai; numbers represent the number of sherds. It is unclear in some sherds whether calcite was naturally present or is a secondary accumulation.

Matrix

Most of the samples have a well-homogenised clay matrix and show little to no clay pellets (Fig. 5.152).

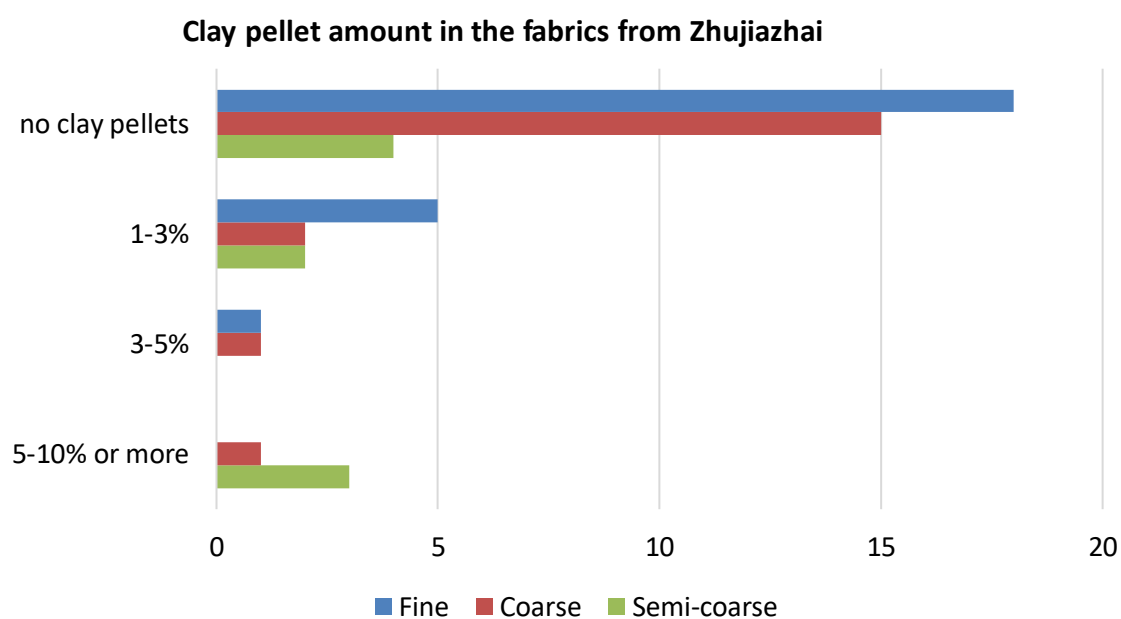


Fig. 5.152. Clay pellet amount in the fabrics identified in selected sherds from Zhujiashai; numbers represent the number of sherds.

Similar to the data from Majiayao, the optical activity of the matrix in the Zhujiazhai samples is either active or moderately active (Fig. 5.153). If the raw clay used to produce Zhujiazhai material is chemically similar to the raw clay used at Majiayao, it can be suggested that the Zhujiazhai sherds were fired under similar firing conditions. The optically active fabrics were probably fired at <900° C and the moderately active fabrics at about 900-1050° C.

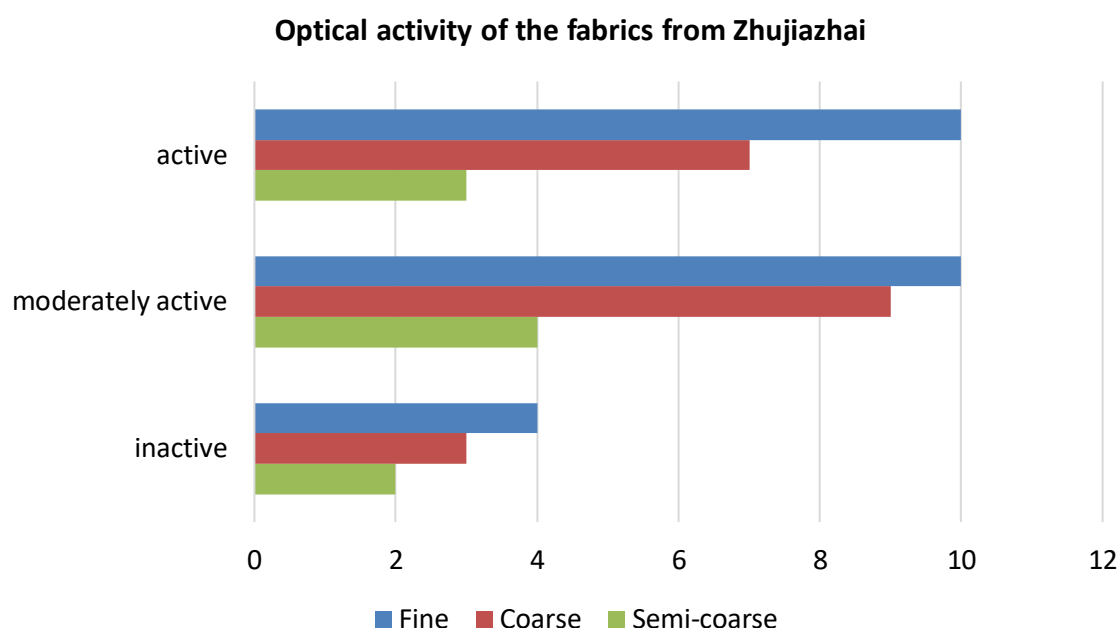


Fig. 5.153. Optical activity of the fabrics identified in selected sherds from Zhujiazhai; numbers represent the number of sherds.

Porosity

The fabrics show on an average a low to medium porosity (Fig. 5.154). More coarse fabrics show a very low porosity than fine fabrics, which is unusual among the coarse samples from all sites and considering their texture. Potentially there was some kind of shrinkage control based on the potter's knowledge of clay properties and firing. The same technique might have been also involved in the production of coarse-fine-combination vessels.

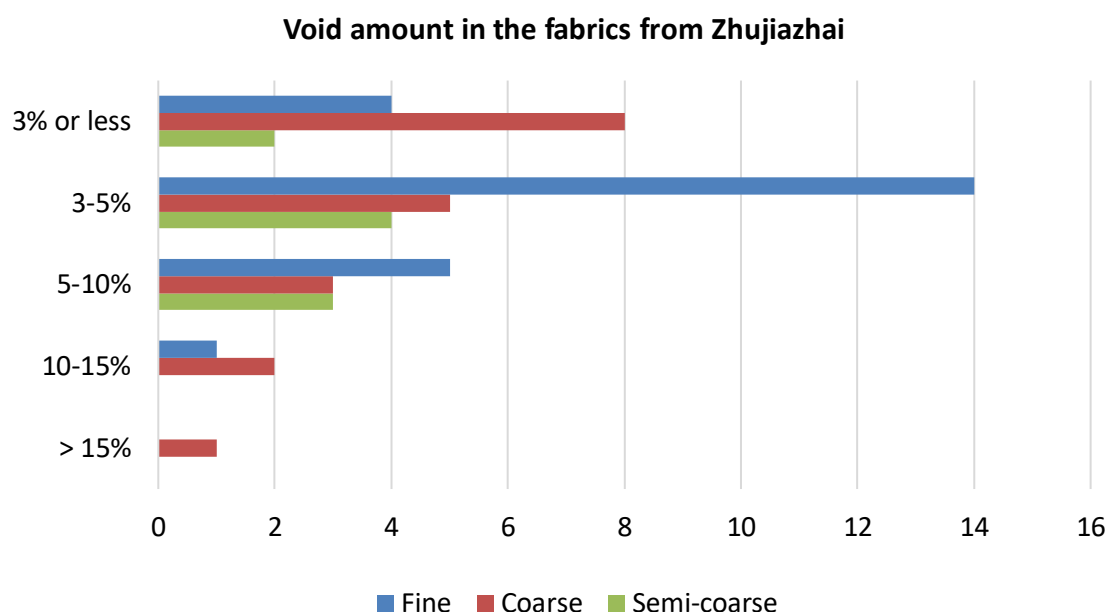


Fig. 5.154. Void amount in the fabrics identified in selected sherds from Zhujiashai; numbers represent the number of sherds.

5.2.4 Luohantang

5.2.4.1 Fabric groups

Nine main fabric groups were identified in the samples from Luohantang (Table 5.33). The coarse fabrics have a greater fabric variety than the coarse fabrics from Majiayao and Zhujiashai (Fig. 5.155).

Table 5.33. List of fabrics identified in the sherd samples from Luohantang.

Fabrics	Number of sherds
Fine fabrics	
1A Fine, Mica-Quartz-Feldspar <i>CNP128, 132, 133, 134, 135, 141, 147, 148, 151, 152, 153, 154, 168</i>	13/55
1B Fine, Mica-Quartz, inclusions MSi-sized and smaller <i>CNP131, 139, 140, 144, 146, 149, 150, 180</i>	8/55
1C Fine, Quartz-Mica, higher coarse fraction and less fine mica than Fabric groups 1A and 1B <i>CNP129, 136</i>	2/55
2B Fine, Mica-Quartz-Feldspar with clay pellets, possibly the same groundmass as in Fabric group 2A <i>CNP173</i>	1/55
Coarse fabrics	
2A Coarse, Quartz-Feldspar-Biotite and Granodiorite fragments with large clay pellets	16/55

<i>CNP130, 138, 142, 159, 160, 161, 162, 163, 164, 165, 166, 167, 169, 170, 172, 179</i>		
3 Coarse Feldspar-Quartz-Granodiorite and Sedimentary rock fragments with large clay pellets <i>CNP137, 156, 158, 175, 177</i>	5/55	
4 Coarse Quartz-Feldspar and Granodiorite fragments with fine fraction MSi-sized and smaller <i>CNP171, 174</i>	2/55	
5 Coarse Quartz-Feldspar vitrified fabric <i>CNP157, 176</i>	2/55	
6A Coarse Quartz and Quartz Mica Schist and Sedimentary rock fragments <i>CNP178</i>	1/55	
Semi-coarse fabrics	none	
Coarse-Fine-combination fabrics		
6B Coarse-Fine-combination: Coarse Quartz and Quartz Mica Schist and Sedimentary rock fragments <i>CNP143</i>	1/55	
7 Coarse-Fine combination: Coarse Granodiorite and Quartz fragments <i>CNP145</i>	1/55	
8 Coarse-Fine combination: Coarse Quartz-Feldspar and Granodiorite fragments <i>CNP181</i>	1/55	
9 Coarse-Fine combination: Coarse Quartz-Feldspar, Granodiorite and Sedimentary rock fragments <i>CNP155, 187</i>	2/55	

Main fabric groups overview: Luohantang site

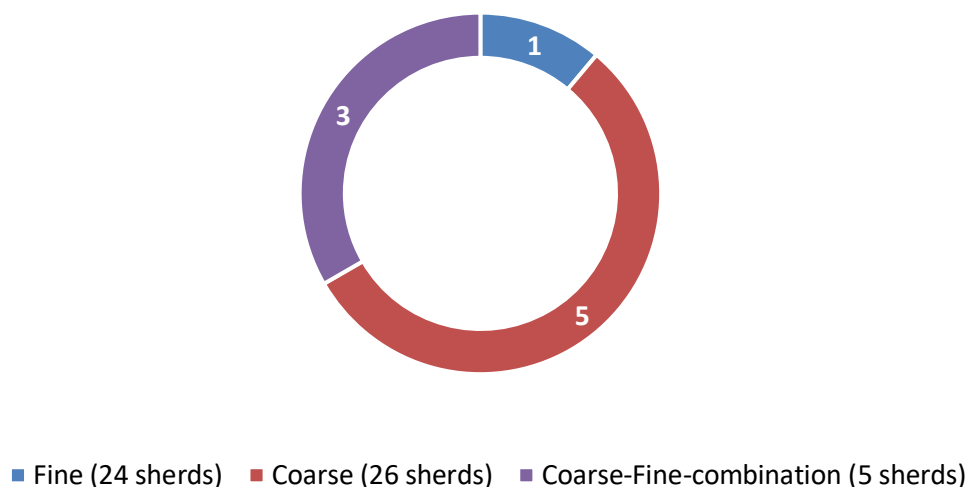


Fig. 5.155. Main fabric groups overview: Luohantang site; numbers represent the number of identified groups.

5.2.4.1.1 Fine fabrics

The fine fabrics all show fine mica, quartz, feldspar inclusions in different frequency and size (Table 5.34, Fig. 5.156a-d). The petrographic differences are minimal; therefore, the sample fabrics, except for CNP173, have been grouped as sub-fabrics of a single fabric and not as separate groups. The excluded CNP173 is possibly a sub-fabric to the coarse fabric 2A.

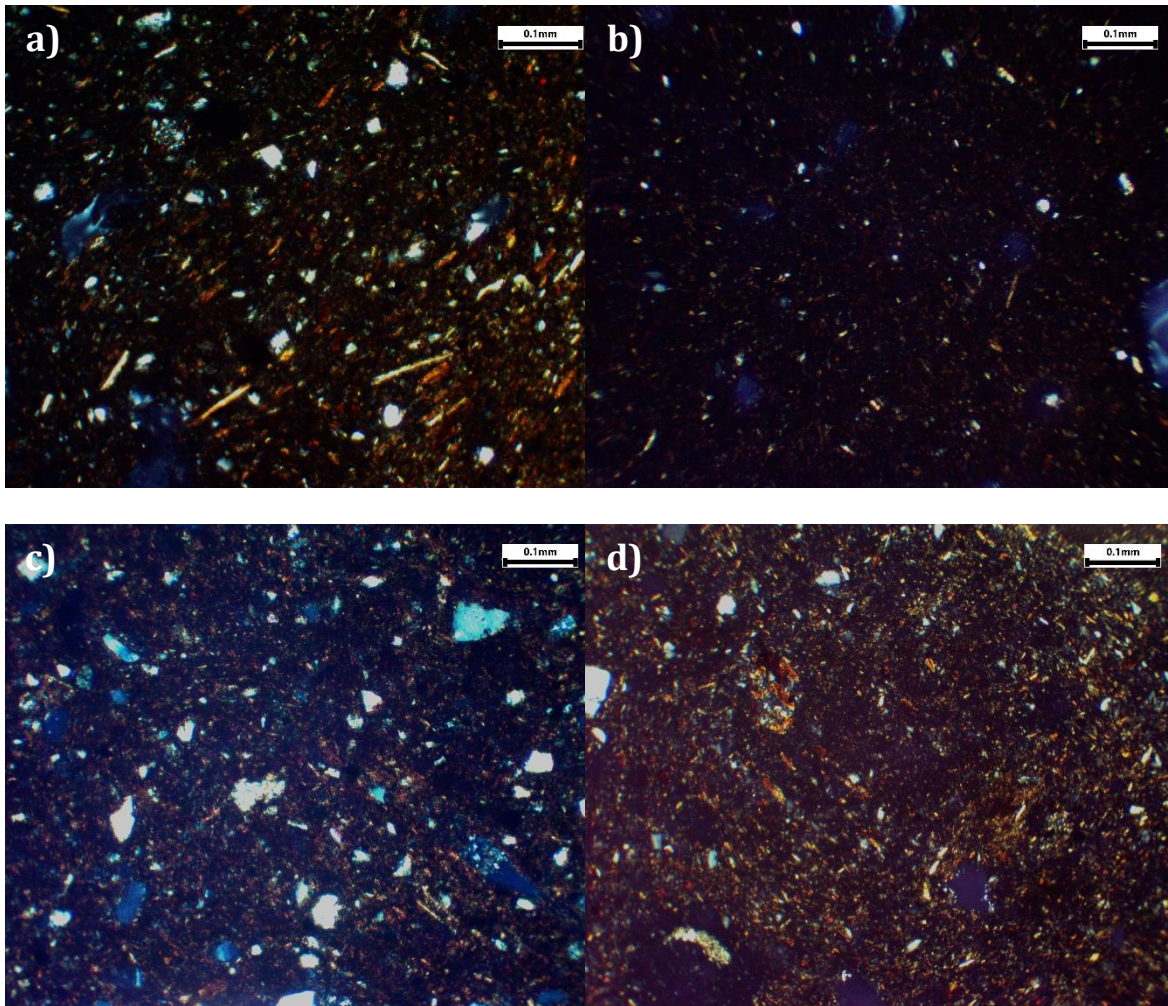


Fig. 5.156. Fine fabrics identified in selected sherds from Luohantang; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 1A, CNP151 b) Fabric 1B, CNP140 c) Fabric 1C, CNP136 d) Fabric 2B, CNP173.

Fabric 1A has equal amount of mica and quartz and a low amount of feldspar. The sample matrices are mostly optically active and show a low porosity (3%). The sub-fabric 1B has medium silt-sized or smaller mica and quartz inclusions. It could

be considered a separate group because of the significant difference in the inclusion size and lack of feldspar. However, feldspar might have been present, but the inclusions of this size are difficult to distinguish. The clay matrices of 1B are mostly optically active and have on average low porosity (5%). Similar fabrics to 1B have been identified in smaller amount at Majiayao and Zhujiashai. It is possible that the clay of this type of fabrics was levigated and it is also possible that it was not, since there are natural clays in the study area which have the same fine inclusion size (section 6.2.1).

Table 5.34. Petrographic description of fine fabric groups identified in selected sherds from Luohantang.

Fabric 1A Fig. 5.156a	Fabric 1B Fig. 5.156b	Fabric 1C Fig. 5.156c	Fabric 2B Fig. 5.156d
Sorting	Sorting	Sorting	Sorting
well	well	CNP129 moderate, CNP136 well	moderate
Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %	Average inclusion frequency %
20%	10%	20%	10%
Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)	Dominant inclusions (average %)
• mica 50% • quartz 45% • feldspar 5%	• mica 64% • quartz 34%	• quartz 50% • mica 47% • feldspar 3%	• mica 55% • quartz 40% • feldspar 5%
Matrix (average %)	Matrix (average %)	Matrix (average %)	Matrix (average %)
• 70-77% • micaceous • mostly homogeneous • mostly optically active	• 85% • micaceous • mostly homogeneous • mostly optically active	• 70% • micaceous • homogeneous • mostly optically active	• 85% • micaceous • heterogeneous • optically active
Voids (average %)	Voids (average %)	Voids (average %)	Voids (average %)
• 3% • macro/meso, vughs, vesicles, channels	• 5% • macro/ meso vughs, vesicles	• 5-10% • macro/ meso vughs and vesicles	• 5% • few mega vughs, macro/ meso vughs and vesicles
Textural features/ Comments	Textural features/ Comments	Textural features/ Comments	Textural features/ Comments
none	mineral inclusions MSi-sized and smaller	none	MSa-FGr clay pellets taken up >10% of the matrix

The sub-fabric 1C has approximately the same amounts of quartz and mica as Fabric 1A. It has a small amount of coarse fraction (3% average) which consists of quartz and feldspar.⁴⁶ The clay matrices of the sub-fabric 1C are mostly optically active and show medium porosity (5-10%).

⁴⁶ See Catalogue 1.

Fabric 2B/CNP173 has similar amounts of mica and quartz, although mica appears to be dominant, and a small amount of feldspar. The clay matrix is optically active and heterogeneous. It has a high amount of medium sand-/ fine gravel-sized clay pellets. The optical activity and large clay pellets classify 2B as possible sub-fabric of the coarse Fabric 2A which has the similar textural features.

Fabric 2B has one coarse carbonate inclusion which is surrounded by a vitrified matrix. This inclusion is a result of lime spalling, which is also visible macroscopically on the sherd surface. However, no further calcite inclusions were detected under the petrographic microscope. The calcareous nature of the fabric is reflected in the pale pinkish colour of the pottery fragment.

As explained above, lime spalling occurs when clay with a high calcite content is fired at least 750°-850° C. It is safe to assume that 2B was exposed to such heat. Fabric 2B also has an optically active matrix which implies that the clay type fired around 800° C is still optically active. Similar temperatures have been suggested for the optically active fabrics from Majiayao and Zhujiazhai.

5.2.4.1.2 Coarse fabrics

Five main coarse fabric groups were identified in the material from Luohantang (Tables 5.35-37, Fig. 5.157a-e). Similar to the coarse fabrics from Majiayao and Zhujiazhai, granitic and sedimentary rock inclusions are the most common in these groups.

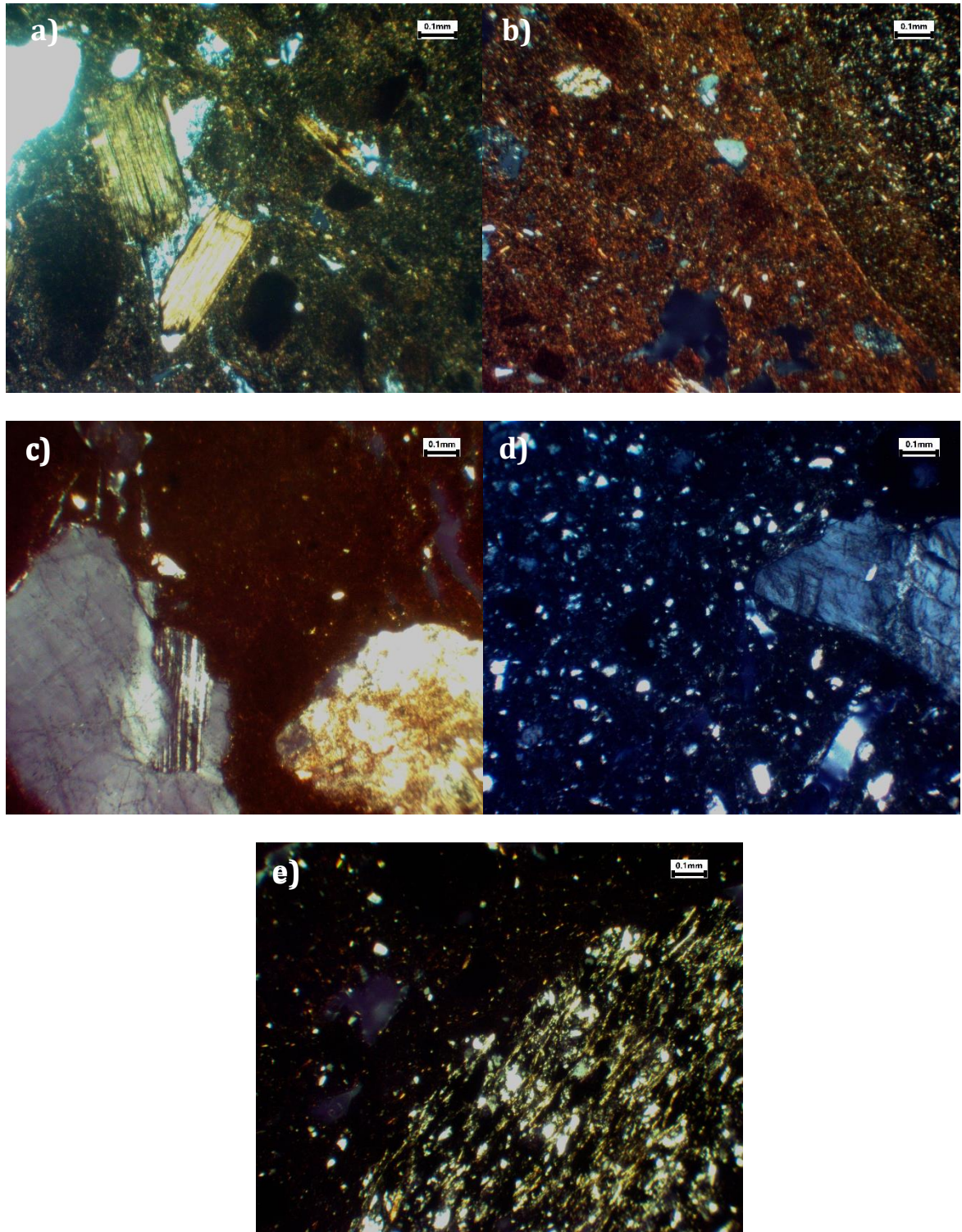


Fig. 5.157. Coarse fabrics identified in selected sherds from Luohantang; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 2A, CNP164 b) Fabric 3, CNP177 c) Fabric 4, CNP171 d) Fabric 5, CNP 157 e) Fabric 6A, CNP178.

Fabric 2A is characterised by coarse feldspar, quartz, fine gravel-sized granitic rock fragments, and a high amount of large clay pellets. The angularity and size of the granitic rock inclusions indicates that it was crushed and manually added by the

potter, like in the fabrics in Majiayao and Zhujiashai. The clay pellets are of different sizes (FSa-FGr) and are distributed all over the sample area. Sixteen samples have been grouped into the Fabric 2A, which could mean that they were either made from a similar montmorillonite/ smectite base clay that needed longer to hydrate (Rye 1981:36), or they were made using the same making techniques in wedging and hydration. The latter implies that there might be a potter or potters who had a routine that included the same time and energy amount for wedging and hydrating the clays. The clay pellets could have also resulted from a combination of both possibilities.

Fine fraction seems to be dominated by quartz; however, the clay pellets prevent an even distribution of the fine fraction. The fine fraction further consists of mica and a small amount of feldspar. The clay matrices of 2A are mostly optically active and show on average medium porosity (5%).

Table 5.35. Petrographic description of the coarse fabrics identified in selected sherds from Luohantang (part 1).

Fabric 2A Fig. 5.157a	Fabric 3 Fig. 5.157b
Sorting	Sorting
poor	poor
Average inclusion frequency %	Average inclusion frequency %
15-20%	25%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 25%	Coarse fraction 30%
• plagioclase/ microcline feldspar (eq, el; ang – s-rnd; FSa-CSa) 34% • quartz (eq, el; ang-s-ang; MSa-CSa) 29% • granitic rock fragments – combination of quartz, plagioclase/ microcline feldspar, biotite and muscovite (eq, el; ang – s-ang; MSa-FGr) 22% • biotite (lamellae; FSa-CSa) 14%	• plagioclase/ microcline feldspar (eq; ang – s-rnd; CSa-FGr) 30% • quartz (eq, el; ang – s-rnd; FSa-FGr) 30% • granitic rock fragments – combination of quartz, plagioclase/ microcline feldspar, biotite or muscovite (eq; ang – s-rnd; CSa-FGr) 21% • sedimentary rock fragments – sandstone and siltstone (euhd, eq; s-ang – rnd; CSa-FGr) 12%
Fine fraction 75%	Fine fraction 70%

• quartz 60% • mica 34% • feldspar 6%	• mica 47% • quartz 44% • feldspar 8%
Matrix (average %)	Matrix (average %)
• 80% • micaceous • heterogeneous • mostly optically active	• 70% • micaceous • mostly heterogeneous • optically active
Voids (average %)	Voids (average %)
• 5% • macro/ meso vughs, vesicles, channels	• 5% • mega/macro channels, vughs, meso vesicles
Textural features/ Comments	Textural features/ Comments
Each sample has FSa-FGr clay pellets taking up >10% of the matrix.	Each sample (except CNP156) has FSa-FGr clay pellets taking up >10% of the matrix. CNP156 is possibly a coarse fragment of a Coarse-Fine-combination fabric.

Fabric 3 is very similar to Fabric 2A but has coarse sand-/ fine gravel-sized sedimentary rock fragments. The coarse fraction of Fabric 3 has quartz and feldspar also in fine gravel size, which Fabric 2A does not. The clay pellet amount, size and distribution are similar to 2A, and the same suggestions why the fabric has this texture apply here, too. Only CNP156 from Fabric 3 does not contain clay pellets. This sherd is interesting because it might come from the middle part of a coarse-fine-combination vessel. It cannot be determined for certain as no clear division between fabrics parts could be seen in thin section. The sherd has painted decoration, which is a rare pairing for coarse fabric as the macroscopic analysis has shown. A small part on the sherd sample indicates that it might had impressed cord decoration (Fig. 5.158). There appears to be a visible change in surface treatment between the two parts. CNP156 was not classified as coarse-fine-combination fabric because the fine part could not be distinguished from the coarse part, which might also indicate that both parts were made from the same base clay.



Fig. 5.158. CNP156, likely a middle part from a coarse-fine-combination fabric; the arrow indicates possible impressed decoration. The area above the arrow also shows a smoother surface texture; sherd length ca 3 cm.

The clay matrices in Fabric 3 are mostly optically active and show similar medium degree of porosity as 2A (5%). Although 3 and 2A have many similarities, Fabric 3 seems to have a mixed temper. While it is likely that the fine gravel-sized granitic rock inclusions were manually added from crushed rock to Fabric 3, it might not be the case for the coarse sedimentary rock inclusions. When looking at the horizontal section of CNP156 (Fig. 5.159), it becomes clear that some of the coarse inclusions have rounded shapes and rather look like particles from loose sand than crushed from a rock.



Fig. 5.159. CNP156, horizontal section showing angular and rounded FGr non-plastic inclusions; length ca 7 cm, max. wall thickness 7 mm.

It could be that two different tempering options were used for Fabrics 2A and 3, Fabric 3 having a mix of granite and sand, and Fabric 2A granitic rock only. It could

be as well that sedimentary rock fragments were in 2A but were not “caught” in the cut sample. Greater sample size of coarse samples from Luohantang could help address this issue of two different temper types in a very similar groundmass.

Fabric 4 has coarse quartz, feldspar and granitic rock inclusions. The granitic inclusions in this fabric do not contain biotite or muscovite as a component like in Fabrics 2A and 3. However, the crucial difference between Fabrics 4 and 2A or 3 is the groundmass. The fine fraction consists of medium silt-sized or smaller inclusions, dominated by quartz, with low amount of feldspar and almost no mica. The clay matrix is mostly homogeneous, clay pellets are not as prominent as in 2A or 3. The matrix is mostly optically active and highly porous (15%). The porosity might be due to the very fine clay which could naturally have a very high shrinkage rate and result in drying cracks around the added rock temper (Müller et al. 2007:146).

Table 5.36. Petrographic description of the coarse fabrics identified in selected sherds from Luohantang (part 2).

Fabric 4 Fig. 5.157c	Fabric 5 Fig. 5.157d
Sorting	Sorting
poor	poor
Average inclusion frequency %	Average inclusion frequency %
15%	20%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse fraction 35%	Coarse fraction 20%
- quartz (eq; s-ang; CSa-FGr) 48% - ortho-(?)/ plagioclase feldspar (eq, el; ang – s-rnd; FSa-CSa) 38% - granitic rock fragments – combination of quartz and plagioclase feldspar (eq, el; ang – s-rnd; FSa-CSa) 10%	- quartz (eq, el; ang – s-rnd; FSa-CSa) 65% - plagioclase feldspar (euhd, eq; s-ang – s-rnd; FSa-CSa) 35%
Fine fraction 65%	Fine fraction 80%
- quartz 92.5% - feldspar 7% - mica 0.025%	- quartz 99.5% - feldspar 0.5%?

Matrix (average %)	Matrix (average %)
• 70% • non-micaceous • mostly homogeneous • mostly optically active	• 55-60% • non-micaceous? • heterogeneous • inactive
Voids (average %)	Voids (average %)
• 15% • mega channels and vughs	• 20% • meso vesicles
Textural features/ Comments	Textural features/ Comments
This fabric is highly porous with fine fraction of MSi-size and smaller.	Matrix is partially bloated; quartz is the only identifiable component in fine fraction.

The matrices of samples in Fabric Group 5 are vitrified and partially bloated. The only identifiable coarse and fine inclusions are quartz and feldspar. Due to bloating and discolouration the matrices appear heterogeneous and are highly porous (20%). Fabric 5 consists of two samples CNP157 and CNP176, both were discussed in the macroscopic analysis section (Fig. 5.80) as they have green coloured bodies. These samples might have a chemically similar clay that turned green after being exposed to a very high temperature.

Fabric 6A/CNP178 forms a group with 6B/CNP143 which is a coarse-fine-combination fabric and will be discussed separately below. Fabric 6A is characterised by coarse quartz, metamorphic schist fragments, feldspar, biotite and sedimentary rock fragments. The inclusion size ranges mostly from fine to coarse sand, only one or two grains are longer than 2 mm. The majority of the grains are sub-angular or sub-rounded, and they do not seem to be fragments of crushed rock. Fabrics 6A/6B and 2A/3/4 could present a similar case of granite temper vs mixed sand temper that was suggested for the different coarse fabrics from Majiayao and Zhujiazhai. The ground mass of 6A does not differ from 2A or 3. The fine fraction contains equal amounts of quartz, mica and a small amount of feldspar. The clay matrix has a high amount of large clay pellets dispersed over the

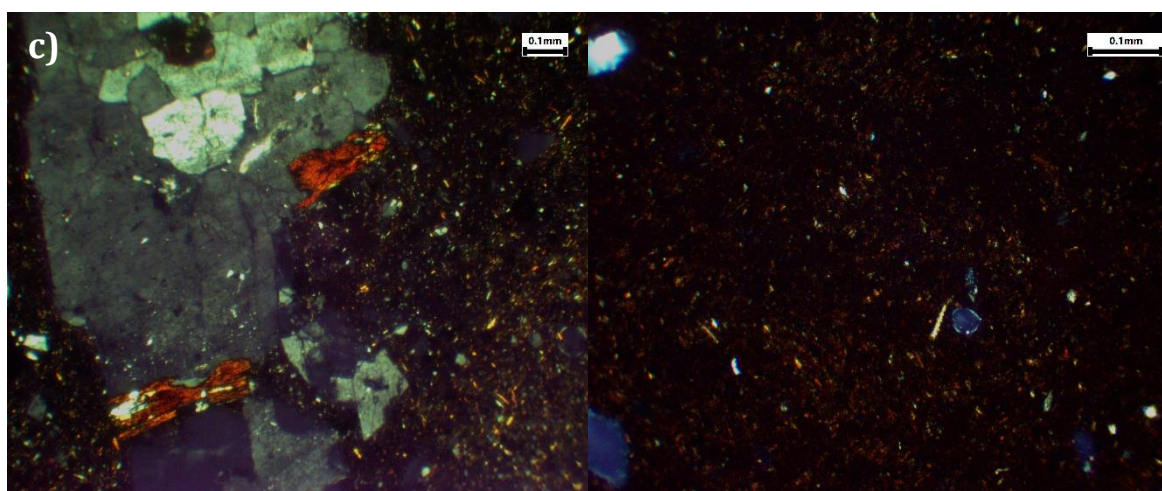
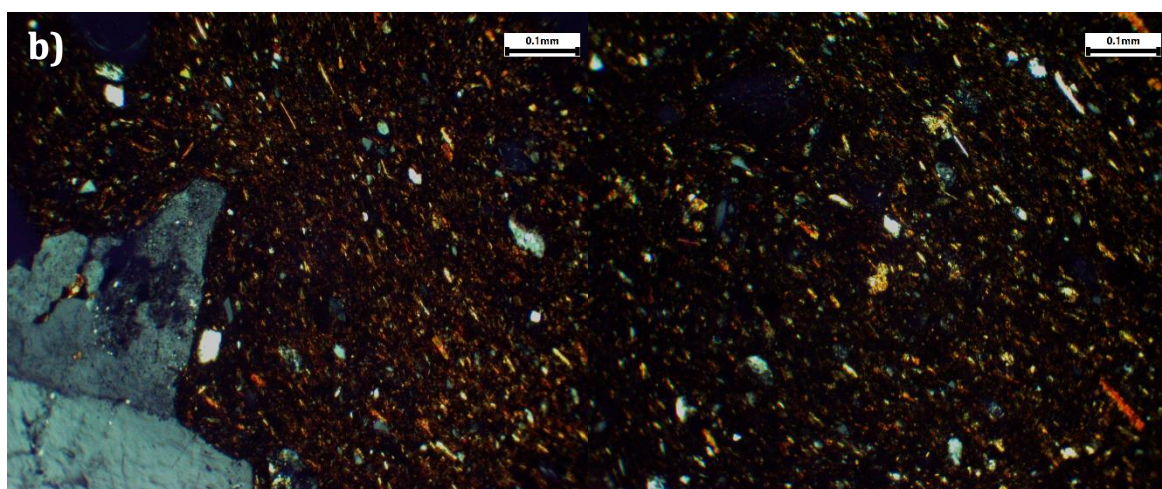
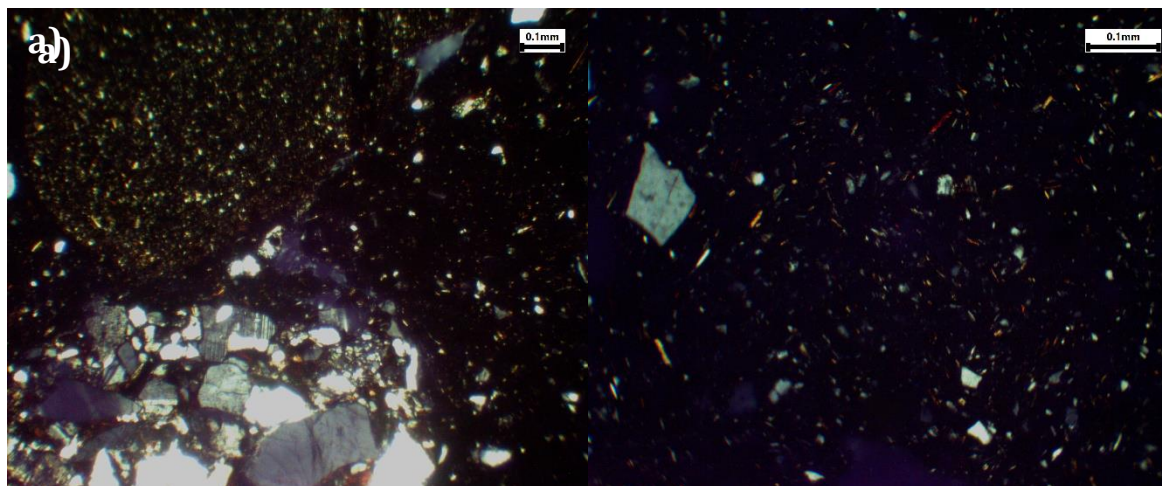
sample area. The matrix shows a moderate optical activity and medium porosity (5-10%).

Table 5.37. Petrographic description of the coarse fabrics identified in selected sherds from Luohantang (part 3).

Fabric 6A
Fig. 5.157e
Sorting
poor
Average inclusion frequency %
30%
Dominant inclusions (average %)
Coarse fraction 20%
• quartz (eq; ang – s-rnd, FSa-CSa) 50% • quartz-mica schist (eq, el; s-rnd; CSa-FGr) 25% • plagioclase feldspar (eq; s-ang; FSa-CSa) 15% • biotite (lamellae; FSa-MSa) 5% • siltstone (eq; s-rnd; CSa) 5%
Fine fraction 80%
• quartz 50% • mica 45% • feldspar 5%
Matrix (average %)
• 75-80% • micaceous • heterogeneous • moderate optical activity
Voids (average %)
• 5-10% • macro vughs, meso vughs and vesicles
Textural features/ Comments
MSa-CSa clay pellets taking up >10% of the matrix

5.2.4.1.3 Coarse-fine-combination fabrics

Three main coarse-fine-combination fabrics and one sub-fabric of the coarse Fabric 6A were identified among the samples from Luohantang (Tables 5.38-39, Fig. 5.160a-d). The coarse parts of the main coarse-fine-combination fabrics mostly reflect the composition of the main coarse fabrics but still show slight differences to be classified as sub-fabrics.



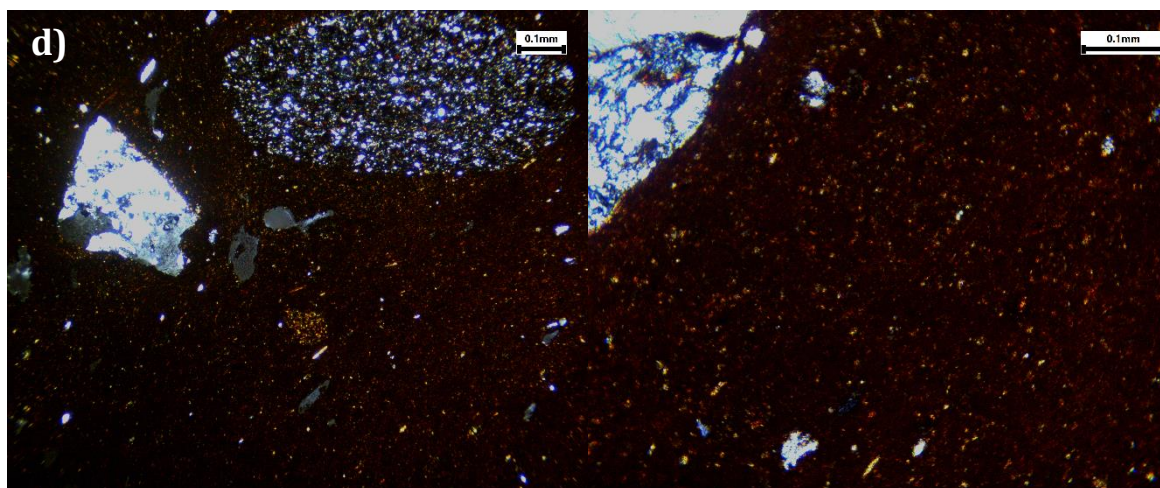


Fig. 5.160. Coarse-Fine-combination fabrics identified in selected sherds from Luohantang; photomicrographs taken under XPL, scale size 0.1 mm; left – coarse part, right – fine part a) Fabric 6B, CNP143 b) Fabric 7, CNP145 c) Fabric 8, CNP181 d) Fabric 9, CNP155.

The coarse part of Fabric 6B is the sub-fabric of the coarse Fabric 6A. It has a similar coarse fraction composition with quartz, sedimentary rock fragments and metamorphic schist. The fine fraction has equal amounts of mica and quartz. Fine feldspar amount was difficult to estimate petrographically because it was difficult to tell it apart from quartz in the fine fraction of this sample. Both coarse and fine part have the same groundmass. The clay matrix is homogeneous and optically inactive. The average porosity for both parts is medium (5-10%). It seems likely that the original clay for this fabric was initially fine like in the fine part and was tempered for the coarse part. If the base clay were coarse like in the coarse part, then it would probably have a higher coarse fraction and overall inclusion frequency. Further, it would show a better sorting as natural sediment. The fine fraction of both parts is the same, which indicates that coarse grains were likely an extra addition. However, it cannot be ruled out that the base clay was purified in some way first, and then the sand temper was added to it.

The coarse part of Fabric 7 contains mostly fine gravel-sized granitic rock fragments and medium sand-sized quartz. It falls into the category of the granite

tempered fabrics but does not show any similarities in the groundmass to the other granite containing fabrics. The fine fraction consists of equal amounts of quartz and mica, and a small amount of feldspar. The clay matrix is homogeneous without clay pellets. It is optically active and has a very low porosity (3%), also in the coarse part. The coarse and fine parts have the same groundmass.

Fabric 7 looks rather similar to coarse-fine-combination Fabric 4D or 4E from Majiayao and coarse granite containing low porous fabrics from Zhujiashai (e. g. 4A) than to the Fabrics 2A, 3 or 4 from Luohantang.

Table 5.38. Petrographic description of coarse-fine-combination fabrics identified in selected sherds from Luohantang (part 1).

Fabric 6B Fig. 5.160a	Fabric 7 Fig. 5.160b
Sorting	Sorting
coarse part: poor; fine part: well	coarse part: poor; fine part: well
Average inclusion frequency %	Average inclusion frequency %
25-30%	30-35%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse part	Coarse part
Coarse fraction 10% - quartz (eq, el; ang – s-rnd; FSa-FGr) 55% - sedimentary rock fragments (eq, el; s-ang – rnd; CSa-FGr) 30% - quartz-mica schist (eq, el; s-rnd; CSa) 15% Fine fraction 90% - mica 50% - quartz 49.9% - feldspar 0.1%?	Coarse fraction 5-10% - granitic rock fragments – combination of quartz, plagioclase feldspar, biotite (eq, el; s-ang; CSa-FGr) 70% - quartz (eq, el; s-ang – rnd; FSa-MSa) 30% Fine fraction 90-95% - quartz 45% - mica 45% - feldspar 10%
Fine part	Fine part
- mica 50% - quartz 49.9% - feldspar 0.1%?	- quartz 45% - mica 45% - feldspar 10%
Matrix (average %)	Matrix (average %)
60-65% - micaceous - homogeneous - optically inactive	62-67% - micaceous - homogeneous - optically active
Voids (average %)	Voids (average %)

• 5-10% • macro/ meso vughs	• 3% • macro/ meso vughs
Textural features/ Comments	Textural features/ Comments
The coarse and the fine parts have the same groundmass.	The coarse and the fine parts have the same groundmass.

The coarse-fine-combination Fabric 8 has a different groundmass in the coarse and fine parts. Fabric 8 is the sample CNP181 which was discussed in detail in the macroscopic analysis section. The coarse fraction of the coarse part contains mostly quartz, granitic rock fragments, feldspar and black opaque inclusions containing fine quartz. The fine fraction has equal amount of quartz and mica; no feldspar was identified. The fine part has approximately equal amount of quartz and mica as well, but the inclusions are all medium silt-sized or smaller. Both parts show a homogeneous without clay pellets. The matrix in the coarse part has a moderate optical activity; the matrix in the fine part is optically active. The coarse part shows a lower porosity (5%) than the fine part (5-10%). This difference is not great, and this could be due to the thin section manufacturing process or the area of the sherd where the sample was cut.

Table 5.39. Petrographic description of coarse-fine-combination fabrics identified in selected sherds from Luohantang (part 2).

Fabric 8 Fig. 5.160c	Fabric 9 Fig. 5.160d
Sorting	Sorting
coarse part: poor; fine part: well	coarse part: poor; fine part: well
Average inclusion frequency %	Average inclusion frequency %
coarse part 30%; fine part 10%	15%
Dominant inclusions (average %)	Dominant inclusions (average %)
Coarse part	Coarse part
Coarse fraction 5-10% • quartz (eq; rnd; FSa-FGr) 30% • granitic rock fragments – combination of quartz, plagioclase feldspar, biotite (eq; MSa-CSa 20% • haematite? with quartz inclusions (eq,	Coarse fraction 35% • plagioclase feldspar (eq; s-rnd – rnd; FSa-CSa) 30% • quartz (eq; s-rnd; CSa- FGr) 27.5% • sedimentary rock fragments (eq, el; s-rnd; CSa-FGr) 27%

- el; rnd; MSa) 20% • plagioclase feldspar (eq; s-ang; CSa) 20% • biotite (lamellae; FSa) 10% Fine fraction 90-95% • mica 50% • quartz 50%	• granitic rock fragments – combination quartz and plagioclase feldspar with/ without biotite (eq; ang – s-ang; CSa) 5.5% Fine fraction 65% • mica 55% • quartz 45%
Fine part	Fine part
• mica 55% • quartz 45%	• mica 55% • quartz 45%
Matrix (average %)	Matrix (average %)
• coarse part: 70%; fine part 80% both parts: • micaceous • homogeneous • coarse part: moderate optical activity • fine part: optically active	• 75-80% • micaceous • homogeneous • moderate optical activity
Voids (average %)	Voids (average %)
• coarse part 5%, fine part 5-10% • macro/ meso vughs, vesicles, channels	• 5-10% • macro/ meso vughs and channels
Textural features/ Comments	Textural features/ Comments
Coarse and fine fabrics have a different groundmass – the groundmass of the coarse fabric has a higher amount of fine fraction; the groundmass of the fine fabric is similar to fabric 1B – mineral inclusions are MSi-sized and smaller.	Both fabrics have the same groundmass; fine fraction is MSi-sized and smaller. These sherds probably belong to the same vessel.

The coarse part of Fabric 9 consists of coarse feldspar, quartz, sedimentary and granitic rock fragments. Both fine and coarse parts have the same groundmass. The fine fraction contains approximately equal amounts of mica and quartz which are medium silt-sized and smaller. The clay matrix is homogeneous and has no clay pellets. It shows moderate optical activity and medium porosity (5-10%).

Fabric 8 looks like a mix of two fabrics that were discussed above. The fine part corresponds to the fine fabric 1B with MSi or smaller mineral inclusions. The coarse inclusions of Fabric 8 are similar to the coarse fraction of Fabric 3 which could be crushed granite mixed with loose sand. The two samples in this fabric

group, CNP155 and CNP187, are possibly two fragments of the same vessel, as their macroscopic and microscopic features indicate.

5.2.4.2 Summary

Inclusions

The average inclusion frequency in the fabrics from Luohantang is 20-40% (Fig. 5.161). This largely corresponds to the data from Majiayao and Zhujiashan. There are more samples in the Luohantang material having less than 20% inclusion frequency including from fine, coarse and coarse-fine-combination groups. Most coarse fabrics fall into this category, possibly due to their low or <MSi fine fractions.

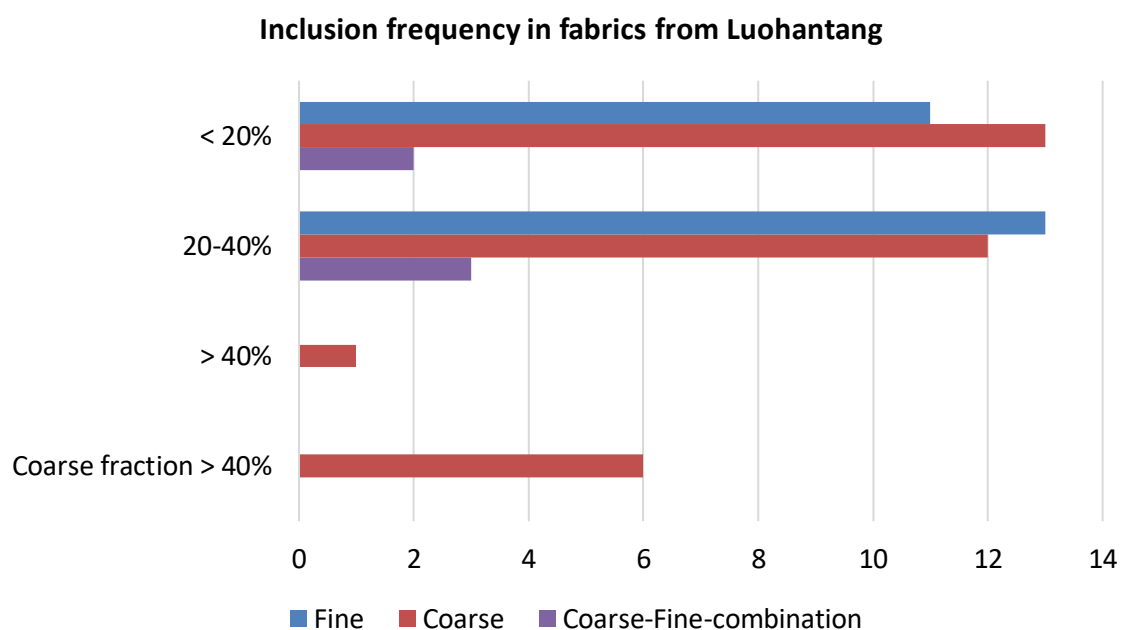


Fig. 5.161. Inclusion frequency and coarse fraction trends in fabrics identified in selected sheds from Luohantang; numbers represent the number of sherds.

The maximum inclusion size in fabric coarse fractions is by far the fine gravel size (Fig. 5.162). It has been discussed previously that fine gravel size might indicate manually added temper – crushed rock or loose river sand. It appears that the clays at Luohantang are naturally fine or very fine the medium silt-sized mineral

inclusions in some samples indicate. It seems plausible to suggest that most clay pastes of the sampled coarse fabrics from Luohantang were tempered according to a recipe.

Maximum inclusion size in coarse and coarse-fine-combination sherds from Luohantang

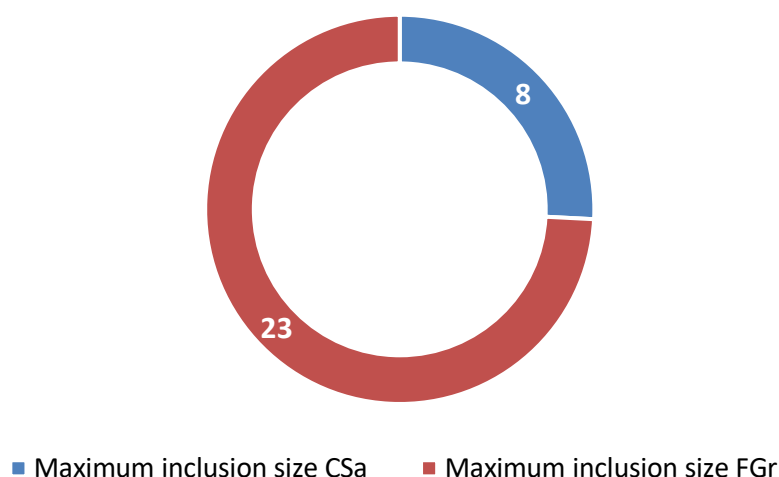


Fig. 5.162. Maximum inclusion size in coarse and coarse-fine-combination fabrics identified in selected sherds from Luohantang; numbers represent the number of sherds.

The most frequent non-plastic inclusion type in the fabrics from Luohantang is feldspar (Fig. 5.163), which was also the case for Majiayao and Zhujiashai material. Here as well, feldspar and quartz could have been used as tempering material due to its physical properties as flux. The second most frequent inclusion is granitic rock which is a source of coarse feldspar and mica – which is the third most frequent inclusion type. The sedimentary and metamorphic rock fragments do not appear as frequent which might indicate a preference for granitic rock temper, but this assumption is limited by the sample size in this study.

Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics from Luohantang

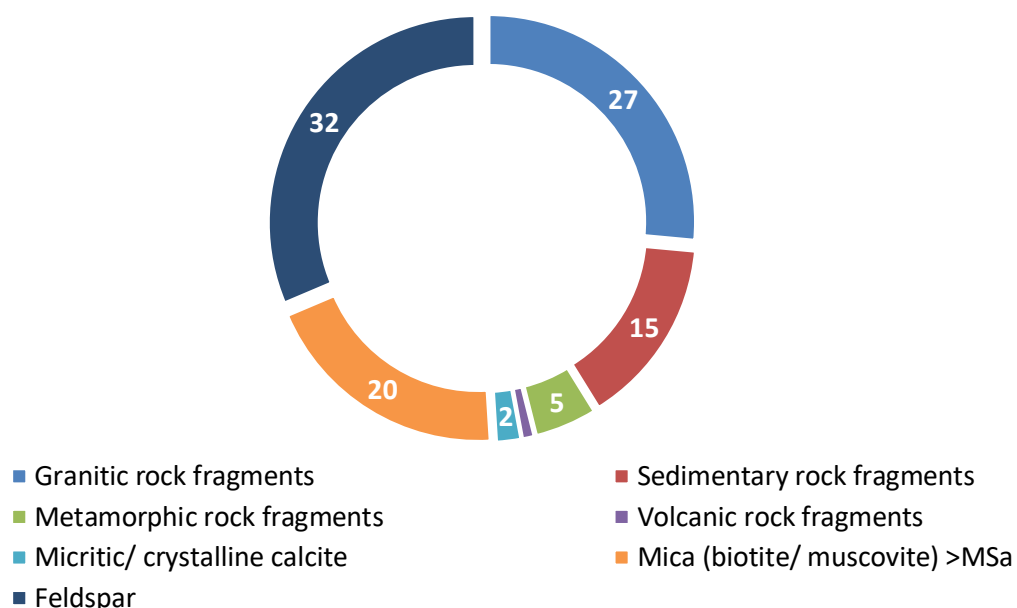


Fig. 5.163. Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics identified in selected sherds from Luohantang. Numbers represent the number of sherds, but a sherd can have a combination of several inclusion types. This chart shows which inclusion types are most common.

Calcite is very rare in the fine and coarse fractions in the fabrics from Luohantang (Figs 5.163-164). Feldspar is more present in the fine fraction of coarse fabrics than in fine fabrics (Fig. 5.164). Groundmass with <MSi inclusions common in all types of fabrics from Luohantang than it is in the material from the other sites. Very fine clay was probably used due to its plasticity and low porosity.

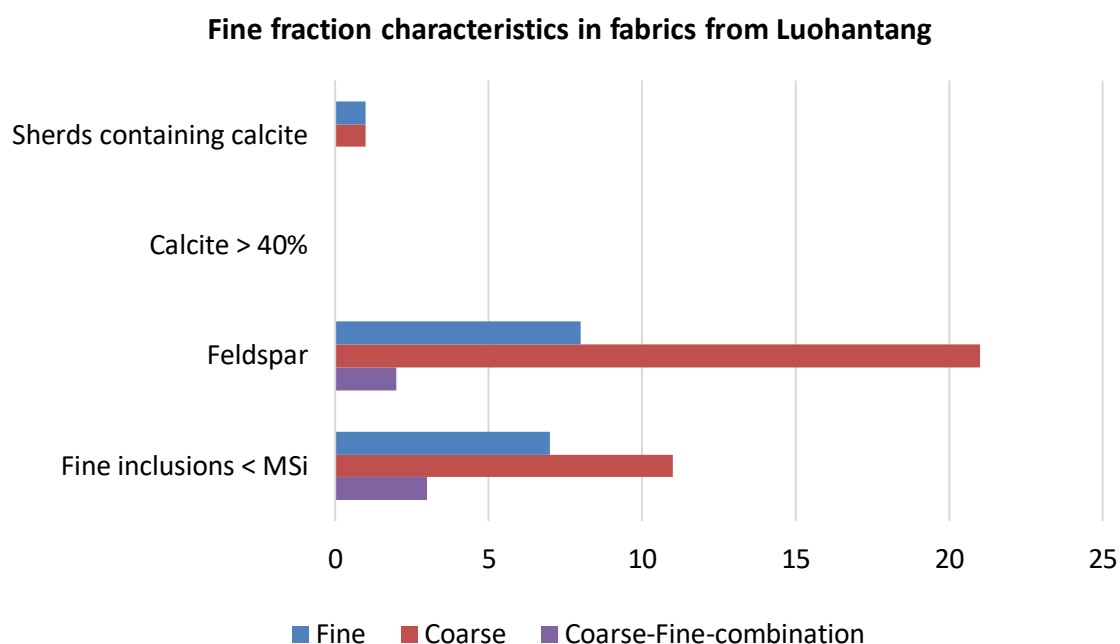


Fig. 5.164. Fine fraction characteristics in fabrics identified in selected sherds from Luohantang; numbers represent the number of sherds.

Matrix

Fine and coarse-fine-combination fabrics all show no to little amount of clay pellets on average (Fig. 5.165). Coarse fabrics with high amount of large clay pellets stand out in the among the fabrics not only in Luohantang but also in Majiayao and Zhujiashai material. Presence of clay pellets might indicate the mineral characteristics of the clay that cause slow hydration process. It might also hint at the clay paste preparation way of the prehistoric potters that included poor hydration and/ or wedging of the clay.

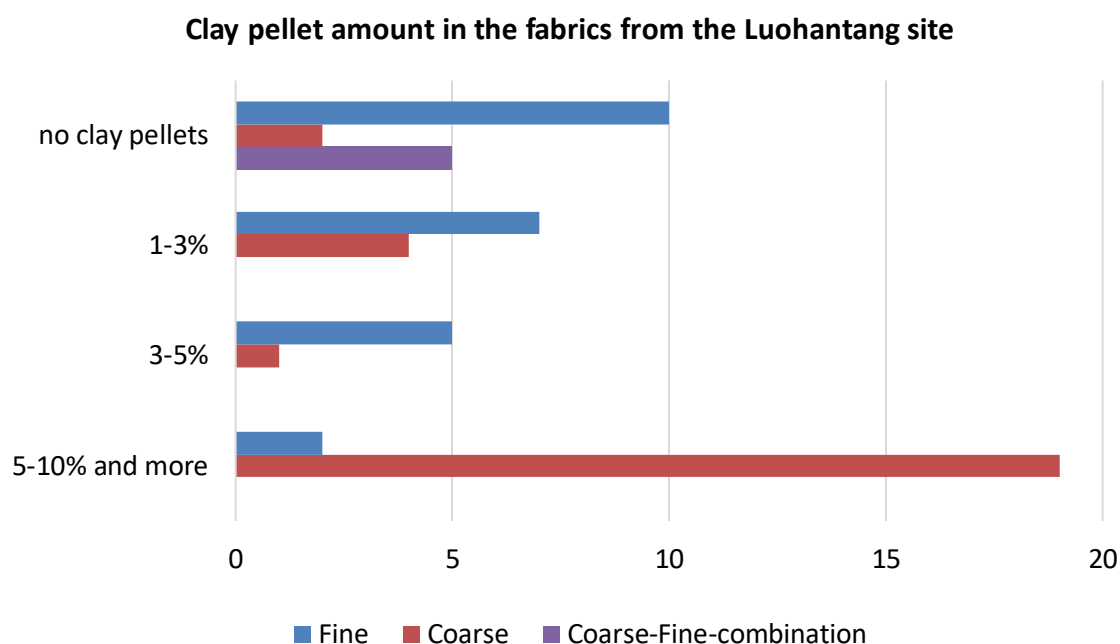


Fig. 5.165. Clay pellet amount in the fabrics identified in selected sherds from Luohantang; numbers represent the number of sherds.

The majority of the fabrics have optically active matrices (Fig. 5.166). An optically active matrix indicates to a firing temperature around 900° C or below (Quinn 2013:191). So far, the data on optical activity from all sites has been consistently suggesting firing temperatures around 900° C.

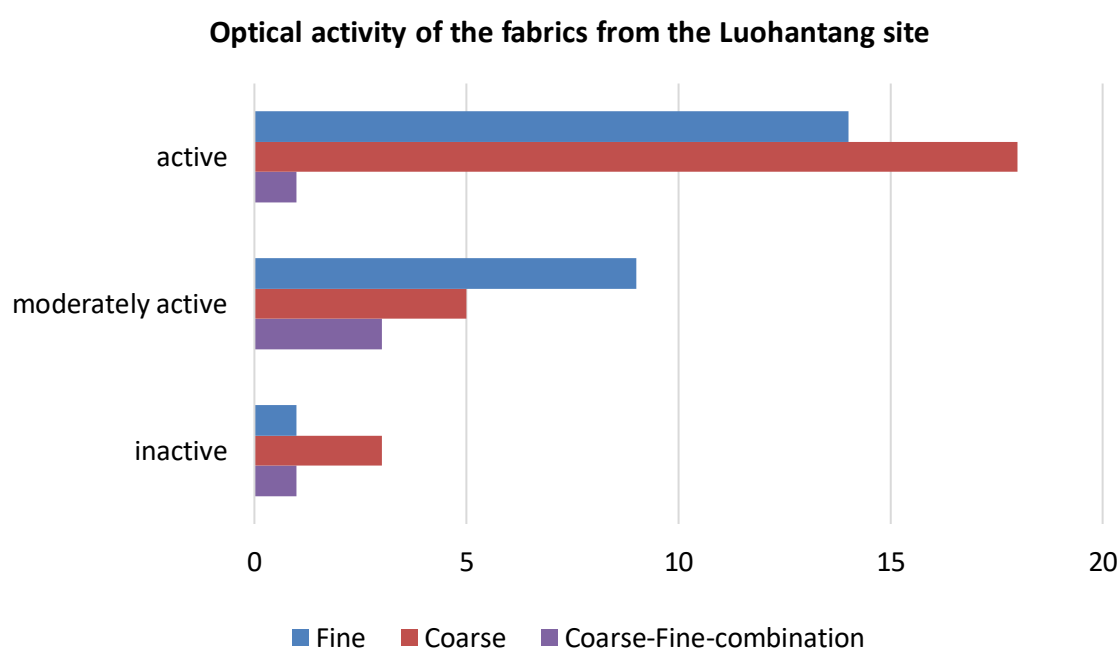


Fig. 5.166. Optical activity of the fabrics identified in selected sherds from Luohantang; numbers represent the number of sherds.

Porosity

The average porosity in the fabrics is low: 3-5% (Fig. 5.167). As has been pointed out above, most coarse and fine fabrics have low porosity. Coarse fabrics from Zhujiashai show similar porosity data, while in Majiayao coarse material is more porous. The reason for this difference could lie in the difference of the raw material and the *chaîne opératoire* of paste preparation and/ or firing. This issue cannot be properly addressed by the petrographic analysis and requires further investigation by chemical analysis and firing experiments.

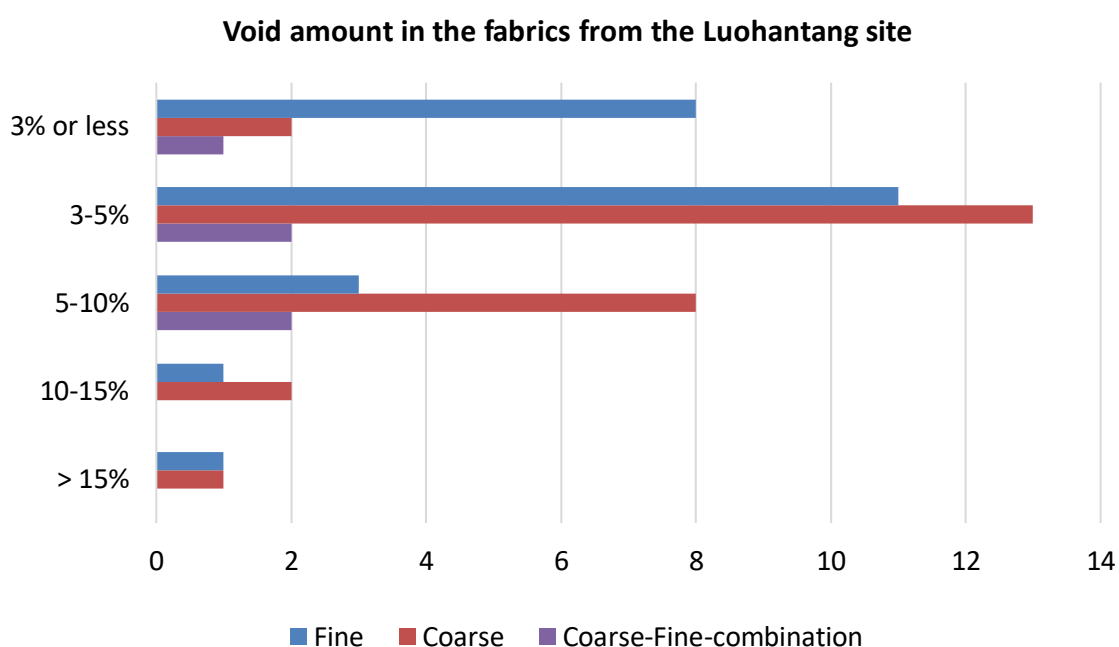


Fig. 5.167. Void amount in the fabrics identified in selected sherds from Luohantang; numbers represent the number of sherds.

5.2.5 Summary of petrographic characteristics of the prehistoric pottery sampled in this study

Before summarising and discussing the data from all sites, it necessary to point out that more samples were taken from the Majiayao material than from the other sites (see section 4.1.1). Therefore, there is more data from for the Majiayao site and the “Majiayao” bar might seem more dominant in some graphs.

5.2.5.1 Inclusions

The average inclusion frequency in the Majiayao-style fabrics analysed here is 20-40% (Fig. 5.168). The next common inclusion frequency is below 20% which is mostly the case in fine fabrics and in all fabrics from Waguangzui. Furthermore, 50% of the coarse Luohantang fabrics have less than 20% of non-plastic inclusions on average. The difference in the inclusion frequency mostly depends on the amount of the fine fraction because fine inclusions are usually most abundant in the fabrics. Few samples have more than 40% inclusion frequency and some show dominant coarse fraction (40% or more). It is rare for a pottery fabric to have more than 40-50% inclusions in the fabrics. Such a high amount of non-plastics in the clay would likely negatively affect clay plasticity and strength. The proportion of coarse non-plastics to the clay matrix in fired fabrics might have been influenced by the increased porosity through shrinkage and repeated exposure to heat if the vessel was used for cooking. Therefore, the non-plastics might appear disproportionately taking up more of the sample than the clay matrix.

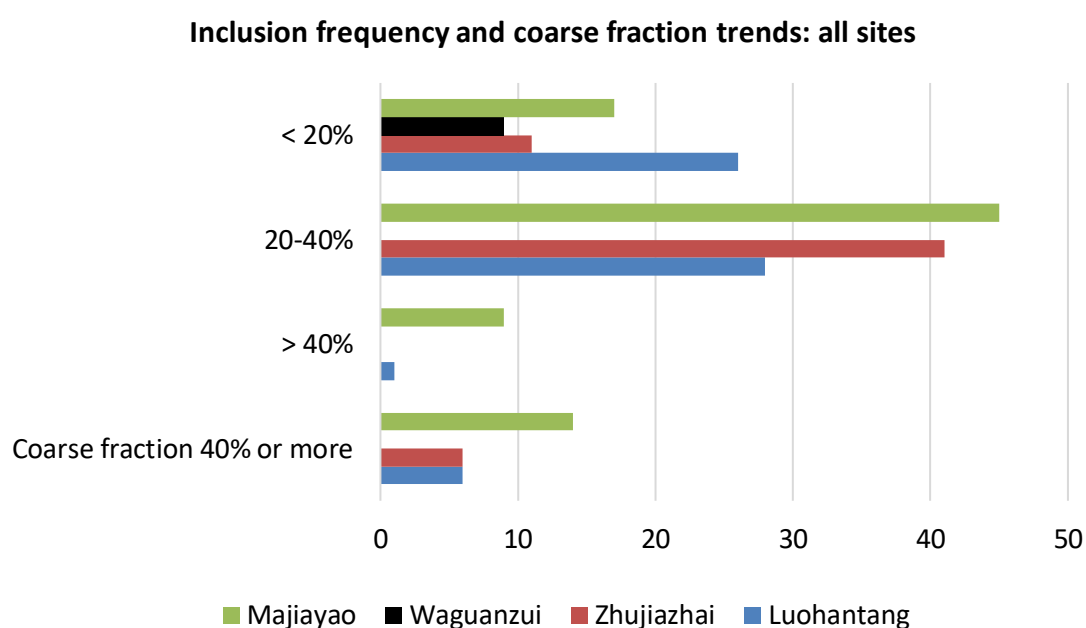


Fig. 5.168. Inclusion frequency and coarse fraction trends in fabrics identified in sherd samples from all sites; numbers represent the number of sherds.

There are different trends in the maximum inclusion size in the coarse fabrics from all sites (Fig. 5.169). Majiayao material has more samples with coarse sand as maximum inclusion size than fine gravel. For Zhujiashai, the sizes are quite equally distributed. The greatest variation of the grain-size is observed in the samples from Luohantang where fine gravel is the dominant maximum inclusion size in coarse fabrics. Fine gravel-sized non-plastic inclusions were presumably added as temper to the clay paste by the prehistoric potters at the sites. This conclusion has been reached after analysing the shapes of these inclusions and the groundmasses of the fabrics they belong to. Coarse-fine-combination fabrics were very useful for determining the characteristics of the groundmasses and assessing if temper was added. The situation with the coarse sand-sized inclusions is less straightforward because these inclusions might be naturally present in the clay. In this case, it helps to look at the amount and type of such inclusions in the fabrics, which might indicate whether they were added on purpose or randomly mixed into the clay.

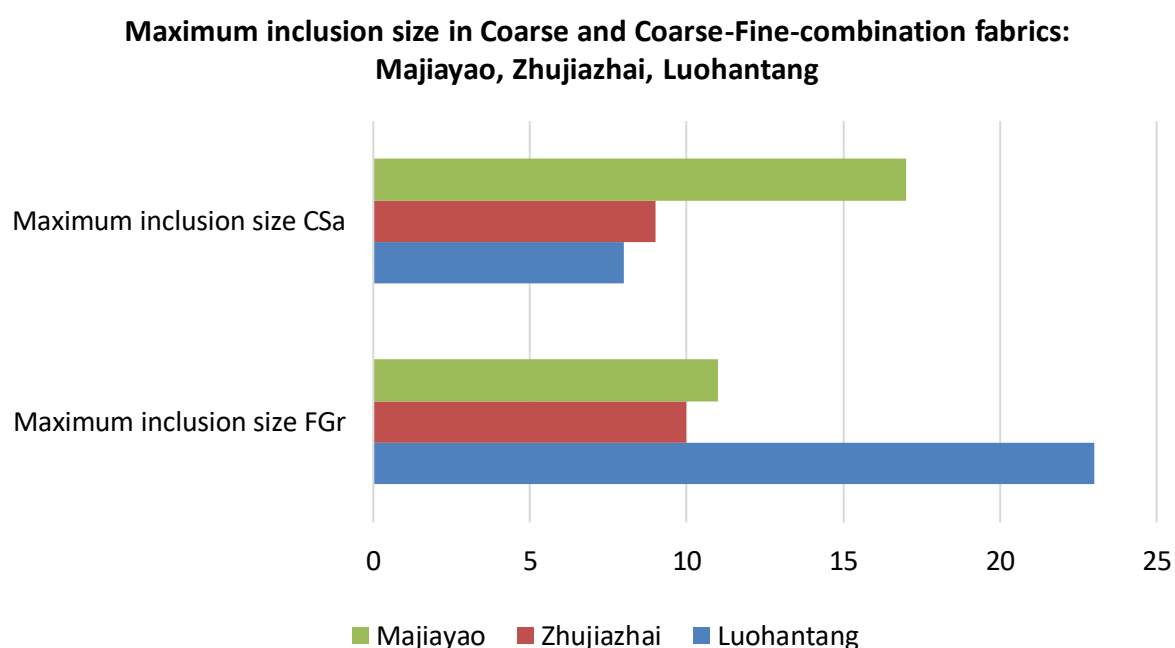


Fig. 5.169. Maximum inclusion size in coarse and coarse-fine-combination fabrics identified in sherd samples from Majiayao, Zhujiashai, and Luohantang; numbers represent the number of sherds. Analysed fabrics from Waguanzui have no coarse inclusions.

As has become clear from the data for each individual site the most common coarse non-plastic inclusion beside quartz is feldspar (Fig. 5.170). In the second place for Majiayao it is calcite closely followed by granitic rock fragments, Luohantang granitic rock fragments and coarse biotite/muscovite, whereas for Zhujiashai these are sedimentary rock fragments and coarse biotite/ muscovite. The discrepancy in the amount of coarse calcite between the material from the three sites is remarkable. It could indicate a difference in available/ used clay types in the different river valleys or a difference in recipes and preferred additives.

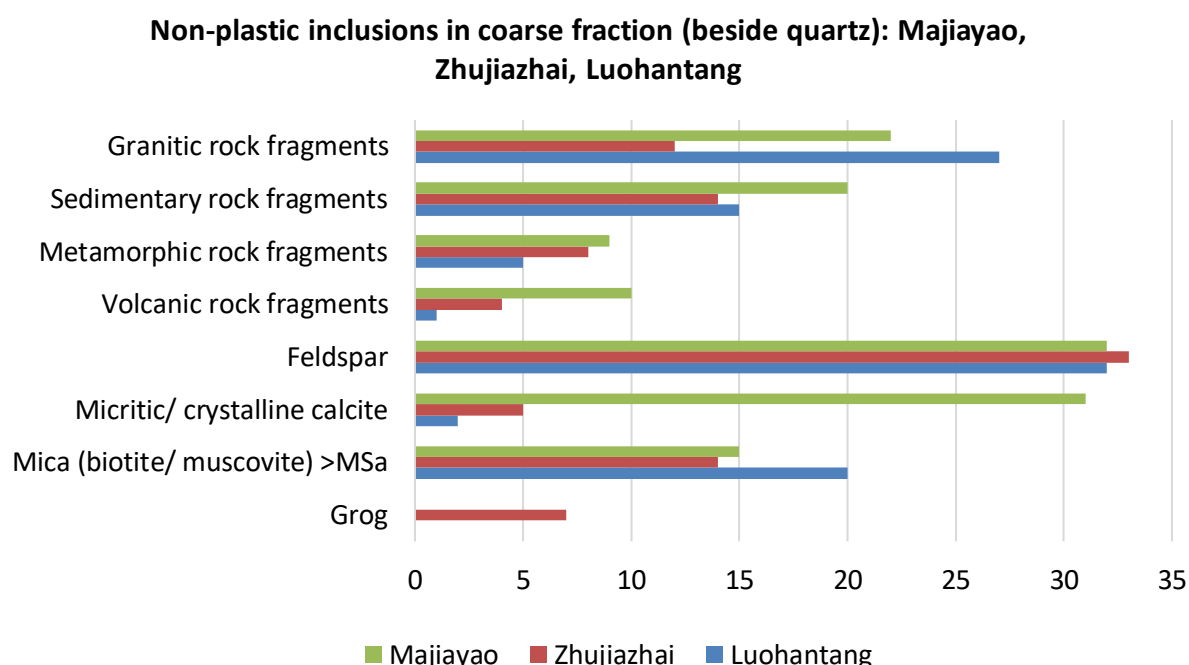


Fig. 5.170. Non-plastic inclusions in coarse fraction (beside quartz) in the fabrics identified in sherd samples from Majiayao, Zhujiashai, and Luohantang; numbers represent the number of sherds. Fabrics from Waguanzui have no coarse inclusions.

Granitic rock fragments seem to be a choice of temper in making of the coarse pottery from all three river valleys, which might be due to its physical properties allowing for better thermal conductivity or acting as flux (Müller et al. 2007:148; Hein et al. 2007:17-18; Rice 2015:79, 108). This observation implies that the prehistoric potters could distinguish granite from other rocks, and it had to be collected and crushed first before mixing into clay. High amounts of coarse mica

have been a by-product from crushing granite. Womack (2017:140) identified coarse mica in his samples from the Tao River Valley but was not sure whether it was naturally present or added manually. He identified this type of inclusion in rock samples but suggested that coarse mica might also naturally occur in yet unsampled clay sources (Womack 2017:140). The present study suggests that coarse-sand or fine-gravel-sized mica in coarse fabrics was a part of granitic temper added to the clay.

Coarse sedimentary, metamorphic and volcanic rock fragments are present in different amounts in the fabrics from Majiayao, Zhujiazhai and Luohantang. It has been suggested in this study, based on the size and shape of these inclusions, that these come from using loose river sand as an additive to the fine clay. In this case, the present study agrees with Womack's (2017:44, 138-139) conclusion that river sand was used to temper the clay. Furthermore, a sand sample from the Majiayao area showed similar sedimentary, metamorphic, and volcanic rock fragments to those identified in the pottery fabrics (section 6.1.1).

Grog temper was identified only in samples from Zhujiazhai, indicating a different recipe for clay paste preparation that did not include crushed granite or sand temper. The grog tempered fabrics could imply local technological choices different from the Majiayao style.

The fine fraction data shows that most of the fabrics from all sites have feldspar in fine fraction (Fig. 5.171). The major differences lie in the calcite content, that is the highest in the Majiayao fabrics, and in fine inclusion size. Very few samples from Majiayao and Zhujiazhai have medium silt-sized and smaller fine inclusions. Over twenty samples from Luohantang including coarse, fine, and coarse-fine combination fabrics with <MSi fine fraction indicate that such a fine clay type could

be a deliberate choice for pottery making. The properties of this clay, such as high plasticity, were known and deemed suitable for vessel construction.

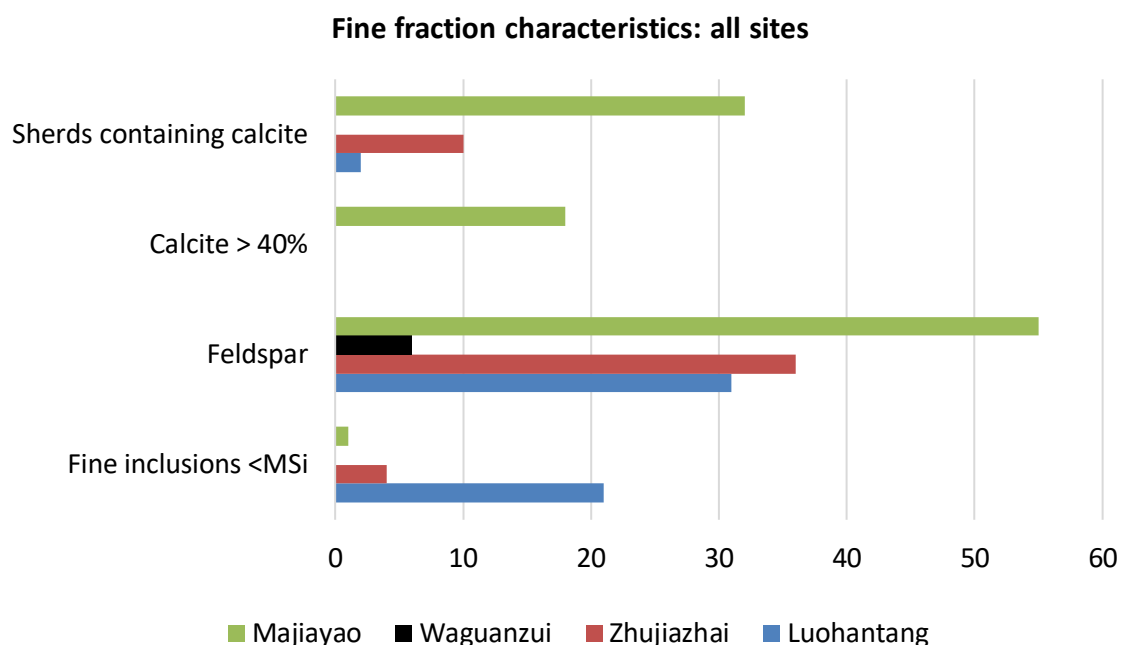


Fig. 5.171. Fine fraction characteristics in fabrics identified in sherd samples from all sites; numbers represent the number of sherds.

5.2.5.2 Matrix

The majority of the fabrics from all sites contain little to no clay pellets (Fig. 5.172). Two coarse fabric groups from Luohantang show a high amount (>10% of the matrix) of large clay pellets up to FGr size.

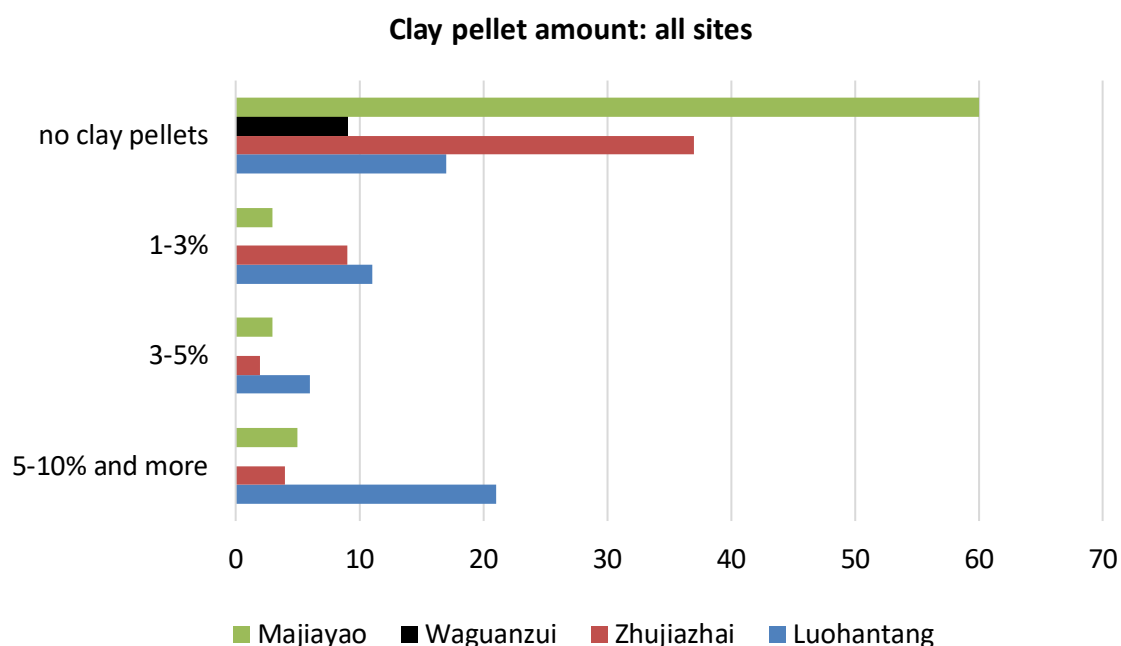


Fig. 5.172. Clay pellet amount in the fabrics identified in sherd samples from all sites; numbers represent the number of sherds.

The majority of the fabrics from Majiayao, Zhujiashai and Luohantang show an optically active and moderately optically active matrix (Fig. 5.173). It has been discussed in the macroscopic and petrographic analyses sections that the Majiayao-style pottery were fired at ca 900° C. The estimations of the firing temperature established by chemical analyses in previous research (Ma and Li 1991; Ma 2000) on the Majiayao-style pottery have been supported by macroscopic and microscopic observations on sherds in this study.

The samples from Wuguanzui all show optically inactive matrices. It is not clear to what degree the optical activity analysis was complicated by the slightly thicker thin section. Nevertheless, it is likely that these samples were fired under high temperatures due to the formed vesicle voids in the matrix indicating vitrification.

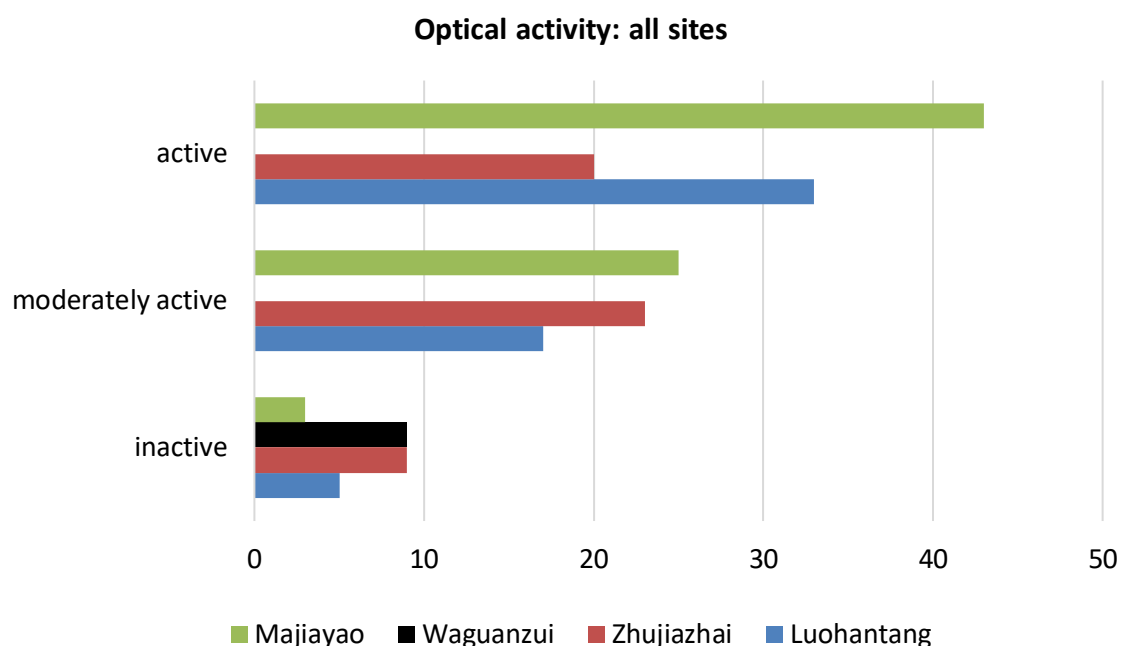


Fig. 5.173. Optical activity in fabrics identified in sherd samples from all sites; numbers represent the number of sherds.

5.2.5.3 Porosity

The average porosity among the fabrics from all four sites is low to medium (<10%, fig. 5.174). During the analysis in the present study, the assessment of porosity has revealed to yield sometimes different results when examining a sherd in cross-section macroscopically or in thin section. The limitation of this assessment is that porosity can vary within the sherd and this needs to be taken into consideration. The data on porosity presented in this chapter is based on the microscopical observations only. There are fifteen samples from Majiayao and Zhujiashai, and twelve samples from Luohantang that show a very low porosity (>3%) including all fabric types: fine, coarse, semi-coarse, and coarse-fine-combination. Presumably, the coarse fabrics with very low porosity have not been exposed to fire again after the initial firing because they would probably crack due to different thermal expansion of the coarse temper and clay matrix and inability to withstand thermal stress (Müller et al. 2007:146; Rice 2015: 326-327). Further investigation into

coarse bodies with low porosity could potentially reveal information about the material knowledge and manipulation by the prehistoric potters. It could also provide information about the usage of such vessels.

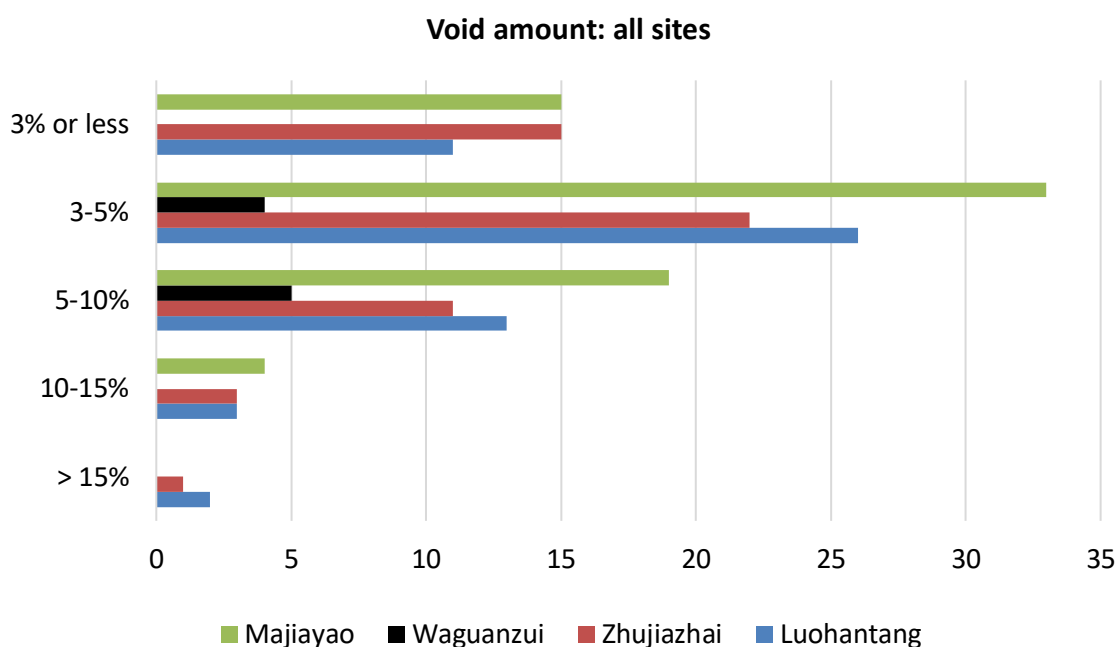


Fig. 5.174. Void amount in the fabrics identified in the sherd samples from all sites; numbers represent the number of sherds.

6 Analysis: geological samples

6.1 Macroscopic analysis

The purpose of this study was to gain insights into the range of clay raw material available in the Tao River Valley and observe the changes in colour and texture it undergoes when fired at different temperatures (700°, 900° and 1050° C). Further, the aim was to see whether it is possible to find correspondence between fired raw material and prehistoric ceramics.

This section discusses the results of the macroscopic analysis of seventeen clay samples, one sand sample, and twenty-nine rock samples. In the first part, the clay samples are first analysed in their unfired state with focus on their behaviour during the sedimentation and forming process. Next, the changes in the clay samples are examined after being experimentally fired in an electrical kiln. The second part of this section is an overview of the rock types collected from the same locations as the clay samples or in the near vicinity⁴⁷. In the end, the results of the analysis are discussed with regard to the broader geological setting in the study area (outlined in section 4.4.1).

6.1.1 Sediment samples

The collected sediment samples consist of seventeen clay samples and one sand sample. The clay samples were subjected to a sedimentation process and drying as described in section 4.4.3. After drying, the unfired samples showed differences in colour (Table 6.1, Fig. 6.1).

⁴⁷ For a detailed description of each geological sample see Catalogue 4.

Table 6.1. Colour variety in the clay samples from the Tao River Valley noted after the sedimentation process.

Colour	GSC
Brown, various shades	1, 4, 5, 6, 8, 9, 13, 14, 16, 17, 18, 19, 20, 21
Pale green	10, 11, 12

Rice (2015:278-279) pointed out that the colour of the raw clay is not determinative of the colour of fired clay. She explains that the lighter the colour of the raw clay the fewer impurities such as organic matter and iron oxides it has. Most geological samples in this study show brown or dark brown colour (Table 6.1, Fig. 6.1) which means they are not pure clays and are rich in organic material and iron oxides, such as hematite. The difference in colour of the samples in this study is further indicative of their outcrop location in the geological setting in the Tao River Valley. The pale green samples were collected at higher altitude than the brown samples. The pale green sediment is loess which is looser than the brown sediment and is usually found on top of the former (see section 4.4.1). This sediment is of aeolian origin, as is the red brown clay found on the upper terraces in the valley (Fig. 6.2, left; Gylesjö and Arnold 2006:183, 189; Zhang et al. 2017). The clay which has a deeper reddish-brown colour (Fig. 6.2, right) was collected at lower terraces at the riverbed level and from alluvial deposit (Miao et al. 2008; Guo et al. 2016).



Fig. 6.1. Unfired processed geological clay samples from the Tao River Valley; from left to right and top to bottom: GSC1, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21.

In the unfired state, based on macroscopic observation, processed and dry clay samples can be divided into three groups.

6.1.1.1 Unfired Group 1

Twelve samples: GSC1, 5, 6, 8, 9, 13, 14, 17, 18, 19, 20, 21

This is a fine red clay that is found in a hard dry state (after the top soft weathered layer is removed, Fig. 6.2, left) and in a soft and wet state around the Majiayao site (Fig. 6.2, right). In raw state the soft type becomes sticky as soon as it gets in contact with water. The hard clay needed to be crushed first and about a minute to soak but then dissolved in water easily. The soft type needed longer time to settle during the suspension process and to dry to become workable than the hard type. This difference indicates that the soft type has a higher clay particle fraction which hold the water longer, therefore, it also occurs in a wet state in nature. The fine clay particles of GSC21 kept the water for two days before settling at the bottom. This sample was collected in the riverbed and was subjected to a more intense

erosion process which resulted in a higher fraction of clay-sized particles than in the soft clays from geological profiles. The hard type of the material settled down faster than the soft type. This observation indicates the difference in clay and silt content among the red clays in the Unfired Group 1. However, as experienced during the briquette making, the difference in silt and clay fractions in the samples of the Unfired Group 1 had no significant influence on their plasticity. The material is plastic and holds its shape when manipulated by hand.

GSC6, a soft brown clay, was the only sample that formed very small lumps when mixed with water. These lumps were very hard to crush manually and prevailed during the briquette forming. This sample was also the stickiest and it was difficult to get it off surfaces and hands while it had a certain water content.



Fig. 6.2. Outcrops of raw clay in the Tao River Valley: left – hard dry clay, right – soft wet clay.

GSC6 required more time for the water to penetrate through the clay particles. The stickiness of this sample made it difficult to shape the briquettes. The addition of sand or another type of clay might reduce the stickiness and improve the workability. After a couple of days left untouched, GSC6 showed high plasticity and

is likely suitable for pottery making. GSC6 is also the clay that the potter Mr Ma Youzhong 馬有忠 from Gansu uses to produce Majiayao-style replicas. Mr Ma is not using a coiling technique but moulding (Fig. 6.3). Using a moulding technique might facilitate working with this sticky clay, since he does not seem to add any tempering material (at the time of sample collection the author was not aware of the nature of this sample and did not ask further questions).



Fig. 6.3. Moulds used by the local potter Mr Ma Youzhong from the Tao River Valley to produce a replica of a Majiayao-style vessel with a drying vessel inside.

GSC5 was collected only a few metres south from GSC6. GSC5 is a hard, dry clay in a raw state different from wet and soft GSC6. Additionally, GSC5 was not able to withstand the firing process in contrast to GSC6. Microscopically they fall into the same petrographic group. The difference seems to be in the chemical composition of the matrix and the connection between the clay particles. A sample vessel has been purchased from Mr Ma by the author and the analysis of its fabric will be included in a future project focusing on the geological samples from the study area.

6.1.1.2 Unfired Group 2

Two samples: GSC4 (containing sand), GSC16 (containing carbonate rock)

This type of red clay is similar to the red clay in Unfired Group 1. It occurs mixed with coarse white carbonate rock or sand (Fig. 6.4). The coarse carbonate fragments were difficult to crush into fine grains or separate from the clay. The samples appeared to be less plastic than the Unfired Group 1 clay because of their high coarse fraction. To reduce the coarse content and increase plasticity, this clay probably needs to be levigated. Levigation – screening the clay slurry through a mesh (Hamer and Hamer 2015:211) – was not performed during the experiment because it would remove potentially important clay components for the study. It would also presuppose that the prehistoric potters levigated their clays. This additional step would have deviated the study from the aim to focus on the raw material and potentially result in losing inclusions important for the analysis. Instead, as described in the section 4.4.3, the samples were processed by sedimentation in a container (Hamer and Hamer 2015:325) to remove any waste present in the soil and large pieces of organics but to keep the clay in its original state as far as possible.



Fig. 6.4. GSC16 mixed with white carbonate rock; left – raw material outcrop, right – crushed sample prepared for sedimentation process.

6.1.1.3 Unfired Group 3

Three samples: GSC10, 11, 12

The samples in this group have a loose dry powder-like texture and have a light creamy/ brown colour (Fig. 6.5). This material occurs closer to hilltops in the survey area and usually does not have another sediment layer covering it (except topsoil with vegetation), like in the case of the red clays. All samples from this group dissolved immediately in water. After the sedimentation process and a short drying phase of several hours, the material appeared to have low plasticity and was weaker than the material in the Unfired Groups 1 and 2.



Fig. 6.5. Outcrop of loose dry powder-like raw material.

The red clay that was collected on the lower terraces at the foot of loessal hills is an alluvial sediment that was transported and deposited by water (Alekseevskiy et al. 2008:95; Stoltman 2017:117). Traces of past streams can also be seen in the geological profiles in the dried-out tributaries and gullies in the Tao River Valley,

where layers of sand mixed with gravel and boulders run through the sediment deposits (cf. section 4.4.1.1; Fig. 4.13). Because the alluvial deposit is a mix of eroded sediments and bedrocks that the river transported from its upper reaches, it can be expected to have a different grain size distribution. The alluvial red clay has a higher proportion of clay particles and less silt than the aeolian loess (Stoltman 2017:117; Wang 2017:18). Loess consists of more than 60% silt and only of 10-30% clay (Zhang 1980:525; Derbyshire et al. 2000:59; Muhs 2018:81) which makes this material coarser and less plastic than clay. This difference was observed during the sedimentation process of the raw material for the firing experiment. The particles of GSC10, GSC11 and GSC12 separated from water and settled down faster than the particles in GSC21 which was collected directly by the Tao River. However, alluvial red clay can be expected to have coarser mineral particles because of its origin from erosion and deposition by water. Whereas aeolian red clay is expected to have fine, better sorted particles (Gylesjö and Arnold 2006:185).

After firing, many of the samples were affected by lime spalling. Lime spalling is a chemical reaction where calcium carbonate (CaCO_3) present in the raw material breaks down to calcium oxide (CaO) when fired at a minimum of 750°C - 850°C (Rye 1981:114; Webb 1994:17; Rice 2015:81). During the cooling process, when the pottery is exposed to air outside the firing structure, calcium oxide can react with moisture in the air to calcium hydroxide (Ca(OH)_2). As calcium hydroxide increases in volume, it pushes the clay particles apart and creates damage to the vessel fabric causing cracks or breaking the ceramic body. Calcium hydroxide is also known as lime and can be identified by its fine powder-like nature and white colour. The fired clay samples in this study show light to heavy lime spalling. Light

lime spalling is defined as single fine lime spalls covering or protruding on the sample's surface. Moderate lime spalling is defined as coarse lime spalls clearly visible on the sample surface, although the sample is still in one piece. Heavy lime spalling is characterised by an amount of calcium carbonate material large enough to break the sample into chunks or dissolve into a powder-like state. The fired clay samples⁴⁸ (Fig. 6.6) can be divided into three groups according to their macroscopic characteristics.

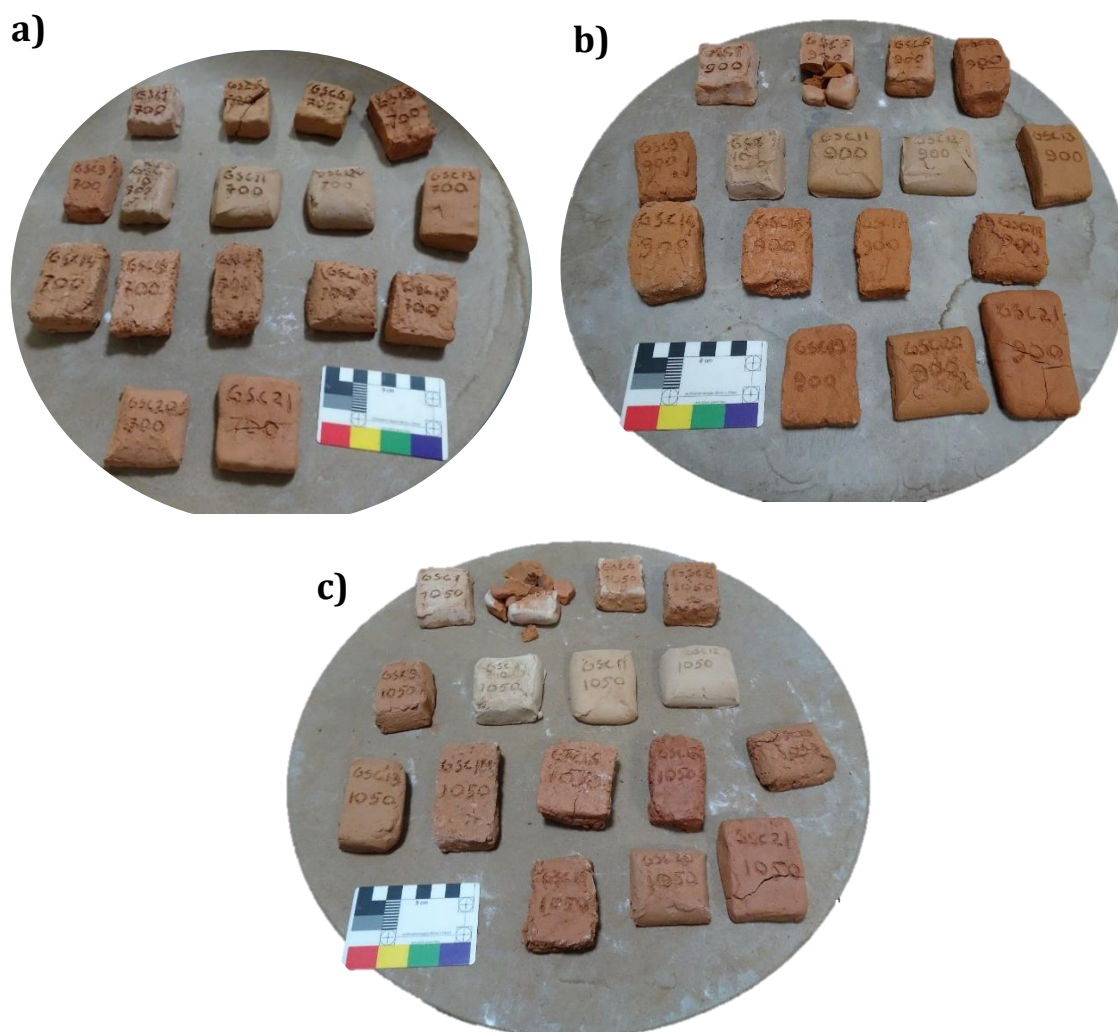


Fig. 6.6. Fired geological clay samples from the Tao River Valley; photos were taken immediately after unloading the kiln; from left to right and top to bottom: a) fired at 700° C: GSC1, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21 b) fired a at 700° C: GSC1, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21 b) fired at 900° C: same as at 700° C c) fired at 1050° C: same as at 700° C.

⁴⁸ GSC4 not included, see section 4.4.3 Firing experiment.

6.1.1.4 Fired Group 1

Five samples: GSC1, 5, 6, 8, 17

After firing, the samples in this group remained in solid shape, without cracks or showing lime spalling over time. The fabric colour ranges from orange-brown to red. Sample GSC5 exploded during all three firings (Fig 6.6.a-c, top row, second from the left). Although it is in pieces after firing, the chunks are not crumbling. High porosity in the cross-section of all three GSC5 briquettes of this sample indicates that the sample exploded because of the accumulation of hot air in the fabric which pushed the clay apart. Even though GSC5 in raw material state proved to be plastic and malleable clay, it probably needed a more thorough kneading to remove all air bubbles for a successful firing. The rest of the processed GSC5 raw material has been brought back to Europe and aged for one year. Clay aging or souring is a process that increases plasticity of the clay. Sealing wet clay and storing it for a long period of time, will allow for bacteria to grow inside and for the water to fully penetrate the clay body contributing to better workability of the material (Rye 1981:39; Schreiber 1999:4; Rice 2015:134).

The second attempt at wedging resulted in improved workability and plasticity. Another experimental firing in the future would show if the aging had any effect on its reaction to heat.

After firing GSC17 (Fig 6.7) showed considerable differences in colour between all three fired briquettes. GSC17 fired at 1050° C shows a deep shade of red in contrast to the light brown fired at 700° C and turns orange when fired at 900° C. This might be due to a very low calcium content in this sample as calcium has an effect on ceramic colour by reacting with iron oxides (de Bonis et al. 2017:8073). The red hue in GSC17 was influenced by its iron content which had not enough

calcium to react with, in contrast to the case with other samples, especially with those in Fired Group 2.



Fig. 6.7. GSC17; from left to right - fired at 700° C, 900° C, 1050° C.

6.1.1.5 Fired Group 2

Eight samples: GSC9, 13, 14, 16, 18, 19, 20, 21

Samples in this group when fired at 700° C exhibit the same characteristics as the Fired Group 1. However, when fired at >900° C the samples showed light to heavy lime spalling. GSC16 shows heavy lime spalling of the sample fired at 900° C (Fig. 6.8, middle). The lime spalling process started several hours up to a day after the sample was taken out of the kiln. The GSC16 briquette fired at 1050° C as depicted on the photo (Fig. 6.8, right) does not show any lime spalling because it was fired a day later than the briquette in the middle and photographed immediately after firing. The lime spalling in the briquette fired at 1050° C started the following day.



Fig. 6.8. GSC16; from left to right - fired at 700° C, 900° C, 1050° C.

After several months, the samples in this group that were prone to heavy lime spalling showed different degrees of disintegration. GSC13 (900° C), GSC14 (900°, 1050° C) and GSC16 (900°, 1050° C) disintegrated into a fine powder (Fig. 6.9a-d). GSC13 (900° C) sample has the finest powder texture (Fig. 6.9a). This sample pulverised earlier than the others taking not more than two months, whereas GSC14 and GSC16 took longer than that. GSC13 and GSC14 kept their initial orange colour but GSC16 turned completely white, indicating a very high amount of calcium carbonate in its mineral composition.



Fig. 6.9. Pulverised fired clay samples due to heavy lime spalling; a) GSC13 900° C b) GSC14, left 900° C, right 1050° C c) GSC16, left 900° C, right 1050° C d) overview of the colour change, from left to right GSC13 900° C, GSC14 900° C, GSC14 1050° C, GSC16 900°, GSC16 1050° C.

Interestingly when fired at 1050° C, GSC13 did not disintegrate completely with about $\frac{1}{4}$ of the briquette still intact. It is possible that the high temperature prevented the rehydration of some calcites because they form new minerals such

as wollastonite (Rice 2015:112). The briquettes fired at 700° C from GSC13, GCS14 and GSC16 all remained whole.

The Fired Group 2 has the highest number of samples, but they have been proven to be unsuitable for firing at >900°C due to heavy lime spalling causing damage to the ceramic body. However, the sample briquettes have a thickness of 1.5-2 cm, whereas the average wall thickness of vessels with fine fabrics is 0.5-1 cm. If the raw materials used for fine fabrics have similar carbonate content to the samples in the Fired Group 2, can lime spalling be controlled or avoided by decreasing wall thickness? The potters at the village of Thrapsano on the island of Crete produce tall thick-walled storage jars (pithoi) using calcareous marl clays. To prevent lime spalling the jar walls are wetted with water and after waiting at least a day they are filled completely with water and left standing for a month or longer (Voyatzoglou 1974:23; Quinn 2013:191; author's personal observation during a research trip to Thrapsano in 2018). Experimentally, this method to avoid or reduce lime spalling was verified by Laird and Worcester (1956). They fired clay briquettes at 1050° C, each briquette having a different limestone content with a minimum of 5% and put them into cold water after cooling. Their experiment showed that briquettes containing <10% limestone were not substantially damaged by spalling as opposed to the briquettes with the same limestone content left at room temperature after firing (Laird and Worcester 1956:547). In another experimental study addressing this issue, Elert et al. (2003) placed the bricks made of calcareous clays in water for two hours immediately after firing. The damage from lime spalling was reduced but could not be prevented completely (Elert et. al 2003:95). Elert et al.'s (2003:98) research confirmed Laird and Worcester's find that damaging by lime spalling only occurs in clays with a high calcite fraction with

grain size >0.5 mm. According to experimental studies, 5-10% fine calcite content in a clay does not lead to heavy lime spalling (Elert et al. 2003:98; also result of an experimental study by Allegretta et al. 2016:231). In sum, it seems unlikely that the wall thickness influences the degree of lime spalling which actually depends on the calcite content in the clay body.

6.1.1.6 Fired Group 3

Three samples: GSC10, 11, 12

The higher the firing temperature the more prominent becomes the pale brown/pale green colour of the samples (Fig. 6.10). This colour may indicate the calcareous nature of the samples.

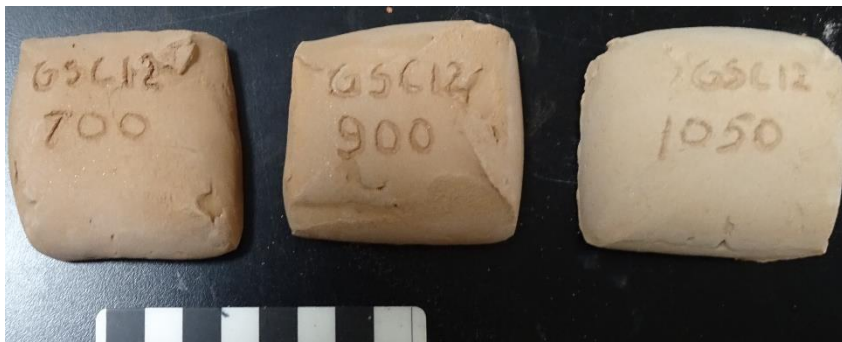


Fig. 6.10. GSC12; from left to right - fired at 700° C, 900° C, 1050° C.

Simpson (1997:54) wrote that light and pale colours are characteristic for fired calcareous clays. However, in his analysis of early pottery from Mesopotamia, the calcareous clays used in pottery production are alluvial. Fired Group 3 appears to be silt rather than clay and is not an alluvial deposit but of aeolian origin. Even though the colour of the unfired version of GSC10, GSC11, and GSC12 implies their calcareous nature, no lime spalling has occurred after firing. As it will be discussed below, no calcium-based inclusions were found in the GSC11 thin section. The texture resembled the loess sample analysed by Guo et al. (2016) in their study of

traces of palaeo-earthquakes and palaeo-mudflows in the Huangshui River Valley. The micrograph of the sample collected from a sediment profile at the Majiayao-period site Machangyuan 马厂塬遗址 shows >50% of silty non-plastic inclusions with little binding agent/ matrix (Fig. 6.11).



Fig. 6.11. Photomicrograph (XPL) of an aeolian loess sample from the Huangshui River Valley, scale size 300 μ m; cropped by the author, original from Guo et al. 2016, Fig. 6.

GSC11 briquettes fired at 700° and 900° C were slowly disintegrating into fine powder, whereas the briquette fired at 1050° C stayed intact. This fact indicates that this type of raw material keeps its shape only when its texture starts to vitrify at a temperature above 1000° C. GSC10 and GSC12 briquettes crumble slightly when in contact with other objects. The firing experiment showed that the samples in this group are unsuitable for ceramic making, because of their low plasticity and condition after firing.

A crucial insight gained from the macroscopic analysis is that none of the fired clay samples have a high fraction of coarse non-plastic inclusions (except for lime) as observed in fired briquette cross-sections. In cross-section, none of the fired samples look similar to the coarse sherds. Only a few samples had rare macroscopically visible rock or mineral inclusions. This might indicate rock tempering, or clay and sand mixing in pottery production. It is possible that a

different raw material was used, which was not sampled in this study. Since the prehistoric fine sherds do not exhibit any moderate or heavy lime spalling it is possible that their fabric composition would be similar to the fabrics of Fired Group 1.

Macroscopically, Fired Groups 1 and 2 have a strong similarity in colour to the prehistoric sherds from Majiayao fired in oxidising atmosphere. Among these two groups, clays of the Fired Group 1 are probably more suitable for pottery production because of the high degree of plasticity and minimal risk of lime spalling. It is an open question how the prehistoric potters at Majiayao dealt with the impact of calcite content in their clays, or if they deliberately chose raw material with less calcite content. The results of principal component analysis conducted by Ma (2000:23-25) have shown that potters appeared to know which material to choose for a successful firing, as they form one cluster in his data. Ma (2000:47) further suggested that the potters might have levigated the clays to reduce the calcium content and the damage after firing. However, a very fine mesh is required for a successful reduction of the calcium content by levigation (Hamer and Hamer 2015:213). The firing experiment in this study has shown that the calcium content in the natural clay can vary and potters may have chosen the clays with low calcium content based on their experience and experiments.

The sand sample GSC2 (Fig. 6.12) contains small sand-sized shell fragments beside the medium gravel-sized rock fragments. Sedimentary rock fragments and minerals such as quartz and feldspar were possible to identify macroscopically. The sand components such as quartz, feldspar and sedimentary rock fragments appear to be similar to the rock types and minerals described in the following section 6.1.2.



Fig. 6.12. GSC2, sand sample collected in the Tao River Valley; 1 scale unit = 1 cm.

6.1.2 Rock samples

During the geological survey, various stones were collected from the same location where the clay samples were extracted; additional separate rock samples were taken from riverbeds. All collected stones have rounded shapes as they were deposited in dried out riverbeds or in still active rivers. As shown above, the dried-out riverbeds have a prominent sand layer in the profile between loess and clay which is abundant with boulders and pebbles marking the water level that was once reached there.

On first macroscopic examination most of the sampled rocks were identified as igneous or sedimentary. The rocks and minerals that could be distinguished among the samples are listed in Table 6.2 with examples shown in Fig. 6.13a-d.

Table 6.2. Rock types identified among the samples collected in the Tao River Valley.

Igneous

Gabbro; granodiorite; andesite; felsic rock sample with K-feldspar, quartz, mica – possibly granite

Sedimentary

Gritstone (fine and coarse); intraclastic carbonate rock from shallow marine environment (limestone); claystone or shale; chert; chert with iron oxide/ reduced iron staining; conglomerate with chert, mica, gneiss, and bioclastic carbonates; sandstone; fine-grained sandstone; fault breccia.

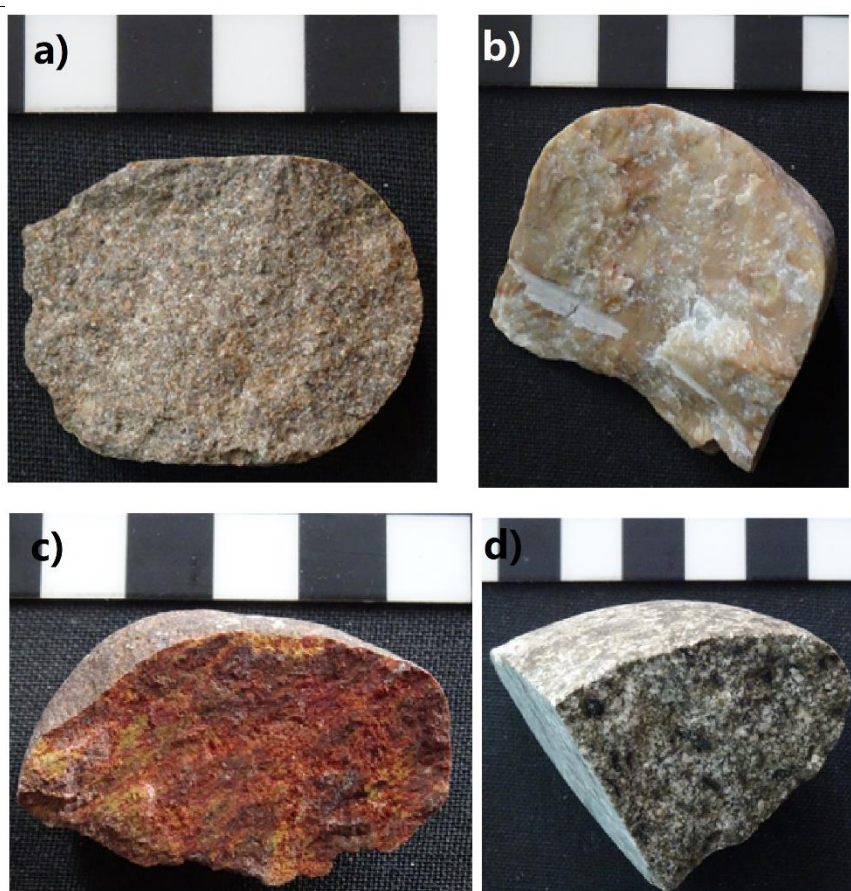


Fig. 6.13. Examples of rock samples collected in the Tao River Valley; a) GSC7-1, coarse sandstone b) GSC15-1, carbonate intraclastic rock c) GSC15-3, fault breccia with iron oxides d) GSC22-8, granodiorite.

The predominance of carbonates and sedimentary rocks in the load carried by the Tao River (section 4.4.1.1) is reflected in the GSC rock samples. The fault breccia sample (Fig. 6.13c) could be a source of iron oxide for pigment production, the red and yellow colour of the cementation in this rock indicates a high content in

hematite and limonite, but also probably organic matter because it is a sedimentary rock. The granite bedrocks appear not to be as large as the sedimentary rock deposits in the upper reaches of the Tao River. This might explain why igneous rocks were not as easily spotted in the sampling area around the Majiayao site. The closest granite bedrock to the archaeological site is located further northeast (ca 60 km) on the Maxian mountain (Fig. 4.11, 4.14), after the river passes the site. Nevertheless, it is a source of granitic rock that would have been accessible from the site.

Having an overview of the rock types around the site and from the riverbed close to the site provides an insight into the available options for tempering clay fabrics or for pigment extraction. Knowing the mineral composition of the collected rocks, which is discussed in 6.2.2, is especially useful for the discussion of very coarse (CSa-FGr) inclusions in prehistoric pottery fabrics. It is not always clear what type and shape of coarse inclusions might be naturally present in the pottery clay, therefore, a comparison with the petrography of the rocks complimentary to the petrography of geological clay samples helps to approach this issue.

6.1.3 Summary

The macroscopic analysis of the unfired geological sediment samples has shown that there are different types of clay material around the Majiayao site. The unfired groups in section 6.1.1 exhibit different plasticity and different behaviour when mixed with water. Different settling time during the sedimentation process in water suggests that the samples have different clay particle content. Most notable is the difference in settling time between the loess samples GSC10, GSC11, GSC12 and clay sample GSC21. GSC21 stayed a few days in suspension before it fully settled onto the bottom of the container. This means that GSC21 has a high

proportion of very fine clay particles which do not let water penetrate easily. GSC10, GSC11 and GSC12 in contrast dispersed and dissolved in water within seconds, meaning that the majority of particles of this material were coarser (silty) and water can permeate it faster. The clay particle content has a direct influence on plasticity. The higher the proportion of fine clay particles in the sediment the higher its plasticity. GSC10, GSC11, GSC12 are silty loess material which had the lowest plasticity of all other samples.

Samples GSC6 and GSC21 both have a high proportion of clay but behaved differently when mixed with water. GSC6 did not stay in suspension as long as GSC21. Instead, GSC6 quickly formed hard lumps which would have needed days for water to fully permeate and for the lumps to soften and disintegrate. GSC6 is a highly plastic but also very sticky clay.

The third observation while working with GSC samples was the natural coarseness of GSC4 and GSC16. GSC4 was deemed unsuitable for the firing experiment at first because it appeared to have a high proportion of sand. In hindsight, GSC4 would have been a sample of naturally coarse sediment in the area. It was collected in the lower terrace of a small west tributary to the Tao River just below the site location on the hill.

After the firing experiment, the GSC clay samples exhibited characteristics such as friability and being prone to lime spalling. Different behaviour of clay after firing led to the conclusion that the samples in Fired Group 1 might be the most suitable for potting. However, this is a conclusion from the practical point of view considering the criteria of plasticity and successful firing. The GSC samples were fired largely retaining their natural composition without undergoing further steps of improving such as aging, souring or tempering.

The collected GSC rock samples are predominantly sedimentary rocks and limestone which is in accordance with the information from the literature on local geology. There were samples of different igneous rocks in the selection including granite, which was identified as one of the preferred temper types for the coarse Majiayao-style pottery.

6.2 Thin-section petrography

This section presents the results of petrographic analysis of sediment and rock samples collected in the Tao River Valley. This study addresses the question of naturally present or added material in the ancient pottery fabrics by looking at the amount, size and type of inclusions which are present in the geological fabrics. Further, the exact known firing temperature and the optical activity matrix of the geological samples provide a starting point for comparing and estimating the firing temperatures of the pottery sherds. The thin sections of sediment material were made from fired clay briquettes and sand. The fired clay briquettes that were not completely damaged by lime spalling were considered for thin-sectioning. From the samples that met this criterium, the briquettes fired at 1050° C were thin-sectioned. This selection allowed the analysis of the mineral inclusions and the changes in the matrix under a very high temperature. Further, the results of this analysis are discussed together with the results of the petrographic analysis of the prehistoric pottery sherds.

Thin sections of rock samples were made from rock types that were deemed to be likely present in the pottery fabrics such as sandstone, granite, and carbonate

rocks. The results of the petrographic rock analysis are summarised in a chart showing the most common occurring minerals.⁴⁹

6.2.1 Sediment samples

6.2.1.1 Clay

Thin sections of eight clay samples fired at 1050° C and one sand sample were analysed using polarised light microscopy. Three fabric groups and one sub-group were identified among the eight clay samples (Table 6.3, Fig. 6.14a-d). The differences between the fabrics are mostly in the amount and size of mineral inclusions but not in their type.

Table 6.3. List of fabric groups identified in fired geological clay samples from the Tao River Valley.

Fabrics (fired at 1050° C)	Number of samples
1A Fine, Quartz-Mica-Feldspar <i>GSC1</i>	1/8
1B Fine, Quartz-Mica-Feldspar with higher inclusion frequency than Fabric group 1A <i>GSC8, 11</i>	2/8
2 Fine, Quartz-Mica, mineral inclusions MSi-sized and smaller <i>GSC5, 6</i>	2/8
3 Semi-coarse, Quartz dominant <i>GSC17, 20, 21</i>	3/8

⁴⁹ A detailed petrographic description of the rock samples is provided in Catalogue 4.

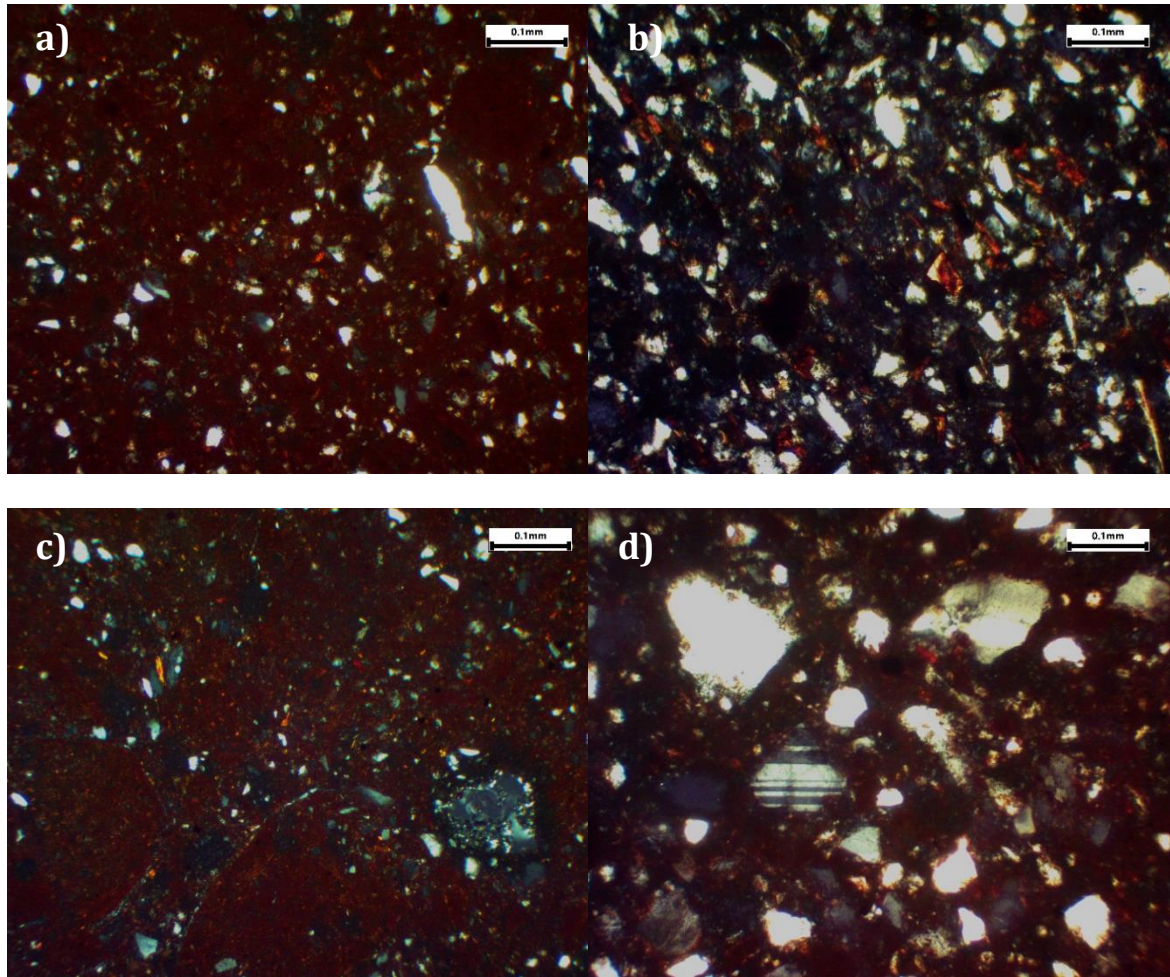


Fig. 6.14. Fabrics identified in the fired geological clay samples from the Tao River Valley. Each sample was fired at 1050° C; photomicrographs taken under XPL, scale size 0.1 mm; a) Fabric 1A, GSC1 b) Fabric 1B, GSC11 c) Fabric 2, GSC5 d) Fabric 3, GSC20.

All fabrics are well-sorted and predominantly fine with semi-coarse samples having medium sand as the maximum inclusion size (Table 6.4). The main coarse inclusions in all fabrics are quartz and feldspar. A summary of the main coarse non-plastic inclusions as it was provided in section 5.2 for the prehistoric pottery is omitted from this section because of no real variety in inclusion type in the GSC clay samples. A detailed description of coarse fraction in the geological fabrics is provided in Catalogue 2.

Table 6.4. Summary of petrographic characteristics of fired clay samples from the Tao River Valley.

Characteristic	Fine sample, N=5	Semi-coarse sample, N=3
Inclusion frequency		
< 20%	0	0
20-40%	3	0
40% or more	2	3
Coarse fraction > 40%	0	0
Fine fraction		
Sherds containing calcite	0	0
Calcite > 40%	0	0
Feldspar	5	3
Fine inclusions < MSi	2	0
Clay pellet amount		
no clay pellets	1	1
1-3%	1	0
3-5%	0	0
5-10% and more	3	2
Optical activity		
active	0	0
moderately active	3	0
inactive	2	3
Void amount		
3% or less	5	0
3-5%	0	2
5-10%	0	1
10-15%	0	0
> 15%	0	0

In the following section the results of the petrographic analysis of fired clays are discussed with the petrographic data from prehistoric sherds. The comparisons in each subsection mainly focus on the petrographic data from Majiayao and Waguanzui material because they come from the same area but the data from Zhujiazhai and Luohantang is also included.

6.2.1.1.1 Inclusion frequency

Starting with the fine fabrics it is notable that none of the geological samples have an inclusion frequency below 20%, whereas the fine fabrics from both sites have samples with less than 20% inclusions. This observation indicates that the clay

was potentially subjected to a levigation process, if the ancient clay and the geological sample are chemically the same. However, the majority of the fine sherd fabrics from Majiayao have an average of 20-40% of inclusions similar to the fine geological samples.

The geological fine fabric group with an average >40% inclusion frequency consists of a silty clay sample and a silt (loess) sample. The silt sample is GSC11 whose friable nature was discussed above in the Fired Group 3 section. The GSC11 micrograph (Fig. 5.185b) resembles the micrograph of a loess sample by Guo et al. (2016; here Fig. 5.135) from the Huangshui River Valley. This comparison shows that GSC11 is a silty raw material with less clay particle fraction than other samples and less suitable for pottery production in its pure form due to its poor plasticity and friability even after firing.

The fine fabrics from Zhujiashai and Luohantang have the same average inclusion frequency of 20-40%. A higher number of fine fabrics from Luohantang has >20% inclusion frequency than the fine fabrics from Majiayao and Zhujiashai.

The geological semi-coarse samples all have an average inclusion frequency of 40% and are well-sorted. The prehistoric semi-coarse fabrics from Majiayao and Zhujiashai have 20-40% inclusions and are mostly poorly sorted. The prehistoric semi-coarse fabrics could also have been made from levigated material which could have led to the difference in the grain-size and poor sorting depending on the tools used for this process. The average coarse fraction in semi-coarse prehistoric fabrics is 20%, the semi-coarse geological samples have 50-55% coarse inclusions.

6.2.1.1.2 Maximum inclusion size

The maximum inclusion size in the semi-coarse geological fabrics is medium sand, while in the sherds from Majiayao and Zhujiashai it is coarse sand. This opens the question whether the semi-coarse prehistoric fabrics were additionally tempered with sand or come from a different clay source which was not sampled in this study. More geological samples need to be analysed petrographically and grain-size data collected to address this issue. The difference in grain size between the samples in Fabric Groups 1A-B, 2 and 3 may point to their origin. Samples in Fabric Groups 1A-B and 2 were collected at higher terraces and show unimodal fine grain size confirming aeolian origin. Samples in Fabric Group 3 show a variety of sizes larger than in Fabric Groups 1A-B and 2. They were collected in the alluvial deposits at lower terraces and at the river.

6.2.1.1.3 Non-plastic coarse inclusions

No coarse fabrics have been identified among the analysed geological samples. Quartz and feldspar are the only coarse inclusions identified in the semi-coarse geological samples. The prehistoric coarse pottery fabrics from Majiayao, Zhujiashai and Luohantang consist of a variety of coarse minerals and rock fragments, the most common of which, beside quartz and feldspar, are granitic and sedimentary rock fragments, and in the specific case of Majiayao - micritic/crystalline calcite. The coarse quartz and feldspar fragments present in the prehistoric fabrics reach fine gravel size, which is not the case for the geological fabrics. As stated above, petrographic analysis of the remaining fired geological samples could provide more insights about the size and type of naturally present coarse inclusions. At this stage of analysis, there is a clear difference in the type and size of coarse inclusions between prehistoric pottery and geological samples.

The prehistoric pottery sherds had a greater amount of fine gravel-sized inclusions of both angular and rounded shapes. This difference may suggest the manipulation of natural raw material by the potter by adding rock temper. However, it is always possible that a clay source with these characteristics was not sampled during the field trip.

6.2.1.1.4 Fine fraction characteristics

A quarter of fine and almost all coarse pottery fabrics from Majiayao have calcium-based inclusions in fine fraction. None of the geological fabrics show calcite content in thin section. None of the semi-coarse fabrics from Majiayao and possibly none of the fabrics from Waguanzui have calcite content either, though the different thickness of the thin sections from Waguanzui sherds might have obstructed the identification of calcite. The samples in the geological Fabric Group 3 “Semi-coarse, Quartz dominant” all exhibit light to moderate lime spalling but no calcium-based inclusions were observed in thin section. In this case, the composition of the raw material used for prehistoric pottery is similar to the composition of the raw samples in Fired Group 3 with a higher calcite content. Future petrographic analysis of more samples from the Fired Group 3 could shed further light on the issue of calcite in fine fraction. Additional analysis of lower fired samples from this group might also offer new insights to discussion of distinguishing post-depositional and naturally present calcite in the clay and sherds from the Tao River Valley.

Fine samples from Zhujiazhai have a small amount of calcite in fine fraction but it is still considerably less than in the Majiayao fabrics. Only two samples from Luohantang showed fine calcite content in the groundmass.

The feldspar content in the fine fraction is mostly in alignment with the pottery fabrics from all four sites. There are a few sherds with fine fabrics and half of the coarse sherds from Majiayao where no feldspar was identified in the fine fraction. The geological Fabric Group 2 with mineral inclusions of less than medium silt-size is reflected in two fine pottery samples from Majiayao, and in two fine, one coarse and one semi-coarse sample from Zhujiazhai. It is not clear whether the pottery fabrics were manually refined by the potter, but the geological Fabric Group 2 shows that naturally very fine raw material was available around the site. Twenty-one fabrics with <MSi fine fraction, including coarse and fine, were identified in sherds from Luohantang. As has been suggested above, this number might indicate that such fine type of clay was probably a choice of the potter due to its availability or physical characteristics.

6.2.1.1.5 Clay pellets

The majority of the geological samples show clay pellets taking up 5-10% (or more) of the matrix. Such a high amount of clay pellets in the experimental samples is likely the result of poor wedging and poor hydration (Spataro 2017:64) or clay mineral characteristics as it was the case with GSC6. Continuous manual wedging and additional hydration did not completely dissolve the lumps in GSC6 which are best seen on the thin section scan (Fig. 6.15).



Fig. 6.15. GSC6, fired sample (1050° C), thin-section scan.

Clay pellets have been identified in only very few fabric types from Majiayao, some from Zhujiazhai and in none from Waguanzui. Few fine, coarse and semi-coarse sherds show different amounts of clay pellets which could be due to the natural property of the clay. Working with the clay during the firing experiment has shown that some samples naturally form lumps when soaked in water. Such clay needs several days to become fully hydrated and improve its plasticity. It is highly likely that the prehistoric potters put more effort into wedging and working with clay than the time limits of the laboratory experiment allowed the author. Coarse fabrics with high clay pellet amount from Luohantang might have been made using the type of clay such as GSC6 but insufficient clay processing by the potter might have also been the case. There is similar uncertainty with the origin of clay pellets in the Clay Pellet Fabric Group identified by Womack (2017:139, 141) in the sherds from the Tao River Valley. The firing experiment in this study has shown, that there are types of clay which naturally form clay pellets and there are types which become homogenised with less effort.

6.2.1.1.6 Optical activity

None of the geological fabrics fired at 1050° C has an optically active matrix, and some show vitrification. The fine, semi-coarse and coarse-fine-combination sherds from Majiayao and Zhujiashai show approximately equal distribution of active and moderately active sherd matrices which implies a firing temperature below 1050° C. Most of the coarse sherds from these sites are optically active. Only twelve samples from both sites have an optically inactive matrix, which indicates a firing temperature at 1050° C or above. All fabrics from Waguanzui are optically inactive which suggests that their firing temperature was close to 1050° C as well. The majority of fabrics from Luohantang are optically active. Different firing technology might have been employed at that site, but a larger sample size might show different results.

6.2.1.1.7 Porosity

All fine geological samples have a very low porosity, always less than 3% of the sample. A quarter of the fine sherds from Majiayao show the same void amount, but the majority of the sherd fabrics have 3-10% voids. The similar void amount of 3-10% has been observed in the fabrics from Waguanzui. The semi-coarse geological fabrics are more porous than the prehistoric pottery fabrics. The variety in porosity in fine fabrics could be due to small pieces of organic material that combusted during firing leaving voids. Thorough wedging can also reduce porosity by removing the air pockets from the clay mass (Hamer and Hamer 2015:396). The low porosity of the fine and coarse fabrics from Zhujiashai and Luohantang could indicate usage of similar low porous fine clays in the experiment.

There are three petrographic characteristics that need to be discussed further:

1. The absence of calcite, micrite or other carbonate rock inclusions in the thin sections of geological samples from Majiayao is notable, whereas there are pottery fabrics from this site rich in calcium-based inclusions. Thin sections of GSC20 and GSC21 belong to the Fired Group 2 that show light lime spalling when fired at $>900^{\circ}\text{C}$ but are not showing any calcium-based inclusions in thin section. There is a possibility that by chance there were no lime inclusions in the portion of the sample where the thin section was cut.
2. None of the samples fired at 1050°C showed a bloated matrix. The fabrics fired at 1050°C show moderate optical activity or are optically inactive. Two insights can be gained from this observation. First, clays that show moderate optical activity can endure temperature above 1050°C before they become inactive. Second, 1050°C is not a high enough temperature for the geological clays to start bloating. The general firing temperature $900\text{--}1050^{\circ}\text{C}$ estimation suggested by Ma (2000:31) can be supported by this experiment.

However, in the case of the experimental firing conducted here, the greater thickness of the fired briquettes than that of the prehistoric sherds might play a role in the thermal conductivity of the clay (Forget et al. 2015:86). One of the conclusions from the firing experiment is that it could be useful to make briquettes of a thickness similar to those of the Majiayao-style pottery to check if the clay would show different degrees of vitrification at temperatures $>900^{\circ}\text{C}$, and whether lime spalling is reduced in this case.

3. The samples show a varying amount of feldspar in fine fraction. The geological Fabric Group 2 has the lowest amount of feldspar in fine fraction:

0.1% in contrast to the other geological fabric groups that altogether have an average of 14% of fine feldspar. A similar observation can be made among the prehistoric pottery fabrics. Sub-fabrics 4B and 4C from the Majiayao site have coarse feldspar inclusions but no feldspar was identified in the fine fraction. Fabrics 2 and 3 from Waguanzui show no feldspar inclusions but the different thickness of the thin sections affected the analysis results of the sherds from this site.⁵⁰ Sub-fabric 4D from Zhujiazhai shows coarse feldspar, and Fabric 5A shows no feldspar inclusions. Fabric 1 from Zhujiazhai and Fabrics 1B, 8 and 9 from Luohantang have fine inclusions smaller than the medium silt size. In these cases, it is not possible to clearly identify feldspar inclusions using a petrographic microscope. The varying feldspar amount in fine fraction could indicate the usage of different raw clays that were available to the potters.

6.2.1.2 Sand

The composition of the sand sample GSC2 combines the most common minerals observed in this petrographic study – quartz and feldspar – and sedimentary as well as carbonate rock fragments (Fig. 6.16) with few metamorphic rock fragments such as quartz-mica schist. Rounded black opaque inclusions similar to the ones identified in the pottery fabrics, were found among the sand grains. These could be fragments of iron oxides, such as haematite. The variety of rock types identified in the sand sample is similar to the mix of sedimentary and metamorphic rock samples that were identified in the coarse pottery fabrics. This could indicate that the clays used to make those fabrics were mixed with sand, as suggested in the petrographic study of the pottery (section 5.2). The common coarse sand-/ fine

⁵⁰ They were cut thicker than 30 µm.

gravel-sized granitic rock inclusions as they appear in the pottery fabrics were absent from the sand sample. Additional petrographic analysis of sand samples might show some granite content in the sand. For now, the data from GSC2 supports the suggestion that granitic fragments came from a crushed rock and were added as temper by prehistoric potters.

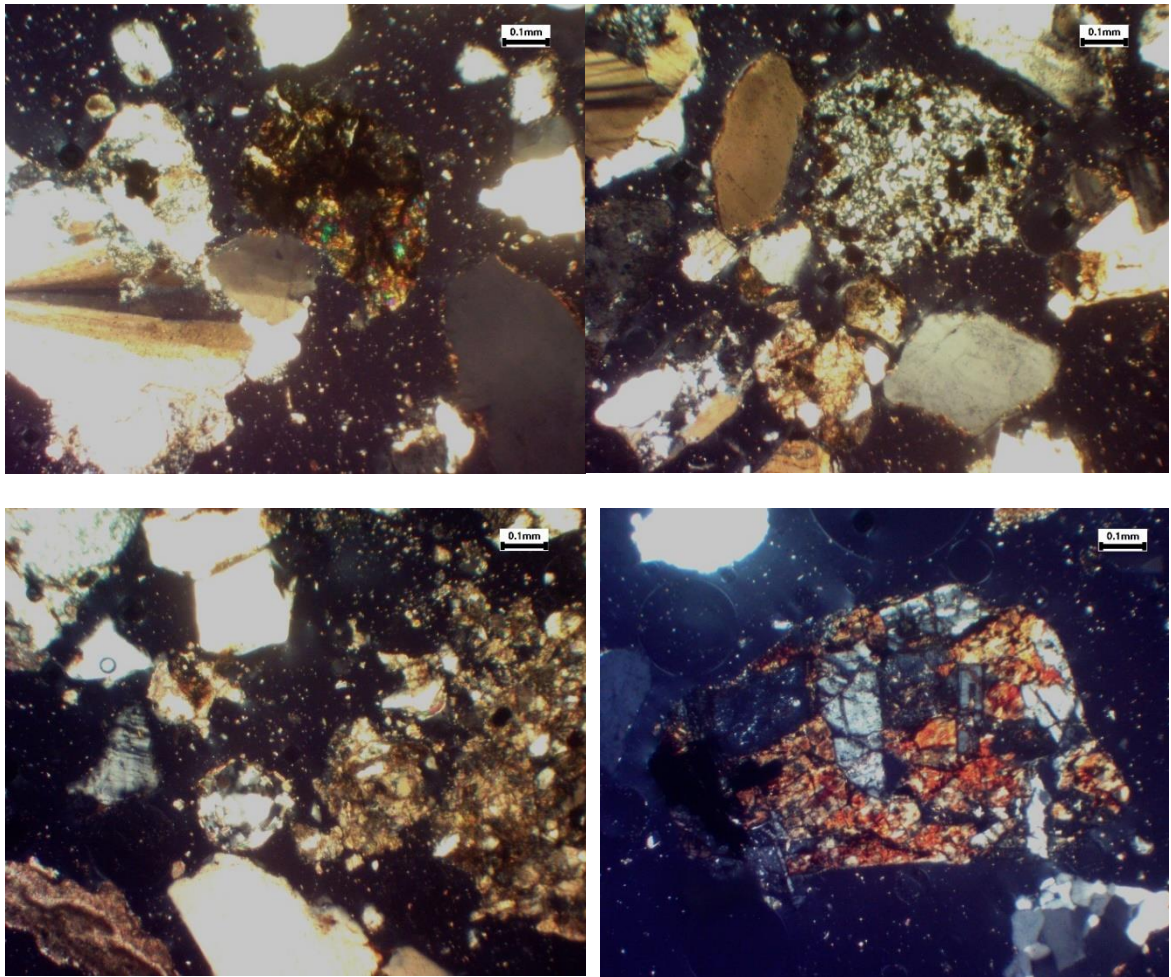


Fig. 6.16. Sand sample GSC2 from the Tao River Valley; unfired, photomicrographs taken under XPL, scale size 0.1 mm. Identifiable grains are quartz, feldspar, sedimentary and carbonate rock fragments as well as black opaque fragments and volcanic(?) rock fragments.

6.2.2 Rock samples

Twenty-nine rocks have been collected from four different locations around the Majiayao site (Table 4.3, Fig. 4.9). Thirteen thin sections were made from rocks from each location (Table 6.5). The selection of these samples aimed to include

different types of rocks which could have been used as a tempering material, in this case sedimentary and igneous rocks.

Table 6.5. Thin-sectioned rocks and their location of collection.

Location	Sample number and total number rocks	Thin-sectioned rocks
South of the Majiayao site, west tributary of the Tao River	GSC3, 9 rocks	• GSC3-1 Fine Sandstone • GSC3-2 Coarse Sandstone
North of the Majiayao site, at the foot of a loess hill	GSC7, 4 rocks	• GSC7-1 Coarse Sandstone • GSC7-2 Fine Sandstone
West of the Majiayao site; hill/mountain top	GSC15, 3 rocks	• GSC15-1 Carbonate rock
North of the Majiayao site; Tao River riverbed	GSC22, 13 rocks	• GSC22-1 Conglomerate • GSC22-2 Gabbro • GSC22-3 Limestone • GSC22-4 Andesite • GSC22-5 Marine limestone • GSC22-6 Coarse Sandstone • GSC22-7 Carbonate rock • GSC22-8 Granodiorite • GSC22-9 Fine Sandstone

Despite the variety in rock types, three minerals – quartz, carbonates and feldspar dominate the rock composition (Fig. 6.17). No metamorphic rocks were identified among the collected samples, which primarily consist of sedimentary and igneous rocks. This does not mean, however, that metamorphic rocks were not present in the area as few metamorphic rock fragments such as quartz-mica schist were identified in pottery fabrics and sand samples. The rare occurrence in the sediment and absence among the rock sample selection indicate that metamorphic rocks occur less frequently in the study area than sedimentary and igneous rocks. Black opaque inclusions have also been identified in the sedimentary rock samples. As suggested for the sand sample composition, these inclusions could be ore fragments or organic matter. Sedimentary rocks such as sandstones, where the

space between the individual mineral inclusions is large, show different types of matrices: calcareous or micaceous clay (Fig 6.18).

Most common minerals in the composition of 13 rock samples from the Tao River Valley (average amount in %)

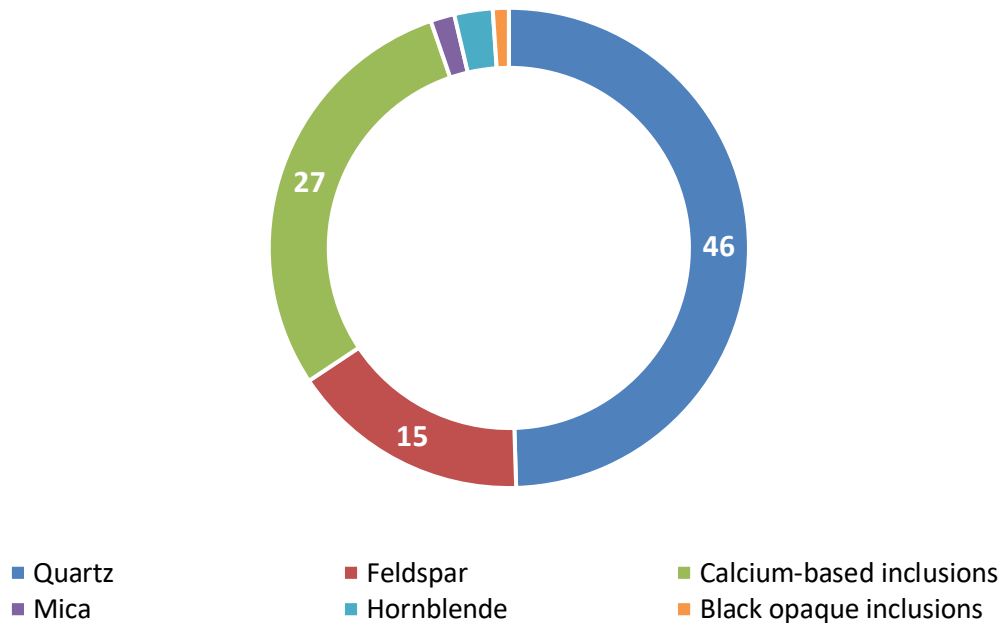


Fig. 6.17. Most common minerals in 13 rock samples from the Tao River Valley; average amount in %.

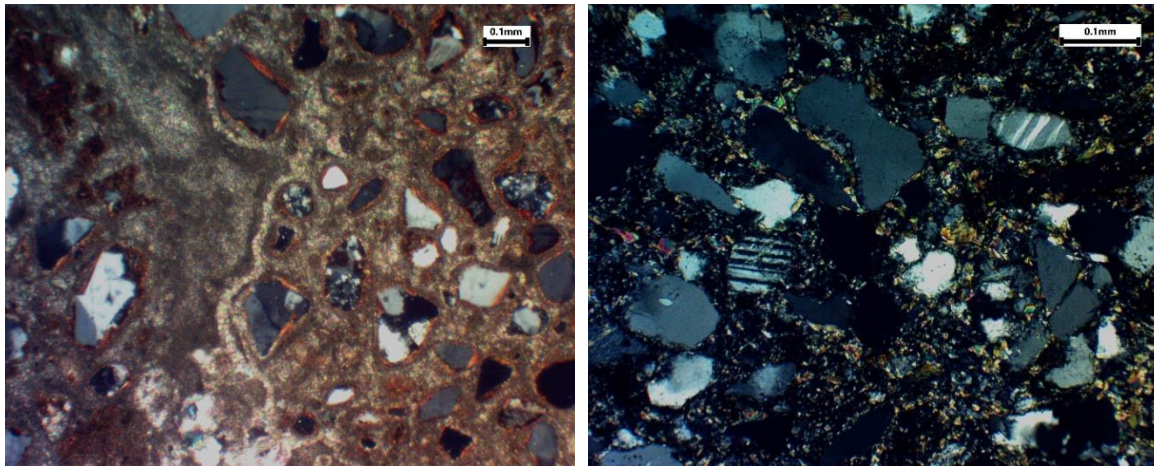


Fig. 6.18. Matrices in the sedimentary rock samples, photomicrographs taken under XPL, scale size 0.1 mm; left – calcareous matrix, GSC3-1; right – micaceous clayey matrix, GSC7-2.

The dominant minerals identified in the rock thin sections reflect the dominant coarse minerals found in pottery sherds. These are quartz, feldspar and calcium-based inclusions (Fig. 6.17).

No coarse granodiorite rock fragments closely resembling the fragments found in the sherds with prominent coarse biotite inclusions have been found in the sedimentary rock samples or in the sand sample. Only GSC22-8, which is a granodiorite, showed grains similar to the inclusions in pottery fabrics.

Rare volcanic rock inclusions that are found in the pottery fabrics have been also identified in the GSC2 sand sample and in GSC3-2 sandstone rock sample (Fig. 6.19). It has been suggested in this study and also by Womack (2017:44, 138-139) that river sand was likely used as temper in the Majiayao pottery. Given that sandstone is composed of consolidated sand and occurs frequently in pottery fabrics it is also possible that crushed sandstone might have been used as temper.

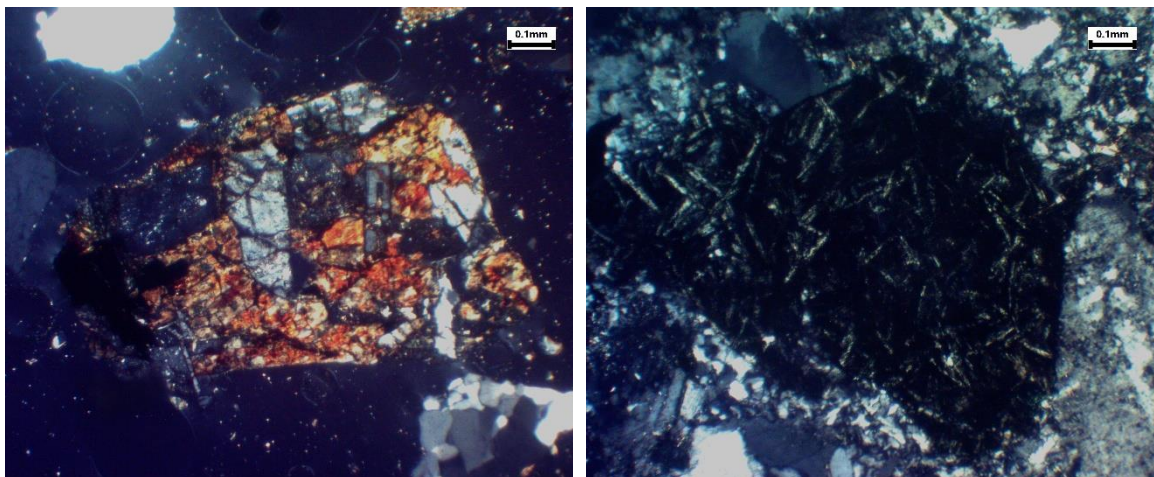


Fig. 6.19. Volcanic rock fragments found in the geological samples and in the pottery sherds; photomicrographs taken under XPL, scale size 0.1 mm; left – GSC2 sand, right – GSC3-2 sandstone.

6.2.3 Summary

Petrographic analysis of the eight GSC sediment samples has shown that naturally present material has mostly fine sand or coarse silt grain size with a few semi-coarse samples. No coarse sand or fine gravel sized inclusions were found in the GSC samples in contrast to the CNP fabrics from Majiayao which led to the conclusion that the coarse CNP fabrics were produced by temper being added artificially by the potters. A further difference between the geological samples and

the coarse CNP Majiayao fabrics was the absence of coarse calcite in the GSC samples which fired successfully and were not damaged by lime spalling. It is possible that a clay type similar to the samples from Fired Group 2 was used to produce the calcite rich CNP fabric from Majiayao but underwent further processing to prevent the damage by lime formation.

Another indicator of clay preparation in most CNP fabrics is the rare presence of clay pellets whereas five of the eight GSC samples have >10% clay pellets in the matrix. The homogenised CNP fabrics suggest thorough working of the clay: sufficient hydration and wedging, and possibly aging.

The analysed GSC thin sections were made from briquettes fired at 1050° C and five of the eight samples show an inactive matrix indicating that the average firing temperature for the CNP samples, if they were made from similar materials, was below 1050° C.

The petrographic composition of the sand sample GSC2 supports the suggestion that river sand could have been used as tempering material next to the crushed granitic rock. Granitic rock inclusions have not been identified in the sand sample in similar shape and size as they were present in the CNP fabrics. The petrographic composition of the GSC igneous rock samples such as GSC22-8 granite or GSC22-2 gabbro is more similar to the coarse granite-rich CNP fabrics than the grains in GSC2. The calcareous matrix in sedimentary rocks such as GSC3-1 sandstone suggests that the coarse calcite in Majiayao CNP fabrics could have come from crushed sandstone. On average, the petrographic composition of the GSC rock and sand samples reflects the types of minerals and rock fragments identified in coarse CNP fabrics from all three river valleys.

7 Discussion: Majiayao-style pottery technology and transfer

The present study argues that the production of the Majiayao pottery in the three river valleys (Tao, Huangshui and the Yellow River) went beyond the copy and replication of visual features and involved exchange of technological knowledge. The first part of this chapter outlines the similarities and the differences in the *chaîne opératoire* between the pottery from the three river valleys. The second part of the chapter discusses the possibility of the technological knowledge transfer in the study area based on the reconstructed *chaîne opératoire*.

7.1 Technological choices in Majiayao-style pottery production

7.1.1 Raw material selection and paste preparation

Analyses of the GSC geological clay samples and CNP prehistoric pottery fabrics suggest that the following steps of raw material selection and paste preparation were undertaken during the Majiayao-style pottery production.

1. Procurement of red clay and rocks/ sand for tempering.
2. Crushing/ grinding clay to create powder; eliminate lumps if it is naturally wet.
3. Crushing/ grinding and adding granitic rock or sand/ crushed sedimentary rock to the clay mass to create coarse fabrics (the mixing with clay can happen in wet or dry state)
4. May or may not have taken place: before adding temper or to create fine paste, clay purification by sieving or sedimentation; clay aging.
5. Mixing with water, wedging the clay paste with or without coarse temper to create a homogenised texture.

Clay and temper selection is discussed in the sections below.

7.1.1.1 Clay selection

The base clays used for the Majiayao-style pottery analysed in this study are aeolian or alluvial red clays. Based on chemical analysis, Hung (2011:225) suggested that Tertiary red clays were used for Majiayao pottery production. The Tertiary red clays are the clay deposits below the brown loess layer described in section 4.4.1 (Hung 2011:69-70). Hung (2011) did not consider the alluvial red clay deposits in her study and came to her conclusion by comparing the chemical composition of Tertiary red clays from geological research to her own pottery analysis results. This study has shown that both aeolian Tertiary clay, such as GSC1 (based on the deposit location on the hill), and alluvial clay, such as GSC21 (from the Tao River riverbed), have a high plasticity and are malleable. However, GSC21 showed lime spalling and was damaged after firing. The clay sample GSC1 fired successfully. It has a finer groundmass than GSC21 which has higher fraction of medium sand-sized grains. Both of these types of clay are of secondary origin which means they were deposited or re-deposited by forces of nature such as wind or water. The secondary origin is reflected in the clay colour and composition, as has been explained previously: the red brown hues are due to the content of iron oxides and carbonaceous matter which accumulated during the transportation process.

The petrographic analysis of the GSC geological clay samples shows that among the clays around the Majiayao site there were naturally fine types and well-sorted semi-coarse types. The inclusion frequency of the GSC fine red clay samples matches the most common inclusion frequency of the fine CNP fabrics: 20-40%, but does not go below it, whereas <20% inclusion content is found in many CNP samples. The GSC semi-coarse red clays have an inclusion frequency above 40%.

These observations raise the question of clay purification in the prehistoric production process. It is possible that levigation or sedimentation could have been involved, for example, for the natural plastic semi-coarse clays (e. g. GSC21) to create fine fabrics. This could explain the 1-5% coarse sand fraction found in some fine CNP samples, which could be a trace of a natural semi-coarse material that underwent levigation. The CNP pottery samples which have a fine fraction of medium silt size or less suggest a screening process. There are two geological clay samples (GSC5 and GSC6) which naturally have a fine fraction of the same size as these pottery samples. These clays were sampled from the clay source used by potter Mr Ma, taken at the same altitude at a few meters distance from each other. The samples are plastic and malleable. However, GSC5 exploded in the kiln during all three firings, and GSC6 needed days to slake and was a very sticky clay. If used by the prehistoric potters in the Tao River Valley, these clays might have undergone additional processing in contrast to, for example, GSC1 which was quite easy to process. If Majiayao-style pottery was made with GSC5 or GSC6, the making process required a specific knowledge in techno-science of preparation and firing of these clays. Slow slaking might further complicate the process of bringing the clay to a plastic state (Shepard 1985:17).

Based on the results from macroscopic and petrographic analyses in this study, it can be concluded that the base clays for fine, coarse and semi-coarse CNP fabrics were natural fine or well-sorted semi-coarse clays which may or may not have been purified. According to the local geology as described in published studies (section 4.4.1) and the author's personal observations, red clay deposits would have been available around all sites. Among the CNP pottery samples with a fine fraction of medium silt size and smaller are more frequent in the coarse and fine

fabrics from Luohantang and Zhujiashai than from Majiayao or Waguanzui. This may suggest a preference of the potters for very fine clay which could have been naturally fine or levigated.

Until further geological sampling in the Huangshui and Yellow River valleys is conducted, it cannot be determined whether the red clay deposits in these valleys are similar to the deposits around the Majiayao site. According to the description of the Xining basin there are clays with a deep red colour and lighter coloured gypsiferous red clays (section 4.4.1.2) which may be similar to the calcium rich red clay GSC samples in the Fired Group 3 in from the Tao River Valley (section 6.1.1.5). High amounts (<40%) of fine and possibly primary calcite were only present in the groundmasses of a few fabric groups from Majiayao suggesting a different clay composition. In the thin-sectioned GSC samples no calcite inclusions were identified, even in GSC21 which showed light lime spalling. The Fired Group 2 in the firing experiment includes the highest number of the sampled GSC clays. The GSC samples in Fired Group 2 showed different degree of lime spalling up to complete pulverisation. Ma (2000:47) suggested that the calcite content in clays can be reduced through levigation. His suggestion appears to be primarily based on the varying calcium amounts in the fine pottery sherds he analysed chemically, finding varying amounts of calcium. The firing experiment in this study has shown that the clays can naturally have different amounts of calcite based on lime building. Nevertheless, levigation may help to reduce the calcium particle size and content in the clay and reduce the risk of damage by lime spalling (Hamer and Hamer 2015:213). Womack (2017:140) sampled a carbonate rich clay bed and suggested that this could be the source for the fabrics with coarse carbonate inclusions from the Tao River Valley. However, he did not fire it to see if it would

show any degree of lime spalling. Coarse carbonate inclusions, such as in the Fabric group 5A-B from Majiayao, could have also come from crushed sedimentary rock with calcareous matrix or calcium-based inclusions (Figs 6.17-18). The firing temperature for the coarse fabrics and its impact on lime building has not been fully addressed in this research, yet, but see section 7.1.4 below.

7.1.1.2 Temper

The three types of temper which have been suggested in this study occur in coarse CNP fabrics from the three river valleys: river sand, crushed rock – granitic or sedimentary, and grog. Womack (2017:44, 138-139) suggested river sand as tempering material in Majiayao-style pottery. He did not identify granitic inclusions in the coarse fabrics from his study area. He found coarse biotite and hornblende but was not certain if this was added material or came from an unsampled clay source (Womack 2017:140). Stilborg and Hein (2019:112) identified crushed granitic rock and river sand as temper in four coarse Majiayao sherds.

In this study, the manually added temper was identified based on its grain-size and comparison with the geological samples. The poorly sorted coarse CNP fabrics indicate that the coarse fraction of coarse sand (CSa) and fine gravel (FGr) sizes was manually added to the base clay. Clear examples are CNP fabrics from Luohantang which have CSa-FGr coarse fraction contrasting with a fine fraction of MSi size and smaller. None of the geological clay samples has shown a FGr sized inclusions in a similar frequency as they occurred in the CNP pottery fabrics. The comparison of coarse rock fragments with the FGr sized grog temper in the CNP samples from Zhujiazhai led to the conclusion that dominant inclusions of this size were likely added manually. Crushed sedimentary rock and river sand are very

similar in composition because sedimentary rock such as sandstone is consolidated sand. Similar inclusion types have been identified between GSC3-2 sandstone and GSC2 loose sand sample (Fig. 6.19). River sand, sedimentary and carbonate rocks can be frequently found in all river valleys. In the Tao River Valley, granitic and other igneous rocks appear more frequently closer the Maxian mountain (Womack et al. 2021:12) northeast of Majiayao than in seems to be the case near the site. Based on the geological description (see section 4.4.1.2-3) river sand, granitic and sedimentary rocks would have been present in the Huangshui and Yellow River Valleys and also in vicinity of the Zhujiashai and Luohantang sites. Grog temper has only been identified in a few coarse CNP pottery samples from Zhujiashai.⁵¹ The material from Zhujiashai had crushed granitic rock and river sand as temper. Grog tempering suggests another way of clay preparation next to the granite or sand tempered fabrics. It is possible that the grog tempered sherds do not classify as the Majiayao style. The size of these sherds does not allow for a certain style identification; however, they have red paint, cord impressions and appliqué decoration. It is possible that these sherds belong to a local as yet unidentified style existing in parallel to Majiayao. It is also possible that these sherds come from a later context but were collected by Andersson together with the Majiayao sherds.

Mixing clay and temper could have happened while the clay was in wet or in dry state. Kneading the temper into a wet clay mass to ensure a well-homogenised paste is more time and energy consuming than dry mixing. Dry mixing of temper with ground clay would result in homogenised clay paste in less time and requires less energy investment from the potter. The majority of the CNP pottery fabrics are

⁵¹ CNP84, 89, 90, 91, 104, 182.

well-homogenised, clay pellets are only prominent in CNP fabrics from Luohantang. Well-homogenised fabrics imply time and energy investment in wedging, hydrating and perhaps aging the clay mass. As observed in the GSC clay samples, there are plastic and sticky clays that require more than 24 hours to fully hydrate and become malleable (e. g. GSC6). Such clays form lumps which are observed as clay pellets in thin section. There was no clear indication for a mixing of two different clays in the CNP pottery fabrics except in the coarse-fine-combination where different groundmasses are clearly distinguishable in the two fabrics.

Overall, among the CNP pottery fabrics there is a clear distinction between coarse and fine fabrics. Semi-coarse fabric is rare among the sampled sherds. The coarse fraction in semi-coarse samples could be naturally present and it differs significantly in size and amount from the coarse fraction in coarse fabrics. It is possible that the prehistoric potters were not aware of the minimal grain-size difference between a semi-coarse and a fine fabric as it can be observed under the petrographic microscope.

The stark distinction between coarse fabrics frequently combined with rough to the touch impressed decoration and fine fabrics with smooth often painted surface opens the questions about social knowledge behind the design of the vessels. Were the consumers of this pottery aware that the pottery with the rough textured surface was also made from a rough coarse fabric? Evans (2003:47, 58) suggested that social knowledge can be investigated through textures of pottery and that feeling coarse and fine textures of clay or soil in general might be associated with some kind of human experience. Evans (2003:58) described barrows constructed as boundaries between different textures of the land on Neolithic sites in Britain. Evans (2003:58-59) suggested that the clear boundaries between virgin and

cultivated land or, rubbly and stone-free soil could relate to a guilt feeling because of the disturbance of the soil through agricultural activity. Construction of the long barrows and separating the virgin soil from cultivated land would then be a means to come to terms with the guilt of the inflicted damage (Evans 2003:58).

While an association of clay texture with any human experience is impossible to test for archaeologically, the contrast between fine and coarse fabric and their deliberate combination with decoration types is highlighted by the sherds with coarse-fine-combination fabrics. Stilborg and Hein (forthcoming) came to a similar conclusion in their study of the sherds with coarse-fine-combination sherds. However, their argument had a somewhat different basis from the argument in this study as it is based on the analysis of the paste and decoration of such type of sherds only. Stilborg and Hein's study (forthcoming) did not include analysis of simple fine and coarse material and concluded that among the sherds combining both fabrics all of them show combination with painted and impressed decoration. The present study extended the discussion of this design issue and established that the deliberate tripartite combination of clay fabric, type of decoration is the case for the majority the sampled fine and coarse sherds from all sites (119 sherds out of 187). The distinction between clay textures is emphasised by the sherds with coarse-fine-combination fabric, even though the coarse grains are not directly observable on the outside. The coarse and fine fabrics are designated by different decoration, in most known cases, implying a common knowledge not only between producers but also between consumers (Kohring 2012:113). This association between clay fabric and vessel decoration as the link between pottery maker and pottery consumers provides a glimpse into social knowledge which cannot be reconstructed based on other archaeological evidence. This link can serve as a

point of departure to discuss whether the makers and consumers perceived themselves as a community over a wider area in a future study.

7.1.2 Forming and finishing

The results of the macroscopic study of the complete vessels and sherds suggest the following forming and finishing steps.

1. Coil-building the vessel walls on top of a base slab with short drying phases in-between.
2. Beating the body to thin the walls and strengthen the coil joins.
3. Coil-building the neck and finishing it on the turntable.
4. Leaving the body to dry enough
 - a) to be burnished/ polished.
 - b) to apply cord impressions.

The primary building technique involved stacking coils of clay on top of a base slab and connecting them by pinching or spreading. The coiling was interrupted by a short drying phase to stabilise the vessel walls and prevent them from collapsing. The secondary forming technique performed on the vessel was beating and pulling to thin the walls and strengthen the coil joins (Wu 1938; Vandiver 1989). The roughed-out coiled shape of the vessel was further refined during this process. The neck was built with extra coils attached to the vessel shoulder. The base coil of the neck was pressed onto the shoulder and possibly strengthened with an additional layer of clay on the inside (Fig. 5.38). The neck was then finished on a turntable to create a round opening and a slightly flared rim as can be inferred from the striations on the neck (see Annex 2: Rim and neck). Based on the findings in this study, it can be concluded that a turntable was known to and used by Neolithic-

period potters in the three river valleys and was used in rim forming. It cannot be determined for certain if the vessel body was also made on a turntable. Roux and Courty (1998; 2019) investigated this issue by using the turntable at different stages of the coiling process and examined the similarities and differences in the orientation of inclusions in thin section. The photomicrographs of the groundmasses of some CNP samples from all three river valleys show a parallel alignment of fine particles clear orientation of inclusions (Fig. 5.45). However, this alignment may be a result of pressure applied by beating. Whether a turntable was used for vessel body construction of Majiayao-style pottery or not requires further investigation through macroscopic analysis of vessels and experimental work.

After the vessel was built, it was left to dry until leather-hard, if the intended decoration was painting. The area of the globular upper body of a vessel was probably burnished on a turntable, as the long parallel horizontal furrows indicate (Fig. 5.46; Schreiber 1999:45), by using a hard object such as a pebble or perhaps a sherd (Rice 2015:149). Smaller areas such as the neck surface were burnished not on the turntable, as the short strokes left on some vessels indicate (Fig. 5.47; Schreiber 1999:46).

The burnishing/ polishing was not performed on the vessels that were intended for cord-impression decoration. These vessels were left to dry enough for the impressed decoration still to be visible. The varying depth of cord impression on the same vessel may indicate different drying stages of the vessel parts or difference in pressure with which the pattern was applied.

7.1.3 Decoration

The steps in applying the painted or impressed decoration are different. The technological sequence for applying painted is outlined and discussed first,

followed by the outline and discussion of the cord-impression and appliqué decoration application.

7.1.3.1 Paint

Paint application involved the following steps:

1. Procurement of raw material: rocks and minerals - for pigment making; possibly organic material as binder.
2. Crushing and grinding raw material into powder. Potentially, the powder could have been subjected to sieving or sedimentation to separate the fine pigment particles from the coarse to obtain a very fine powder when its dry. Very fine pigment powder would ensure even layering of the paint on the vessel surface without coarse grains interrupting the flow. However, no evidence of this process was found in the research material.
3. Preparing the paint mixture of desired viscosity using pigment
4. Painting the geometric ornaments characteristic for the Majiayao-style on a vessel using a turntable and a brush.
5. Letting the paint dry.

The application of a slip could not be identified for certain using petrography and macroscopic analysis, but it cannot be ruled out. SEM analysis would have helped but was not possible due to restricted lab access because of Covid-19. Two different mineral pigments were used for making paint. It is likely that these pigments were mainly obtained from hematite and manganese in the Tao River Valley, possibly even from the deposits close to the Maxian mountain (Su 2006:61; see section 4.4.1.1), and the same minerals were possibly used for the pottery production in the Yellow and Huangshui River Valleys as well (Palmgren 1934: 174, ft-note 2; Ma 2000:54-58; Li and Yu 2018:50). The predominant colours are black

and red; however, red can appear in different hues from brown to dark blue (Fig. 5.57). The differences in paint hues may be caused by the presence of different major elements or trace elements, as suggested by Ma (2000:60).

The time and energy invested in paint preparation depends on the hardness of the raw material containing the pigment. Soft material such as earthy hematite or limonite with a high clay particle content may have been easier to crush and levigate to reduce the particle size (Shepard 1985:43; Hamer and Hamer 2015:172, 215, 245). The pigment obtained from a crystalline rock such as manganese ore needs to be crushed and grinded into powder and possibly additionally levigated to get the particles as fine as possible (Li and Huang 1993:74; Constantinescu et al. 2007:282-283).

The soft earthy pigments do not require binding material to adhere to the vessel surface; they contain a high amount of clay that acts as a natural binder (Shepard 1985:33). The mineral pigments from a crystalline rock may require a binding material made from organic matter (Siddall 2018:201), unless they contain enough impurities such as clay particles for better adhesion (Shepard 1985:40, 42). If used without binder, manganese paints need polishing to compress the particle and better attach to the surface (Shepard 1985:42). A high proportion of alumina in a paint sample may suggest that the clay was present in the pigment (Shepard 1985:42) or may have been added as a binder (Stewart and Adams 1999:679).

The complete vessels analysed mostly show a high degree of paint preservation. There are examples where the paint, particularly black, did not preserve as well (Figs 5.57c, 5.58a-b). Vessels from Zhujiazhai show the lowest degree of red and black paint preservation (e. g. Fig. 5.59a). It has been pointed out by Womack (2017:174) that the post-depositional environment in the study area was unlikely

the cause for different paint preservation. Possibly, miscalculation in pigment, clay and binder proportions in the clay recipe caused the paint to fade. The proportions of these elements in the research of pigment used for the Majiayao-style paint have not yet been addressed; this will have to be a topic for future research. The chemical composition of the organic binder may not show up on the data sheet because it would have combusted during firing (Stewart and Adams 1999:679) but the clay content reflected in the alumina amount might be present. Li and Huang (1993:74) crushed red hematite in their experimental study and described that the finer the particles of the pigment, the better adhesion. The authors did not mention use of any binder and just added water to the crushed powder (Li and Huang 1993:74). The authors further pointed out that the consistency of the pigment must not be too thin or too thick because it will negatively affect the paint flow (Li and Huang 1993:74).

Painted decoration was applied using a brush on a dry vessel for better adhesion (Li and Huang 1993:74; Rice 2015:161) and on a burnished or polished surface to ensure an even paint layering, as an uneven surface could interrupt the paint flow. The geometric ornaments running around the vessel body imply the usage of a turntable at this stage as well (Li 1984:57).

7.1.3.2 Cord impression and appliqué

1. Producing cord marks by:

- a) Pressing a tool wrapped with a woven cord to a leather-hard surface to create a single or cross-cord pattern.
- b) Wrapping around and pressing a woven-cord sheet into a vessel to create an even diagonal cord pattern.

2. The appliqué could be applied before or after the cord impressions. The most common appliqué type among the vessels and sherds analysed in this study are flat clay bands pressed by a finger or a slim tool onto the vessel surface.

The cord impression required a woven cord which was possibly wrapped around a stick or a dowel to create single or cross-cord patterns. The diagonal cord impression which creates a spiral wrap-like effect would require a sheet to create an even uninterrupted cord pattern.

The repeated design of impressed cords implies technological knowledge of cord weaving. The size of cords varies slightly and appears to be very similar in all three river valleys. The cords could have been impressed using a cord-wrapped tool (La Duc and Chang 2017), a cord-wrapped paddle during the beating process or a cord-sheet as a wrapping, as has been suggested in this study for the diagonal cord pattern.

Appliqué decoration is commonly applied in form of horizontal bands. These bands can run continuously around the vessel body (e. g. K-06309) or are applied in short strips (e. g. CNP137). They have an undulating relief which could have been created either by a finger or a tool with a flat rounded end pressing down on it in short intervals. Appliqué bands can be applied after the surface has already been impressed with cords (CNP137). It can also be applied before the cord-impression so that it does not create an interruption in the cord pattern (CNP28). There is a case among the sampled sherds where the appliqué bands were attached after the body was impressed and then received their own cord-impression (CNP23).

7.1.4 Firing

Insights into the firing process gained from the macroscopic and petrographic analysis of the complete vessels and sherds mainly concerns firing temperature and atmosphere. The steps in the process regarding the kiln work listed here come from published research (Ma and Li 1991; Gosselain 1992; Ma 2000; Livingstone Smith 2001; Thér 2004; Rice 2015) and the author's own observations of modern built wood-fuelled updraft kilns.

1. Kiln building and fuel procurement.
2. Kiln loading and sealing.
3. Starting the fire.
4. Overseeing the temperature degree and oxygen supply.

It is unclear how long the firing process lasted and at what point after firing the kilns were unloaded. Archaeological research in the Gansu Province has shown that downdraft and updraft kilns were used on sites dating to the Majiayao period (Ma and Li 1991:268; Zhongguo Ciwang 2020), although very few kiln features have been excavated in the entire Gansu-Qinghai region. The potter Mr Ma, who lives in the Tao River Valley, uses an updraft kiln that he built himself to fire his Majiayao-style replicas. From the outside the kiln appears to have two chambers connected by a corridor for convection (Figs 7.1, 7.2).



Fig. 7.1. Mr Ma's kiln: fire chamber; the chamber for loading pottery is on the right.



Fig. 7.2. Mr Ma's kiln: tall chamber for pottery loads; the firing chamber is on the left.

The maximum temperatures which can be achieved in updraft kiln firings range between 900°-1000° C (Rice 2015:169). This temperature has also been estimated for the firing of the painted Majiayao-style pottery in the previous research by using XRD, FTIR and high temperature dilatometer (Ma and Li 1991; Ma 2000). The present study agrees with these temperature estimations based on the petrographic analyses of the clay matrices of the CNP pottery samples and comparison to the high fired GSC clay samples. The firing temperature for the coarse pottery has not been separately researched with scientific methods yet. Bylin-Althin (1946:436) suggested 600° C for the firing of the coarse pottery based on the fabric's high porosity. The pottery becomes less porous the higher the firing temperature, because the clay matrix shrinks and closes the pores (Rice 2017:105). However, shrinkage of the matrix can also create ring-shaped voids around large inclusions (Quinn 2013:158). It is unclear which of these two types of porosity – in the matrix or around coarse inclusions – was meant by Bylin-Althin (1946:436). It is possible that the firing processes and temperatures could have been different for the coarse and fine pottery. The differently coloured layers in cross-sections of CNP samples have shown that there were discontinuities in the firing atmospheres e. g. in oxygen flow and temperature control. Most coarse fabric samples analysed in this study had been fired in reduction as the last firing atmosphere, and the majority of the fine fabrics in oxidation as the last firing atmosphere. This difference suggests that pots with different fabrics were fired separately. The majority of samples fired in a fully reducing atmosphere have been identified in the material from Majiayao.⁵² Most of these samples are coarse and contain coarse or fine calcite inclusions. Interestingly, according to Rice (2015:81) and Gliozzo

⁵² See Annex 3.

(2020:8), the decomposition of calcite and lime spalling can be avoided by firing in reducing atmosphere. It is not clear, if the knowledge of this process was a part of the techno-science of the prehistoric potters or the pottery containing coarse calcite was fired dark because it had coarse fabric and had impressed decoration. There are no samples from Waguanzui, Zhujiashai or Luohantang which show full reduction in cross-section. Most pottery from these sites which was intended to have a dark coloured surface has an oxidised core. Different degrees of incomplete iron reduction were observed in the cross-section – from clearly visible dark margins to a thin dark layer on the outer surface. This implies that the reducing atmosphere was created towards the end of the firing after the carbonaceous matter in the clay has completely oxidised. A method to create dark coloured surface towards the end of the firing is smudging (Rice 2015:177). It involves covering the pots with a fine organic matter to stop the oxygen flow and let the carbon set on the surface (Rice 2015:177). Smudging can be seen in cross-section as thin layers of carbon deposition in the pores on the margins (Rice 2015:280). However, smudging is process done in an open firing to have access to the pots to place the organic matter on top. There are examples of sherds where the dark outside surface has different shades of black and grey, suggesting uneven reduction, and sporadic red spots on the outside or complete red inside (e. g. Fig. 5.119).⁵³ If the assumption about two separate firings for coarse dark fired and fine red fired pottery is correct, there may be a possibility that dark-coloured pottery was fired in an open firing instead of a kiln. Experimental firing of replicas in a pit involving smudging at the end may show how well this firing method would have worked for creating the dark coloured surface.

⁵³ Further examples are CNP23, CNP28, CNP30, CNP103, CNP137, CNP175.

The comparison of the oxidised painted CNP samples and oxidised GSC clay samples revealed that an additional technological step could have been involved in firing to create the pale yellow/ buff background colour on the painted pottery. None of the GSC clay samples show a similar hue of yellow, and are mostly orange, similar to the colour on the unpainted vessel K-05279 (Fig. 5.68 and Annex 2) from Waguanzui. K-05279 was fired in oxidation but was not painted indicating that it was fired differently than the painted vessels. Possibly, the combination of a particular raw material type and a firing technique created the uniform yellow background on the painted pottery. It is yet unclear what influences the colour the most – the clay preparation or the firing technique. Nevertheless, there are examples of pottery from all four sites which were fired in oxidising atmosphere, and all the unpainted vessels/ sherds analysed in this study show a brighter shade of orange than the painted ones.⁵⁴

Apart from the colour difference between the prehistoric pottery and the geological samples fired in oxidising atmosphere, both groups show a different hardness. Ma and Li (1991) determined the hardness of the painted sherds to be 3-4 on Mohs scale of mineral hardness which applies to the most CNP fine fabrics. However, CNP72-74 and CNP76-80 from Waguanzui appear to be softer because they were leaving yellow streaks on the surfaces and on the fingers if slightly rubbed. Significant variations in hardness were also registered among the GSC fired clay samples. For example, when fired at only 700° C GSC1 became very hard and was difficult to crush with a hammer. The samples GSC10-12 were friable and crumbling. Similar to the above mentioned softer CNP samples from Waguanzui, GSC13 also left a streak on the fingers when touched. Sample GSC16 was easy to

⁵⁴ The plain yellow sherds from Waguanzui likely belonged to the lower body of a large painted vessel.

break apart using just hands. The effect of firing on the durability and hardness of the pottery could have played a role in the raw material selection.

No specific research has been done to address the type of fuels used in firing during the Neolithic, but it can be assumed that wood was used (Womack 2017:44; Rice 2015:182). At the present time the landscape in the study area mainly consists of grasslands with rare forests (Ma et al. 2004; Zhang et al. 2014). The vegetation could have been different in the Neolithic, as a climate change occurred during that time (Huang et al. 2004; Dong et al. 2012). It is unknown in which environment the largest production centres were located regarding fuel procurement. Based on the temperature estimations discussed in this study, the fuel amount should have been appropriate to allow for a full oxidation of the pottery.

7.2 Indicators for and extent of pottery technology transfer between different parts of northwest China

The reconstruction of the *chaîne opératoire* presented above includes newly inferred and already known techno-science for making Majiayao-style pottery. The technological choices discussed in this study suggest not only considerable experience in pottery making techniques, pyrotechnology, and painting and relief design but also extensive geological knowledge among the makers of Majiayao-style pottery. The choice of tempering material such as granite, sedimentary rocks and/ or river sand appears to be consistent over the study area, implying a background knowledge of their function and properties when added to the clay paste. The usage of coils, paddling, and turntable to shape specific vessel parts is identifiable on vessels from all sites. Creating different firing atmospheres for coarse and fine pottery and possibly two distinct techniques – kiln and open firing

– can be suggested based on the macroscopic analysis conducted in this study. It is yet unknown whether the natural properties of the clay or an additional step in the *chaîne opératoire* caused the fine pottery to fire a pale-yellow colour providing a contrasting and uniform background for painting. This characteristic is common on the fine painted pottery from all four sites and probably required specific knowledge of how to create it.

Before focusing on the discussion of the technological knowledge transfer in the study area it is necessary to summarise the differences in production inferred from the pots and sherds analysed in this study. Differences in the pottery from the four sites were identified mainly in the choice of clay and temper, decoration application and its preservation state, and firing technique.

Grog as the choice of temper was only identified in a few sherds from Zhujiashai and from no other site. It has been suggested above that those sherds may have belonged to a region-specific pottery style. The small sample numbers in this study do not allow for an investigation of local styles in each valley. However, it cannot be ruled out that local styles existed parallel to or imitated the Majiayao-style over the course of its lasting period of about one thousand years. Further variation in the choice of clay was observed on sherds from Waguanzui which were softer than the sherds from the other sites and left a streak on a hard surface. The firing experiment has shown that the clays in the Tao River Valley reach different hardness levels after firing and can become hard and difficult to break already after being fired at 700° C.

One significant difference in the firing technique that was identified among the samples is the reduction degree of the clay from the core to the margins. Full reduction of the core and margins was observed only on the samples from the

Majiayao site. This difference in the control of firing atmosphere could indicate generally varying techno-science of firing in the study area or personal experience of a potter. As it is the case with the variation in the raw material choice, the small sample number in this study does not allow for definite conclusions about this issue.

The macroscopic differences in the painted decoration were identified in its preservation level and in the hues of the red paint. Painted pots from Majiayao, Waguanzui and Zhujiashai exhibited varying levels of paint preservation: from very good (bright colours showing no use-wear traces or cracks) to very poor (colours almost completely faded on the entire vessel body). The shades of red varied greatly on the pots from the Tao River Valley which may have been influenced by the choice of pigments, paint preparation process and firing temperature. The possible causes of the red colour variety will be investigated in a future study involving SEM analysis.

Although the sherd number from the selection exhibiting these variations in the *chaîne opératoire* is small, it cannot be ruled out that the differences in production were much greater. This study includes a limited number of samples in comparison to the temporal dimensions of Majiayao-style pottery production. The technological choices may have varied over time not only between the three river valleys but also in within a valley as the samples from Majiayao and Waguanzui show.

Nevertheless, the similarities in almost every step of the Majiayao-style *chaîne opératoire* found in the pottery from the three river valleys are striking in their consistency. Possibly, this techno-science has developed not completely independently in each valley but was transferred or shared among potters in some

way. The possible starting points and destinations of the knowledge transfer will be discussed below. First, however, it needs to be clarified if the inferred techno-science from the pottery from all sites indeed suggests a technological transfer as defined in this study.

Technological transfer has been defined here as an adaptation of shared techniques to work with locally available raw material (Gosselain 2000:206; Nikolakopoulou and Knappett 2016:109). Even though the geology and potential available raw material are similar throughout the study area, it remains unclear if there was a preference for a particular clay type until geological survey and field sampling is conducted in the Huangshui and Yellow River Valleys. The identified types of temper in coarse samples from all sites suggest that the potters deliberately procured and worked with granite and river sand. In general, the pottery was made in a very similar way suggesting that it was not only copying the outer appearance. A possible imitation of the Majiayao style might have been produced in Zhujiashai, using different clay paste and paint recipes. However, this difference only reinforces a suggestion that specific techno-science and *chaîne opératoire* existed for producing pottery in Majiayao style. Therefore, this study suggests that transmission of technological knowledge to produce this pottery took place in prehistory.

It is generally assumed that the prehistoric people who used and produced the Majiayao-style potter split from the Yangshao pottery-making communities in the east (Shaanxi and Henan provinces) (An 1987; Ding 2010; Wang 2012; Han 2013; here Chapter 1). This hypothesis seems plausible as during the Neolithic Majiayao period there appears to be no contemporaneous painted pottery production further west (Chen and Heibert 1995). However, the distribution of pottery

technology might not have been linear and going strictly from east to west. The intersection of the two pottery styles Zongri and Majiayao in the Guide Basin, Luohantang area (Hou et al. 2016; Ren et al. 2020) might have resulted in creation of vessels combining two different decoration techniques. The question is from which direction did this happen? Was the combination of two decorations a characteristic of the Zongri pottery which was adopted into the Majiayao style and spread along the Yellow River into the Tao River Valley or vice versa? Archaeological research on Zongri pottery suggests that the Zongri style was influenced by the Majiayao style, but it also shows independent local characteristics in ornaments and shapes in its later period (Ding 2010:76; Wang 2012:220; Hong et al 2012; Hou et al. 2016). It is not known if the Zongri pottery vessels combining two decorations were also made from two different fabrics. Zongri style may have had a different *chaîne opératoire* from the Majiayao style. A comparative study between the technologies of the two pottery styles could further illuminate the issue of spatial distribution and links between early pottery technologies. At the current state of research there is more evidence that the craft of making pottery spread from Central Loess Plateau westwards into the Gansu Qinghai region than there is for any other hypothesis (Han 2013). Shifting the focus back to the three river valleys, it is necessary to discuss how the transfer of knowledge might have happened between the sites in the study area.

The mapped data from surveys and excavations shows high density of sites in the study area (Zhongguo Wenwuju 1996:15-16; 2011b:70-71; here Figs 2.1-2) with the average shortest distance between sites being 5853 m as calculated by Hou et al. (2012:117). It is possible that the inhabitants of the different sites spaced in dense clusters were in regular contact with each other. There is not much

archaeological evidence for the organisation of pottery production and distribution strategies. Hung (2011) argued for a large-scale production of painted vessels which allowed for export from the Tao River area as far as into northern Sichuan. She also suggested that the painted vessels with poor painted preservation from the Huangshui River Valley were local products and the vessels of higher quality were imported from the sites in Gansu (Hung 2011:225). Local imitation of the Majiayao-style pottery in the Huangshui River Valley has also been considered in this study, as the pottery from Zhujiashai suggested. If only the Majiayao fine painted pottery found in sites in the Huangshui River Valley was an import from the Tao River Valley, how can the presence of Majiayao coarse cord-impressed pottery at the same sites be explained? The similarities in the composition and decoration of the coarse ware from the Huangshui and Tao River Valleys are significant, as has been shown in this study. These similarities might be interpreted as coarse ware being exported from the Tao River Valley additionally to the painted ware. This study argues that this was not the case. Instead, the coarse ware was likely produced locally, as Hung (2011) suggested, however, the painted pottery may have been a local product as well. If the technology and presence of coarse and fine ware are considered together in a study, then the argument of large-scale export from the Tao River Valley does not seem very convincing, though long-distance exchange cannot be ruled out completely for the painted ware until further research on its production technology is conducted.

Large-scale production for export implies a high demand for pottery and possible existence of multiple workshops and potters producing not just only for local household market. Considering the number of vessels deposited in graves (Allard 2001; Hung 2011), the demand was high. However, as noted at the beginning of

this thesis, two things are unclear about the pottery deposited in the graves. First, whether the pots were used in everyday life prior to their deposition in graves, as the use-wear analysis by Womack (2017; and Wang 2020) has shown, and buried with the deceased or whether some of them were made specifically for the funeral. Second, whether the people associated with the deceased added any vessels with content to the burial. Nevertheless, the data from the burials suggest high demand at least for the painted pottery.

Womack (2017:214-215, 220) suggested that different pottery workshops were active in the Tao River Valley and were exchanging coarse pottery and raw materials based on petrographic and macroscopic analysis. If, according to Womack (2017), the potters were indeed exchanging raw materials, then they were sharing their knowledge of techno-science in clay selection and paste preparation. The hypothesis of raw material exchange presupposes a degree of communication between potters. However, as the geology in the Tao River and in the entire study area is very similar, it would require additional petrographic data on pottery and geological samples from multiple sites to approach the issue of raw material exchange.

Insights into organisation of production may be inferred from the kilns found archaeologically. As has been pointed out above (Chapter 1 and section 5.1.1) the kiln evidence for the Majiayao period includes sites with multiple kiln clusters such as Dadiwan or Baidaogouping, where pestles, grinding stones, flat dishes, and containers for keeping the paint and manganese ore have been found (Li and Huang 1993:74), and it also includes kiln features found near houses at the habitation sites, such as at Linjia (Womack et al. 2019b:2). Andersson (1925:5; Andersson 1943:84; Bylin-Althin 1946:431) recorded two features which he

interpreted as kilns at Luohantang which was a habitation site. No kiln features have been recorded for Majiayao or Zhujiashan, yet.

Possibly, these different locations for kilns suggest different production strategies: one is for the household or local market and the other is for a larger scale production of pottery. If the organisation of production was multileveled, this means that pottery craft was one of the prevalent activities of the prehistoric life at least in the Gansu area, and required generations of trained potters preserving the technological knowledge.

One of the transmission strategies for the technological knowledge discussed in this study was a teaching framework with long-term close contact between a master potter and an apprentice. Scholars have argued that teaching would be the most reliable strategy for transmitting technological knowledge (Schiffer and Skibo 1987; Gosselain 1998, 2000; Pollock 2013; Schier 2013; Lis et al. 2015). There is no archaeological evidence to outline what a pottery apprenticeship in prehistoric northwest China may have been like. However, Gao (2013) made an interesting suggestion about pottery apprentices and demand based on his analysis of pottery deposited in the graves at the Liuwan burial site. Highlighting the multitude of pottery excavated at Liuwan, Gao (2013:316-317) suggested that the vessels which were not made as elaborately as the others of the same type, e. g. with poorly-drawn ornaments or lopsided shape, were made by less experienced apprentices to meet the high demand. Although, Gao (2013) did not conduct an in-depth study of this issue, his suggestion for looking at poorly-made pottery is worth keeping in mind when assessing local technological knowledge and demand in pottery production. A similar approach was taken by Crown (2001) who investigated less elaborate examples of Hohokam Red-on-buff and Mimbres Black-

on-white pottery in American Southwest (AD 700-1150) from the perspective of apprenticeship and how this pottery differs from the vessels made by master potters.

While teaching frameworks contribute to the preservation of technological knowledge they might not necessarily contribute to its spatial transfer on a large scale. The apprentices and teachers often belong to the same family or come from neighbouring communities, so that the technological knowledge stays within a small geographical area (e. g. Gosselain 1998; Crown 2001). The present study argues that the transmission of technological knowledge over far distances within the three river valleys happened via potter networks or moving potters within this area. There is no extensive evidence for workshops or other facilities pottery production, except few sites with several kiln clusters where raw materials and tools for pottery making were found (Li and Huang 1993:74; Gansusheng Bowuguan 1983:21). These sites suggest that multiple people were using them and meeting each other. Ethnographic research shows that exchange between practicing potters about their craft can happen at those sites (Gosselain 2016:292). The knowledge transmission was probably accelerated by the dense settlement along the rivers and in the valleys allowing for the information to be passed on between sites. The successful production of Majiayao-style pottery in the three river valleys following a similar *chaîne opératoire* is regarded as the result of this knowledge transmission in the present study. Studies by Wright (2001) and Roux (2013, 2015) discussed in Chapter 3 emphasised the contact between specialised potters being the main driving force between spatial spread of pottery technology and not short-term events of trade and exchange. It is unknown whether the potters producing Majiayao-style pottery were specialised and formed a specific

social group. The complexity of the *chaîne opératoire* and specific techno-science may be a supporting argument for that.

Shared complex technological knowledge may further indicate the degree of connectivity between the users of the Majiayao-style pottery who were not potters. First, as suggested by Roux (2013:317-318; 2015:71), two different communities are less likely to borrow entire *chaînes opératoires* from another if they already have their own pottery production technology. Possibly, next to similar burial customs in the Gansu and Qinghai area (Hung 2011), shared pottery technology may suggest a close link between the communities in the three river valleys.

Secondly, as has been suggested above, the technological choices for creating distinct textures and colours identified here may reflect some kind of social knowledge. The users of the Majiayao-style pottery were probably aware what the different wares were made of, even if the fabric texture was concealed by the surface treatment on the outside. The different surface treatments could have served as a recognition factor for the consumers designating the fabric a vessel is made from. The function of the coarse pottery is not entirely clear, and pots meant for cooking or frying have not been properly identified and researched, yet. Was an unknown social knowledge the main factor of distribution of this style? Why make two pottery wares that are so different, except for the construction technique? The present study has explored the question about how the Majiayao-style pottery was made but its purpose is still unclear. Analysing vessel function could be one of the many ways to approach the issue of pottery function.

8 Conclusion

This project aimed to contribute to research on the Majiayao-style pottery technology, assess the complexity of the production process and investigate the connectivity of the people producing and using this pottery. This project started with the question whether Majiayao vessels from different area that look the same way were also made in the same way. Based on macroscopic and microscopic analyses, it can be concluded that the *chaîne opératoire* of the Majiayao style shows significant similarities in technological choices at all steps to produce coarse and fine pottery. This conclusion has been reached by considering coarse and fine pottery together, allowing investigation of the prehistoric potters to a greater extent than by studying only one ware in isolation as has largely been done in the past. Pottery of both wares has similar shape, and it has been suggested in this study that the primary and secondary construction techniques were the same. However, the technological choices in clay preparation, surface finish and firing require the knowledge of different techno-science for the fine painted and yellow fired ware and for the coarse cord-impressed dark fired ware. The inclusion of geological samples in this study has not only contributed to the discussion of the selection of raw clay and tempering material but also pointed out previously unnoticed issues of firing techniques.

The similarities in technological choices inferred from the Majiayao-style pottery from remote sites in the three river valleys led to the conclusion that there was a close connection between people who possessed the knowledge of the techno-science of pottery technology. This study suggested that the potters engaged in knowledge exchange within different frameworks, perhaps as teachers or as members of the same specialised group.

The results of the investigation into the techno-science of clay preparation and firing considered together with the exterior design of the pottery revealed patterns which may have gone beyond practical function and imply shared social knowledge between producers and consumers. At present, this suggestion cannot be supported by other archaeological data and needs to be tested by petrographic sampling targeting sherds with different decorations and firing patterns regardless of the fabric texture to investigate if there are patterns in the combination of decoration, fabric and firing.

There is a cluster of open questions which needs to be addressed in future research using chemical analysis and scanning electron microscopy. Specifically, the calcareous nature of the pottery samples and sampled clay and its effect on firing, paint recipes, and the issue of slip on the painted vessels. Additional geological surveys and field sampling in the Huangshui and Yellow River Valleys in Qinghai and a more targeted survey of clays and rocks in the Tao River Valley would bring the investigation closer to answering question of raw material availability in these areas. Firing the collected field samples as a part of this study has proven to be a useful method for studying the *chaîne opératoire* of Majiayao-style pottery. Investigating and identifying the cooking pots among the Majiayao-style pottery by the means of experimental archaeology would be an enriching contribution to understand pottery function and the function of temper in coarse fabrics.

Research into possible contacts and shared technology with contemporaneous communities producing and using Zongri-style pottery would be a promising avenue to gain a different perspective on the spread trajectory of Majiayao-style pottery. Investigation of the pottery technology of the Majiayao style as the earliest

pottery style in the Gansu Qinghai region lays the foundation for studying the technology of pottery styles of the Bronze Age period such as Qijia or Xindian from this region which might have contributed to the westward spread of painted pottery in Xinjiang and Central Asia (Chen and Hiebert 1995; Debaine-Francfort 2001; Lhuillier 2007; 2011).

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