Serial learners: interactions between Funnel Beaker West and Corded Ware communities in the Netherlands during the third millennium BCE from the perspective of ceramic technology

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Interactions between Funnel Beaker West and Corded Ware Communities in the Netherlands during the Third Millennium BCE from the Perspective of Ceramic Technology

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That unbridled hopefulness was succeeded, naturally enough, by a similarly disproportionate depression. The certainty that some bookshelf in some hexagon contained precious books, yet that those precious books were forever out of reach, was almost unbearable. One blasphemous sect proposed that the searches be discontinued and that all men shuffle letters and symbols until those canonical books, through some improbable stroke of chance, had been reconstructed. The authorities were forced to issue strict orders. The sect disappeared, but in my childhood I have seen old men who for long periods would hide in the latrines with metal disks and a forbidden dice cup, feebly mimicking the divine disorder.

Jorge Luis Borges (1988 p. 70); translated by A. Hurley

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For David Fontijn, I wish you could have asked many of your ever thought-provoking questions about this dissertation and many other things besides.

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1

Beakers, Plagues, and Battle Axes

5000 years ago, a migration shaped Europe's future. Migrating communities from the Eurasian steppe spread from Russia to the Rhine in a little over a century, leading to lasting changes in genetics, language, and connectivity. Archaeologists recognised this migration as early as the nineteenth century as the widespread appearance of S-shaped, cord decorated ceramics (Klopfleisch 1883; see Fig. 1.1). Hence the name of this entity: Corded Ware.

Corded Ware did not appear in an empty continent. These migrating communities encountered the descendants of hunter-gatherers and early farmers, societies with

Figure 1.1: Typical Corded Ware vessels from Denmark (left; CC BY-SA, Roberto Fortuna & Kira Ursem, The National Museum of Denmark) and the Netherlands (right; Source: Rijksmuseum van Oudheden, Leiden). These vessels feature a uniform style despite the intervening distance. Both vessels are S-shaped with the eponymous cord impressions on the upper body and a row of elongated impressions just above the shoulder. These ceramics first led archaeologists to argue for a migration event and continue to inform such arguments as geneticists rely on ceramics to situate human skeletal remains in historical contexts.

millennia-old roots in Europe. Yet, the migrants had an outsize impact on European history. What interactions between migrating and indigenous groups led to this outcome? I argue here those typical ceramics can shed new light on this issue.

1.1 A Very Short Introduction to the Third Millennium BCE

This section is an introduction to the two major themes in the current debate on the third millennium BCE in Northwest Europe: culture change and migration. The introduction is far from exhaustive but highlights crucial studies and issues. The interpretations of the third millennium BCE discussed in the next section all revolve around these themes.

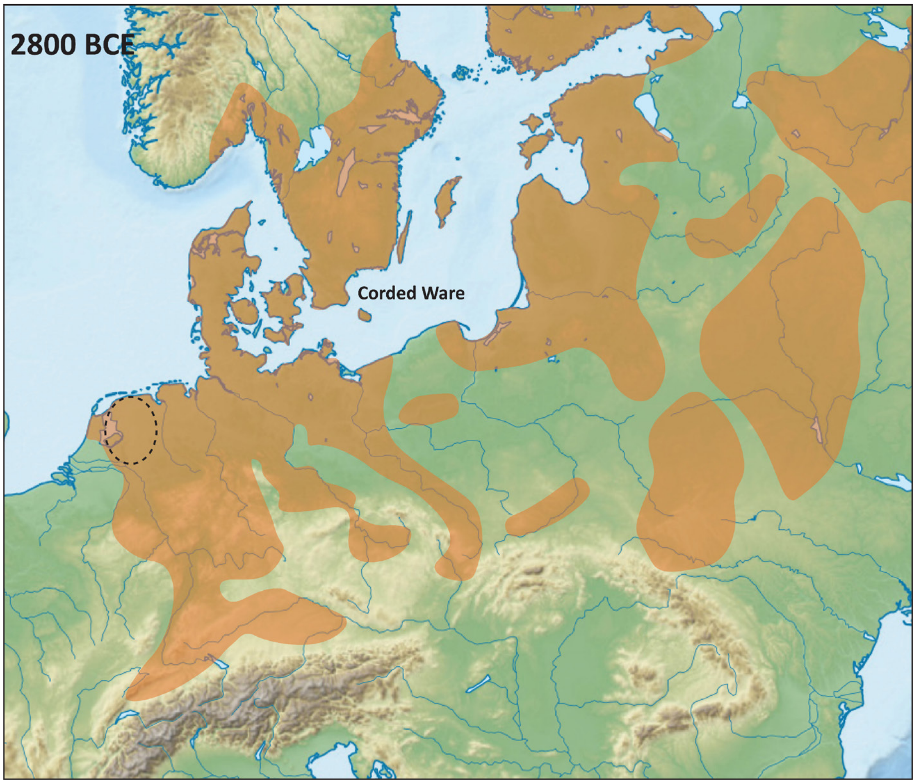
The third millennium BCE was a period of change in Europe. The protagonist in these changes is an entity referred to as Corded Ware. The defining traits of Corded Ware are similarities in ceramics (see Fig. 1.1) and funerary rituals (cf. Bourgeois and Kroon 2017; Furholt 2014a). These two elements spread rapidly across Europe between 3050-2900 BCE (Heyd 2021 p. 393). Their spread is also seen as the end of older, regional entities, such as Funnel Beaker, which are defined by their own typical ceramics and funerary practices, and have roots in the fourth millennium BCE (cf. Furholt 2014a; see Fig. 1.2).

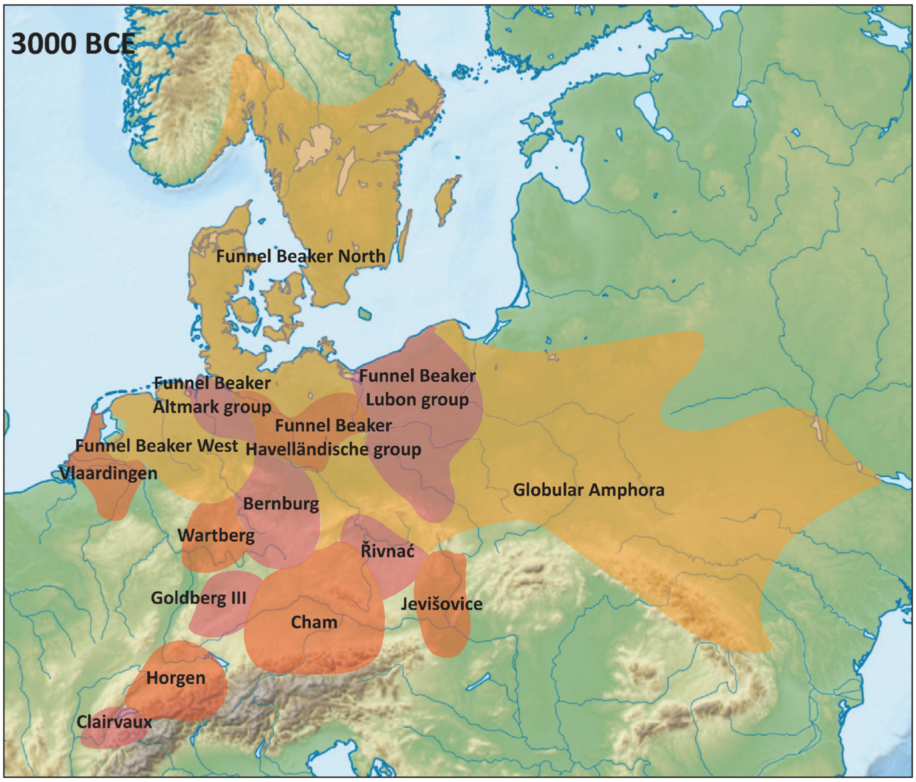
The problem is that the meaning of these similarities in funerary rituals and ceramics (and the changes therein) is unclear (Roberts and Vander Linden 2011; Sørensen 2015). Archaeologists tend to approach these similarities through a culture-historical perspective, which envisions these entities as cultural phenomena or groups with particular historical trajectories (cf. Rebay-Salisbury 2011; Trigger 2006 pp. 240; 311–3). Crucially, this perspective structures (*sensu* White 2014) these entities, and all evidence relating to them, along a narrative of emergence, rise, decline, and fall. The past essentially becomes a continuous cycle: the emergence and rise of Corded Ware follow the decline and fall of Funnel Beaker, the decline and fall of Corded Ware give rise to Bell Beaker, and so forth.

Migration played a crucial role in these cycles. Given that each group or phenomenon has characteristic funerary rites and ceramics, disruptive migration events served to account for changes in these traditions (cf. Cabana and Clark 2011 pp. 3–4; Cameron 2013 p. 220; Hakenbeck 2008 p. 13). A key point for upcoming sections is that this culture-historical perspective was rejected but not abandoned in (post-)modernity, which has impeded further thinking about the nature of migration and similarity (Anthony 1990; Burmeister 2000; Sørensen 2015). Consequently, reiteration of this narrative structure continues to colour interpretations of the third millennium BCE (see Section 1.2) and is a key background factor in the debate about this period.

Ancient DNA (aDNA) analysis has re-ignited debates on the role of migration in explaining the above-mentioned similarities. Analyses show humans buried with Corded Ware ceramics differ in ancestry from older Neolithic populations. These individuals have so-called steppe ancestry, indicating they descend from populations thought to inhabit the Eurasian steppe before the third millennium BCE. By contrast, the genomes of individuals associated with older archaeological cultures in Europe typically do not feature steppe ancestry but a mixture of genetic profiles associated with early farmer,

Figure 1.2 (opposite page): The culture-historical view of the first half of the third millennium BCE in Northwest Europe (after: Von Schnurbein and Hänsel 2009). The emergence of Corded Ware leads to the disappearance of a patchwork of regional archaeological cultures between 3050-2900 BCE. The figure above shows the study area encircled with a dotted line.


2800 BCE
Corded Ware


3000 BCE
Funnel Beaker North
Funnel Beaker
Altmark group
Funnel Beaker
Lubon group
Funnel Beaker
Havelländische group
Funnel Beaker West
Vlaardingen
Globular Amphora
Bernburg
Wartberg
Řivnać
Goldberg III
Cham
Jevišovice
Horgen
Clairvaux

and various hunter-gatherer populations (Allentoft *et al.* 2015; Damgaard *et al.* 2018; Haak *et al.* 2015; Mathieson *et al.* 2015, 2018; Mittnik *et al.* 2017, 2018; Olalde *et al.* 2018; Papac *et al.* 2021). Therefore, this change in ancestry indicates a migration of people with steppe ancestry into Europe.

There are many additional findings about this period which are relevant to the debate. Most notably on possible plague outbreaks (cf. Andrades Valtueña *et al.* 2022; Susat *et al.* 2021 for a critique), male sex bias in migrating communities (Goldberg *et al.* 2017; cf. Lazaridis and Reich 2017; Scorrano *et al.* 2021; Frieman and Hofmann 2019), and personal mobility and kinship structures (Sjögren *et al.* 2016; cf. Brück and Frieman 2021; Linderholm *et al.* 2020; Mittnik *et al.* 2019; Monroy Kuhn *et al.* 2018). A full discussion of these findings is beyond the scope of this dissertation, but they do inform various interpretations of the changes in archaeological culture and ancestry in the third millennium BCE (see below).

The migration event during the third millennium BCE leads to three historic changes in Europe. Firstly, the admixture of steppe ancestry gives rise to the genomic diversity seen in all European populations and may have introduced traits such as lactose tolerance in these populations (Haak *et al.* 2015; Lazaridis *et al.* 2014). In addition, this migration event is probably associated with the introduction of Indo-European languages, spoken today throughout Europe and the world (Iversen and Kroonen 2017; cf. Heggarty 2018). Lastly, the interconnectedness of Corded Ware communities during and after the migration event (Bourgeois and Kroon 2017, 2023) facilitated the spread of metallurgy and the onset of the Bronze Age (Kristiansen and Larsson 2005). This combination of changes in material culture, ancestry, language, and connectivity points towards the fundamental impact of this migration event.

The outcomes of aDNA analysis have put migration back at the forefront of archaeological debates about the third millennium BCE. Yet, migration in itself does not necessarily result in the discontinuity of indigenous groups in terms of language, ancestry, or material culture (Furholt 2017a; Heyd 2017; Vander Linden 2016). Therefore, the key question in the debate about the third millennium BCE is: what interactions between migrating and indigenous groups drove these changes?

The above question is the central question in this dissertation. However, there is a second problem which needs to be addressed to answer this question. This problem is the continued reliance on the culture-historical perspective and concepts for understanding the large-scale developments during the third millennium BCE (see above). A brief discussion of three seminal explanations for the developments during the third millennium BCE illustrates this problem. Sections 1.3 and 1.4 are an outline of a new perspective on ceramics which moves beyond this issue.

1.2 Three Answers, One Problem

Since the initial aDNA studies of the third millennium BCE (Allentoft *et al.* 2015; Haak *et al.* 2015), three seminal, explanatory accounts of the large-scale developments in the third millennium BCE have emerged in archaeology. All of these models identify the same central concern: how does the spread of genetic information relate to the spread of cultural information? The discussion below looks at the connections between genetic and cultural information proposed in these models. My criticism of these connections is crucial for the perspective on ceramics outlined in Sections 1.3 and 1.4.

The oldest explanatory account stems from Kristiansen *et al.* (2017; Kristiansen 2022). This publication ties together a broad range of studies in a provocative account (cf. Frieman *et al.* 2019; Furholt 2021). Kristiansen *et al.* (2017) suggest older Neolithic societies collapsed due to a plague outbreak (cf. Rasmussen *et al.* 2015), followed by a migration of, predominantly, men from the Eurasian steppe who spoke Indo-European languages (cf. Anthony and Brown 2017; Iversen and Kroonen 2017). These men leveraged an advantage in mobility and weapons to take wives from the indigenous groups, and these wives then fashioned ceramics after the basketry of their new husbands, resulting in Corded Ware styled ceramics (Kristiansen *et al.* 2017 p. 342). The overall scenario closely resembles Diamond's (1997) *Guns, Germs and Steel* (hence the chapter title).

The second explanatory account stems from Furholt (2021) and is born out of a critique of Kristiansen *et al.* (2017). Furholt bases his account on modern migration theory, specifically the concept of translocality (cf. Furholt 2017b). He argues the third millennium BCE saw a general increase in mobility (cf. Sjögren *et al.* 2016; Wentink 2020) with migrating groups acting as a go-between among various indigenous groups. This increased connectivity led to the adaptation of a single standard (i.e. Corded Ware) in pottery production and burial ritual among various communities (cf. Booth *et al.* 2021). The adoption of this new style would also have led to the decline of the signature material culture and funerary practices of various indigenous groups.

The third explanatory account is from Heyd (2021) and is well-sourced for Central and East Europe. This account uses the same elements as that of Kristiansen *et al.* (2017) but places more emphasis on migration as a driving mechanism for change. Heyd (2021 pp. 404–5) suggests migrating communities with a specific ceramic style and funerary ritual settled in Northwest Europe and disrupted indigenous communities, contrary to Central and East Europe, where he argues more continuity and mixing of populations took place (ibid. p. 387). He suggests famines, plagues, and violence may have played a role in the lack of resistance from indigenous communities (cf. Kristiansen *et al.* 2017).

The above three explanations all provide different mechanisms for the spread of Corded Ware and the interactions between migrating and indigenous communities. These mechanisms tie the spread of genetic information (steppe ancestry) to the spread of cultural practices (i.e. Corded Ware ceramics and funerary rites). The shared problem is that they draw a connection from similarities in ceramics to genetics via past groups to do so. This connection re-introduces the issues surrounding cultural history.

The connection between genetics and ceramics results from the contextualisation of genetic samples. A genetic sample from human remains becomes 'Corded Ware' if the burial contains Corded Ware pottery (e.g. Olalde *et al.* 2018 Supplementary Information 2; see Fig. 1.1). Various archaeologists point out that interpreting this connection as an indicator for groups is problematic (Frieman and Hofmann 2019; Furholt 2017a; Heyd 2017; Vander Linden 2016), but to my mind the problem lies with archaeology, not genetics. Geneticists use these labels because archaeologists continue to reiterate the cultural histories in which entities such as Corded Ware are protagonists (cf. Booth 2019; Eisenmann *et al.* 2018).

This reiteration of cultural history is also apparent from the connection between ceramics, migration, and genetics in Kristiansen *et al.* (2017), Furholt (2021), and Heyd (2021). All three models treat similarity in ceramics as a sign of group membership. Kristiansen *et al.* (2017) depict ceramic style as an indicator of the integration of women from one group into another. Furholt (2021) argues the spread of this style is the coalescence of multiple groups within an interaction network. Lastly, Heyd (2021) considers ceramic style as a typical habit for a group. In addition, all three models also follow the culture-historical narrative for this period: the rise of Corded Ware equals the fall of indigenous groups with migration, through one mechanism or another, as the driver of this process.

Not only do these relations between migration, genetics, and ceramics contradict earlier criticism of culture-historical approaches (see above), they also clash with studies about the long-term integration of migrants in host societies from migration studies (Castles *et al.* 2014; De Haas 2023), as well as archaeological (e.g. Iversen 2020; see Section 2.5) and genetic evidence for the survival of indigenous groups (cf. Haak *et al.* 2015 on the resurgence of hunter-gatherer and early farmer genetic profiles).

However, the foremost problem for these models is that neither genetics nor ceramics necessarily relate to groups. Ceramics are not similar because people belong to the same group, or have the same genes. Ceramics are similar because potters learned, and chose, to do the same thing (cf. Sørensen 2015) and these choices and learning processes may or may not relate to groups (e.g. Gosselain 2008a p. 169; Roux *et al.* 2017; see Section 3.1).

These problems go to show how much archaeological thinking about large-scale developments still relies on the culture-historical perspective (see Section 1.1). Consequently, the methodological challenge in understanding the spread of genetic and cultural information during third millennium BCE is to move beyond this perspective. In this dissertation, I address this challenge by developing a new approach to ceramics. This approach does not consider ceramics as the typical product of past groups but as the product of transmitted technical knowledge. An outline of this approach is presented below after a brief discussion on migration.

1.3 Migration: A Link Between Scales

Migration has a long history of being conflated with (abrupt) one-way relocation of groups in archaeology. This conflation goes back to the culture-historical view of the past as a sequence of groups with characteristic traditions (Hakenbeck 2008 p. 13; see Section 1.1). Therefore, two qualifications about the use of the term migration in this study are necessary.

Firstly, the definition of migration used here stems from De Haas (2023 p. ix) who states that migration is a form of geographic mobility which leads to a prolonged (min. 6-12 months) change in area of habitual residence. This change of residence is often temporary and reversible (cf. Anthony 1990 p. 904; Cabana and Clark 2011 p. 5). This definition may appear too focussed on micro-scale processes for prehistoric archaeology (see below) but in fact isotope analyses have already demonstrated the existence of such complex, micro-scale migrations in the third millennium BCE (e.g. Haak *et al.* 2008; Knipper *et al.* 2017; Sjögren *et al.* 2016; see also Booth *et al.* 2021). The value of aDNA analysis and specifically isotope analysis should then be clear in light of this definition. These methods provide direct empirical evidence for migration of individuals, bypassing the need for detecting migration on the basis of material culture (cf. Anthony 2023; Burmeister 2016 pp. 44; 50, 2017 p. 63; Kristiansen 2014). Interpreting the impact and role of such migrations however remains a matter for archaeologists (cf. Burmeister 2017 p. 65).

The second qualification is that archaeological investigations of migration operate at macro-scale out of necessity. The resolution of the archaeological record does not allow us to systematically discern the journeys, experiences, and motivations of individual migrants or hosts which are crucial for modern migration studies (Anthony 1990;

Tsuda *et al.* 2015). However, investigating migration at macro-level does not imply archaeologists should return to studying groups of people migrating over larger distances (*contra* Burmeister 2000; McSparron *et al.* 2020; Tsuda *et al.* 2015 p. 19). This is especially clear in light of the above-mentioned isotopic evidence that migration during the third millennium BCE was as complex, varied, and dynamic at micro-level as present-day and historic migrations (cf. Cameron 2013; Castles *et al.* 2014; De Haas 2023). Therefore, an archaeological perspective on migration should look at macro-scale patterns visible in the archaeological record while accepting and accommodating for complex individual behaviour at micro-scale.

As such, the perspective on migration (and technical knowledge of potters; see below) taken here revolves around aggregate effects. These are general patterns which emerge when we view the complex and varied behaviours of many individual agents as a whole (*sensu* Durkheim 2002). For example, the labels 'migrating groups' and 'indigenous groups' are used here not to indicate that every individual in this group was a migrant (or not), but that on the whole members of this group arrived in Europe relatively recently at the start of the third millennium BCE (migrating), or had been in Europe for longer at that time (indigenous). These terms refer to macro-scale patterns visible in the aggregated micro-scale behaviours of many individuals over centuries (qualification 2), but remain agnostic about their individual behaviours and life histories without reducing them to groups (qualification 1). The focus on aggregate effects enables a macro-level understanding of the past which acknowledges the complexity and intricacy of human behaviour at micro-scale.

The goal of this dissertation then is not to detect migration or assess the lives of individual migrants, hosts, and potters. It is to understand and interpret the patterns which emerge from countless such lives and migrations. The same perspective also shapes the approach to learning and ceramic technology outlined below.

1.4 Thinking with Ceramics

Ceramics will remain a vital source of information for archaeology. Ceramics survive better than other material categories and are abundant in the archaeological record from the moment of their appearance (cf. Jordan and Zvelebil 2009). Moreover, ceramics mattered. The far-flung appearance of similar vessels indicates people in the past attached value to their production (cf. Sørensen 2015; see above). The question is: what kind of information do we extract from ceramics?

Archaeological studies of ceramics often exhibit a narrow focus on the visual aspects of these artefacts: decoration and shape, taken together as style (see above). Instead, the focus here is on the *chaîne opératoire* of ceramics. A *chaîne opératoire* consists of an ordered sequence of techniques (i.e. efficacious gestures with(out) a tool on matter) which went into the production of a vessel. This sequence can be reconstructed from traces on a vessel (cf. Roux 2019a). Contrary to ceramic style, which may simply be copied, production techniques are taught, embodied knowledge (cf. Gosselain 2018; Roux 2019a). Therefore, the *chaîne opératoire* approach enables the reconstruction of learning in the deep past.

There are several other studies which look at ceramic *chaînes opératoires* to understand the developments in the third millennium BCE (for recent examples: Derenne *et al.* 2020, 2022; Kroon *et al.* 2019; for older examples: Hulthén 1977; Van der Leeuw 1976). The approach below departs from these studies by focusing on variability over time, rather than identifying a particular technical practice with a particular group.

Why Variability over Time? And How?

As stated, the techniques and their ordering in a *chaîne opératoire* are learned, technical knowledge. This learned nature itself implies variability. Ethnographic studies show potters generally know multiple, alternate (orders of) techniques to produce ceramics (e.g. Gosselain 2008a p. 169). This is because they continuously acquire such knowledge throughout their lives via direct and indirect interactions with other potters, including potters who live across social boundaries (Gosselain 2017, 2018). Therefore, the knowledge of potters must be seen as a changing technical repertoire which allows for many alternative *chaînes opératoires*. Each singular *chaîne opératoire* is but one actualisation of the variation possible within a technical repertoire when the ceramic vessel is made (see Ch. 3).

In practice, this means we must look at many different *chaînes opératoires* to build up an image of technical knowledge. This goes especially for archaeology because the archaeological record does not allow us to consistently discern individual technical repertoires. Moreover, we must accept that a difference in production techniques might merely be an alternative choice within the same technical repertoire. As such, the core question is when such differences are significant.

The approach to ceramic technology developed here incorporates these two notions. The units of analysis are large groups of vessels, referred to as bodies of knowledge, which represent the variability in ceramic production among migrating and indigenous groups during the third millennium BCE (see Section 1.3 on aggregate effects). Moreover, I develop a new, probabilistic comparison for *chaînes opératoires* to compare these bodies of knowledge (see Ch. 4). Put simply, this comparison calculates a distance between two groups of *chaînes opératoires* by looking at the number of new, or different (combinations of) techniques which appear in one group of *chaînes opératoires* relative to the other. The more of these changes, the greater the distance. Consequently, the distance is an indicator of the amount of new technical knowledge that indigenous potters would need to learn to produce Corded Ware vessels. If this distance is small or becomes smaller over time, this suggests knowledge transmission between migrating and indigenous potters. A large distance on the other hand indicates such knowledge transmission is unlikely. A comparison against a control group of unrelated *chaînes opératoires* serves to assess the significance of these distances: if the distance between the *chaînes opératoires* of indigenous and migrating groups is smaller than that to the unrelated control group, this points towards sharing of knowledge (and vice versa).

The probabilistic comparison enables a test of the scenarios which have been proposed for the impact of migrations during the third millennium BCE. For example, Kristiansen *et al.* (2017) propose that the same potters who produced the ceramics associated with indigenous groups also produce Corded Ware ceramics. Therefore, a comparison of bodies of knowledge for indigenous groups and Corded Ware should result in a distance which is much shorter than the distance to the control group. After all, the same technical repertoires produce both groups of *chaînes opératoires*.

The power of the probabilistic approach is the ability to detect this development, and potentially many others, in the transmission of knowledge from ceramics. By treating this as a probabilistic problem, we allow for the possibility past potters learned particular techniques and production methods. This also means ignoring the *a priori* classification of people by pottery style. Making Corded Ware pottery is something one can learn, today and in the past. Ultimately, the approach outlined here is not about people, but about the knowledge transmission in which people figure. Therefore, this approach goes beyond culture-historical perspectives and offers a new perspective on the third millennium BCE.

There is one final point about learning ceramic technology before we move on to the research question and broader relevance of this study. Throughout this dissertation, prehistoric potters are not identified as either men or women. It is commonplace in prehistoric archaeology to envision potters as women working in household contexts (e.g. Holmqvist *et al.* 2018; Larsson 2009 p. 410). This connection between women and ceramic technology can even form the link between changes in material culture and genetics (cf. Kristiansen *et al.* 2017 pp. 340; 342). However, there is no direct evidence for this assumption. Instead, it is a sweeping generalisation based on old anthropological studies (Frieman *et al.* 2019 pp. 158–9), which themselves are often more nuanced (cf. Murdock and Provost 1973 Tab. 4). New methods may soon remedy the lack of direct evidence for the sex of prehistoric potters (cf. Fowler *et al.* 2019, 2020, but see Bécue and Champod 2023; Sharma *et al.* 2021) but until such time we should remain open-minded about who past potters were.

1.5 Research Question and Study Area

The sections above discuss the pivotal problem in archaeological, genetic, and linguistic studies of the third millennium BCE, and the potential of a new approach to ceramic technology to unravel this problem. This leads to the following research question:

> *What can be inferred from developments in ceramic technology about the nature of the interaction between migrating and indigenous communities that shaped the Corded Ware transition?*

This question is applied here to the interaction between indigenous Funnel Beaker West, and migrating Corded Ware communities in the Netherlands (see Fig. 1.2). There are three reasons to select the Netherlands as the study area.

Firstly, ever since the arguments of Glasbergen and Van der Waals (1955; cf. Beckerman 2012; Fokkens 2012), the Dutch archaeological record has played a prominent role in debates about the third millennium BCE (cf. Olalde *et al.* 2018 for a recent example). Moreover, the transition from Funnel Beaker West to Corded Ware in the Netherlands is thought to be a rapid, disruptive process (cf. Lanting and Van der Plicht 2000). This interpretation informs ideas about massive migrations as proposed by Heyd (2021), and Kristiansen *et al.* (2017). Therefore, studies of the Dutch archaeological record are of importance for the debate about the third millennium BCE as a whole.

Secondly, systematic studies of Funnel Beaker West and Corded Ware sites go back more than a century in the Netherlands (Bakker 1992, 2010; Fokkens 2005 pp. 364–6) and continue to date (cf. Beckerman 2015; Fokkens *et al.* 2016; Wentink 2020). As such, there is a rich archaeological dataset available for study. This is crucial for attempts to capture the variation in Funnel Beaker West and Corded Ware ceramic technology.

Lastly, Funnel Beaker West and Corded Ware sites in the Netherlands are located in areas with poor preservation of organic remains (cf. Fokkens 2012), leading to relatively poor sample density in aDNA studies (cf. Olalde *et al.* 2018). Therefore, there is all the more urgency to developing an approach which harnesses inorganic materials such as ceramics for understanding the major issues in prehistory.

1.6 The Third Millennium BCE: A Matter of Concern

Studying the migration event during the third millennium BCE takes on additional urgency in light of popular outreach about this event. Popular accounts often stress a violent, disruptive interpretation of the migration event. More nuanced stances appear as an afterthought (e.g. Barras 2019; Callaway 2017; McKie 2017). These publications contribute to a popular image of migration as erosive to society, fuelling political extremism during the ongoing migration crisis (cf. Hakenbeck 2019).

The problem is that such depictions themselves draw upon a few, one-sided narratives about historical migration events. Notably, the ideas of Diamond (1997) about the colonisation of the Americas, and Heather (2009) about the Migration Period. More nuanced stances on historical migrations (e.g. Geary 2002; Halsall 2013; Oosterhuizen 2019 for the Migration Period) are absent in the debate. The same applies to the depiction of Corded Ware and Yamnaya as highly mobile, warlike nomads. This image leans into stereotypes about nomads but ignores more nuanced studies of nomadism (cf. Chang 2018; Hämälainen 2008; Khazanov 1994; Spengler *et al.* 2021).

The risk then is that archaeology becomes part of a circular argument. The narratives about the third millennium BCE feed into and normalise certain views on contemporary and historical migrations. In turn, these views feed back into archaeological conceptualisations of migration. This circular argument is already underway: in a recent publication about nomadic empires on the Eurasian steppe, Hoppenbrouwers (2023 Chapter 1) places Corded Ware and Yamnaya on equal footing with the empires of Atilla the Hun and Dzjengis Khan. The only way to break this circular argument is a detailed investigation of migration processes on the ground during the third millennium BCE. Archaeology should not touch up cases with (tacit) parallels to history and anthropology when studying migration but should seek new perspectives and tools which play into its strengths. I hope that the perspective on ceramic technology and migration outlined here contributes both to our knowledge about the third millennium BCE and the search for such a perspective.

1.7 Outlook

This dissertation has three parts. The first part contains background information and the theoretical fundaments of this study. This part encompasses Chapters 2, 3, and 4. Chapter 2 is a critical examination of our knowledge about Funnel Beaker West and Corded Ware in the Netherlands. The core point in Chapter 3 is that we should not study this period by drawing associations between technical traditions and past groups, but by looking at the long-term variability in ceramic technology which results from learning. Chapter 4 is an outline of the probabilistic method to compare *chaînes opératoires* which can take this variability into account.

The second part of the study includes Chapters 5 to 8. The focus of this part is ceramic technology in Funnel Beaker West and Corded Ware. Chapter 5 is a discussion of the sampling strategy and analytical tools applied to reconstruct *chaînes opératoires*. The analytical methods are macroscopy and ceramic petrography. The outcomes of the macroscopic analysis of Funnel Beaker West and Corded Ware ceramics are reported in Chapters 6 and 7 respectively, whereas the outcomes of the petrographic analyses are presented in Chapter 8.

Lastly, Chapters 9 to 14 form the final, synthetical part of this study. Chapters 9 and 10 are comparisons of the results from Chapters 6 to 8 with the standard, abductive method and the new probabilistic method from Chapter 4, respectively. The comparisons yield complementary results and shed new light on the transition between Funnel Beaker West and Corded Ware. The discussions in Chapters 11, 12, and 13 tie these findings back into broader debates about Neolithic ceramic technology, indigenous groups, and migrating groups in the third millennium BCE. Lastly, Chapter 14 contains the answer to the research question and a summary of the key findings of the study.

2

Funnel Beaker West and Corded Ware Communities Co-existed

This chapter is a discussion of background information about the third millennium BCE and in particular on the transition from Funnel Beaker West to Corded Ware in the Netherlands. Based on a review of this evidence, I argue Funnel Beaker West and Corded Ware communities co-existed in the Netherlands for several centuries during the first half of the third millennium BCE.

Section 2.1 is an introduction to the state of knowledge for the third millennium BCE in the Netherlands. Focal points in this introduction are the pivotal role of ceramic typology and funerary practices, as well as the current interpretation of the transition from Funnel Beaker West to Corded Ware. This interpretation proposes a rapid, disruptive process that takes place around 2800 BCE, which is highly suggestive of a 'massive migration'.

Sections 2.2 to 2.5 are a critique of this state of knowledge. The notion of a rapid, disruptive transition is shown to follow from a culture-historical narrative structure interwoven with the ceramic typology (see Section 2.2). A re-examination of the available radiocarbon evidence with Bayesian chronological modelling shows there is no evidence for such a rapid transition. Instead, the radiocarbon evidence points towards a co-existence of Corded Ware and Funnel Beaker West during the first half of the third millennium BCE (see Section 2.3). This re-examination also leads me to reconsider the chronology of Funnel Beaker West (Section 2.4), and several archaeological cases in which the funerary practices of these groups overlap (see Section 2.5). Taken together, these critiques revise our understanding of the third millennium BCE in the Netherlands. An overview of the findings from this chapter is presented in Section 2.6.

2.1 The Age of Ceramics

This section is an overview of the state of knowledge for Funnel Beaker West and Corded Ware in the Netherlands. The overview is not exhaustive but sets up the crucial points of discussion in this chapter and the dissertation in general.

The conventional chronology places Funnel Beaker West in the Middle Neolithic B (3400-2900 BCE), and Corded Ware in the Late Neolithic A (2900-2500 BCE; Van den Broeke *et al.* 2005 Fig. 1.10). Dutch archaeologists continue to approach these periods from a culture-historical perspective (Fokkens *et al.* 2016, 282-3). A criticism of this approach is crucial in the upcoming sections. For now, this perspective is treated as an integral part of our knowledge. Therefore, the section starts with a brief reflection on the definition of archaeological cultures in the Netherlands during this period and then introduces each of these entities in more detail.

Various maps exist for the Neolithic of Northwest Europe (cf. Fig. 1.2; Von Schnurbein and Hänsel 2009 for a recent example). These maps depict three archaeological cultures in the Netherlands during the latter part of the Neolithic: Vlaardingen, Funnel Beaker West, and Corded Ware (see Fig. 2.1). The visual rhetoric of the maps presents these entities as modern nation-states: areas in which people uphold a certain commonality. However, the only shared element depicted is the shape and decoration of ceramics, taken together as ceramic style. The names Funnel *Beaker* West and Corded *Ware* hint directly at the pivotal role of ceramics. The name Vlaardingen refers to the type site of a specific ceramic style (cf. Beckerman and Raemaekers 2009 p. 63). The dependence on ceramic style to define basic culture-historical building blocks is commonplace in European Neolithic archaeology (Furholt 2020 p. 3; Piezonka 2015 p. 558). Nevertheless, it is important to specify that designations such as 'Funnel Beaker West settlement' or 'Corded Ware funerary rituals' refer here to graves or funerary practices associated with these ceramics.

Whether or not populations with distinct ancestry produced and used these ceramics remains unclear. Human skeletal remains from Funnel Beaker West, Corded Ware, and Vlaardingen are rare due to a combination of soil acidity and funerary practices (Fokkens *et al.* 2016 p. 37; Gehasse 1995 p. 218). As a result, archaeogenetic data from this period is as yet sparse for the Netherlands (cf. Olalde *et al.* 2018 for exceptions). Based on broader patterns in the European Neolithic (Allentoft *et al.* 2015; Haak *et al.* 2015; Mathieson *et al.* 2015; Mittnik *et al.* 2018; Olalde *et al.* 2018), Vlaardingen and Funnel Beaker West are assumed to be indigenous populations, whereas Corded Ware corresponds to migrating groups (cf. Furholt 2020 pp. 9–10).

Funnel Beaker West: Beakers and Megaliths

The conventional chronology for the Netherlands dates Funnel Beaker West between 3400 and ca. 2800 BCE (cf. Brindley 2022 p. 112; Lanting and Van der Plicht 2000 p. 68). Brindley (1986b) distinguishes seven sub-phases, so-called horizons, within this period based on ceramic typology. Funnel Beaker West sites can be found in the uplands of the Netherlands and northwestern parts of Germany (see Fig. 2.1, Bakker 1979; cf. Fokkens 2012 Fig. 5; Menne 2018 Fig. 122 for more recent distribution maps).

Despite growing attention for German Funnel Beaker West sites in recent years (e.g. Kossian 2000; Menne 2018; Mennenga 2017), the Dutch sites have been the subject of more intensive study and remain quintessential for our understanding of Funnel Beaker West, among others in terms of chronology (e.g. Menne 2018 p. 20).

What is Funnel Beaker West? The defining elements of this archaeological culture are ceramic style (Brindley 1986b), megalithic tombs (Bakker 2010; Midgley 2008), and agricultural intensification with a focus on livestock and horticulture (Bakker 2003 pp. 268–70). However, megaliths and ceramics have been the focus of Funnel Beaker West research. This is in part due to the paucity of the archaeological record in terms of settlement sites, and in part due to the typological focus of previous researchers. Only a few Funnel Beaker West settlement sites with actual house plans are known (cf. Mennenga 2017 Sec. 4.4). Most other 'settlements' are chance finds of artefact scatters with few and/or highly fragmented objects (cf. Bakker 1982 pp. 88–90). By contrast, megalithic

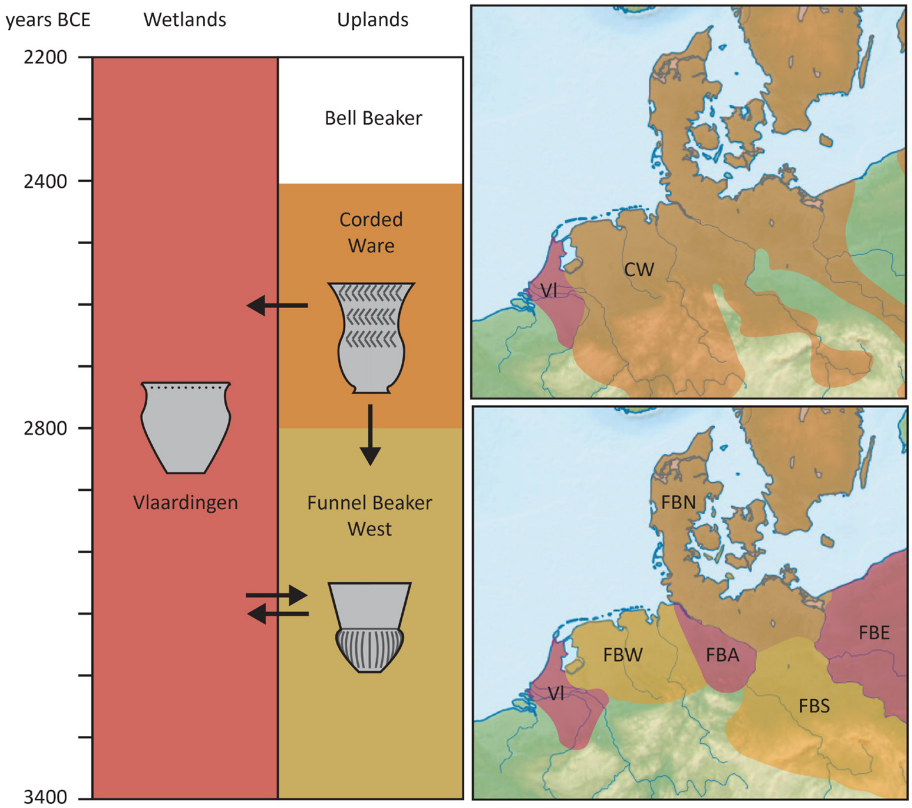


Figure 2.1: The culture-historical framework for the Netherlands between 3400 and 2200 BCE. The timeline on the left indicates the duration of the various archaeological cultures (see text for dates), and is split into the two main geomorphological zones of the Netherlands: uplands and wetlands (cf. Fokkens 2012). Arrows indicate ceramics from one archaeological culture appear in contexts from another. The maps on the right show the extent of these archaeological cultures and other Funnel Beaker groups in Northwest Europe (after: Midgley 2008 Fig. 1.1; Von Schnurbein and Hänsel 2009). Abbreviations: CW = Corded Ware, FBA = Funnel Beaker Altmark Group, FBE = Funnel Beaker East, FBN = Funnel Beaker North, FBS = Funnel Beaker South, FBW = Funnel Beaker West, Vl = Vlaardingen. Funnel Beaker South East not shown.

tombs have sparked public and scientific interest for centuries, and yield large ceramic assemblages which suit the need of typology-focused researchers (cf. Bakker 1992, 2010). Consequently, Funnel Beaker West, as a culture-historical entity, boils down to specific ceramics associated with specific funerary practices. Most, if not all, we know about Funnel Beaker West research can be retraced to these two components.

Studies of Funnel Beaker West ceramics are discussed in detail in upcoming sections (see also Ch. 6, and 8). For now, two crucial points suffice. Firstly, the research is exclusively focused on ceramic style, and our information on other aspects (f.e. provenance, technology, and use) is at best rudimentary. Secondly, these limited studies nevertheless underlie all our knowledge about Funnel Beaker West communities from chronology (e.g. Brindley 1986b) to social structure (e.g. Voss 1982).

The second crucial component of Funnel Beaker West are funerary practices. Funnel Beaker West funerary sites fall into two categories. The first category consists of the *hunebedden*, which are communal megalithic tombs related to passage graves (Bakker 2010; Midgley 2008). The second category is flat graves: (presumably) single interments in pits which lack above-ground markings (Kossian 2000). Flat graves can occur in isolation but are often found in cemeteries numbering anywhere between a handful of burials (e.g. Uddelermeer: Bakker 1979 pp. 194–7) to more than 100 graves (e.g. Dalfsen: Bouma and Van der Velde 2022). Both flat grave cemeteries and megalithic tombs are thought to be the burial grounds of local descent groups (Raemaekers and Van der Velde 2022 p. 186; Voss 1982 pp. 90–1).

Flat graves and megaliths are not exclusive categories. Both burial types may occur nearby (e.g. Lanting and Brindley 2004 on megalith O2) or be part of alignments in the landscape (e.g. Arnoldussen and Scheele 2012 on Angelslo; Bakker 1976; Midgley 1992 pp. 465; 471–2). The reason some individuals came to be interred in megaliths and others in flat graves is unknown, but no distinction exists in the surviving grave goods (Bakker 2010 pp. 8; 12). The current typochronology does suggest the majority of the flat graves are younger (ca. 2975-2750 BCE) than the main use and construction of megaliths (ca. 3350-3050 BCE). However, burials in megaliths continue right until the last sub-phase of Funnel Beaker West (Bakker 2010 p. 15).

Two final observations about Funnel Beaker West funerary practices are about cremation and vessel use. Firstly, the cremation of deceased individuals appears to become the norm in Funnel Beaker West funerary practices during later stages. Cremated human remains appear both in megalithic tombs and flat graves, and are associated with ceramics from the last two horizons of Funnel Beaker West (Bakker 1992 p. 93; Kossian 2000 pp. 50–2; 135). Secondly, Funnel Beaker West ceramics in megaliths and flat graves relatively often exhibit repair holes. This is said to indicate these vessels are not special funerary wares but had long use lives before their deposition in funerary contexts (Brindley 2022 p. 140; Brindley and Lanting 1992 p. 137).

Funnel Beaker West is part of a broader phenomenon. This archaeological culture is considered the youngest and westernmost branch of the Funnel Beaker groups. These groups span present-day Ukraine, Poland, the Czech Republic, Germany, Denmark, Sweden, and the Netherlands from ca. 4500 to 2800 BCE (Iversen 2020 pp. 120–1; Midgley 1992 Fig. 10; Mischka *et al.* 2014 Fig. 2; Müller *et al.* 2012; see Fig. 2.1). Funnel Beaker groups emerged in Poland around 4500-4400 BCE from older Neolithic groups (Midgley 2008 p. 2). Ceramics again play a crucial role in tying these regional groups together. In fact, Furholt (2012, 2014 p. 21) argues most other characteristics of the various Funnel Beaker groups are either a-specific or variable (e.g. monumentality, subsistence economy), and that only a shared ceramic style during the earlier part of the fourth millennium BCE lends a degree of uniformity to this archaeological culture. The various regional groups would diversify in ceramic style after this point. This pattern of initial similarity followed by regional diversification is crucial in later chapters.

In terms of this broader context, Louwe Kooijmans (2018 pp. 494–8) argues Funnel Beaker West best resembles Funnel Beaker North. Again, ceramic style forms a pivotal argument, as the earliest Funnel Beaker West ceramics would resemble Funnel Beaker North ceramics from Denmark and Germany (cf. Brindley 1986b p. 103). Further similarities are Funnel Beaker West depositional practices involving axes from Danish flint (cf. Visser 2021; Wentink *et al.* 2011); the construction of monuments such as causewayed enclosures (e.g. Bakker 1979 p. 195; Hamburg and Lohof 2011 p. 524; e.g. Jager 1985 p. 215; Waterbolk 1960) and passage graves (Bakker 1979 p. 148, 1992 pp. 92–3; Midgley 2008); as well as the agricultural subsistence economy which contrasts with that of earlier Swifterbant communities in the Netherlands (cf. Bakker 2003 pp. 268–70, Tab. 25). Therefore, Louwe Kooijmans (2018 pp. 493–4) argues the origins of Funnel Beaker West lie in Southern Scandinavia. Again, these close ties to Funnel Beaker North become relevant in later chapters.

Vlaardingen: The Only Constant

Apart from Funnel Beaker West, Vlaardingen groups form the second indigenous archaeological culture in the Netherlands during the third millennium BCE (see Fig. 2.1). Vlaardingen communities, and their interactions with Funnel Beaker West and Corded Ware, become relevant for the interpretation of the third millennium BCE in the final chapters, hence the brief introduction here.

Vlaardingen groups occupy the wetland areas of the Netherlands, principally the river delta and the western coastal area between 3400 and 2200 BCE (Beckerman 2015; Fokkens *et al.* 2016 pp. 281, 283–4 footnote 964; see Fig. 2.1). The definition and periodisation of these groups are based on ceramic typology (Beckerman and Raemaekers 2009). Further characteristics of Vlaardingen groups are settlements on high grounds next to surface water, and a subsistence economy which combines agriculture with hunting, gathering, and fishing (Raemaekers 2005 p. 273). Amkreutz (2013) argues Vlaardingen groups are part of a long tradition in the Dutch wetlands which goes back to Mesolithic hunter-gatherers.

There is some evidence for two-way interactions between Vlaardingen, Funnel Beaker West, and Corded Ware in the Netherlands (Bakker 1982; Louwe Kooijmans 1983 p. 59). This evidence is, again, based on ceramic typology, but relevant for future chapters. Funnel Beaker West vessels and baking plates are common finds at Vlaardingen settlement sites (Amkreutz 2013 p. 342; Drenth 2019). Vice versa, Vlaardingen vessels occur at potential Funnel Beaker West settlements (Beckerman and Raemaekers 2009 p. 79; Drenth 2019). These contacts continue right until the last phases of Funnel Beaker West, as indicated by the presence of ceramics from Brindley's (1986b) horizon 7 at the Vlaardingen site Hazerswoude-Rijndijk N11 (Diependaele and Drenth 2010; cf. Fokkens *et al.* 2016 for site interpretation). These interactions are thought to be limited to the occasional exchange of these items; no deeper exchange of knowledge would take place (Bakker 1982 pp. 95–6; Drenth 2019 p. 832; Louwe Kooijmans 1983 pp. 58–60). We return to that interpretation in Chapter 12.

The interactions between Vlaardingen and Corded Ware groups are more complex. Drenth *et al.* (2008) and Beckerman (2015) discuss a number of Corded Ware settlement sites in the wetlands in relation to these interactions (cf. Fokkens *et al.* 2016). These sites are indeed interesting in this light, but the attribution to Corded Ware is problematic. Only a small number of Corded Ware vessels appear on these sites, amidst larger quantities of contemporaneous Vlaardingen ceramics. Moreover, earlier phases of these settlements are ascribed to Vlaardingen groups, and the phases with Corded Ware ceramics do not mark a break with these earlier phases in (f.e.) ceramic production, or the typical subsistence practices of Vlaardingen communities. Moreover, the typical Corded Ware funerary practices (see below) are absent on these sites (Kroon *et al.* 2019; Wentink 2020 pp. 34–5).

Therefore, designating these sites as Corded Ware settlements is not entirely accurate. These sites are Vlaardingen settlements where some Corded Ware vessels appear. The appearance of these ceramics shows interactions occur between Vlaardingen and Corded Ware communities, similar to Funnel Beaker West, but are no reason to attribute the entire site to Corded Ware.

Corded Ware: Barrows and Beakers

Corded Ware in the Netherlands is commonly referred to as *Enkelgrafcultuur* (EGK), or by the literal English translation of this name: *Single Grave Culture* (SGC). Older publications may also refer to *Standvoetbekercultuur* (SVB, lit. Protruding Foot Beaker culture or PFB). Regardless of the label, this archaeological culture is seen as part of Corded Ware on the basis of similarities in ceramics and funerary practices (cf. Furholt 2020). Therefore, this general label is applied to the Dutch finds here.

The conventional chronology dates Corded Ware in the Netherlands between 2800 and 2400 BCE (Lanting and Van der Plicht 2000 pp. 35, 79; see Fig. 2.1). Corded Ware vessels appear throughout the Netherlands (Fokkens 2012 Fig. 6), but the typical Corded Ware funerary sites only appear in the northeastern and central Netherlands (Wentink 2020 p. 36; see Fig. 2.1).

Beckerman (2015 Sec. 1.2.3) recently provided a broad characterisation of Corded Ware groups in Northwest Europe (cf. Wentink 2020). The more recent contributions from genetics have been discussed in Chapter 1. For now, the focus here is on the appearance of Corded Ware in the Dutch archaeological record.

Similar to Funnel Beaker West, Corded Ware funerary sites, and the typology of the ceramics from these sites, have been the focus of archaeological research in the Netherlands (Beckerman 2015 pp. 29–30; Fokkens *et al.* 2016 pp. 23–5; Wentink 2020 p. 34). However, Corded Ware is now effectively understood *to be* these funerary practices and ceramics (Bourgeois and Kroon 2017, 2023; cf. Furholt 2019, 2020). Bourgeois and Kroon (2017) argue Corded Ware is the emergent result of an information-sharing network for funerary practices. These practices involved positioning the body of the deceased in a specific, flexed position, placing specific items (i.e. the ceramics, along with amber beads, amphorae, battle axes, flint axes, and flint daggers) around the corpse, and erecting a mound over the burial. These mounds can be positioned in the landscape to form larger alignments (Bourgeois 2013 pp. 183–5). Archaeologists recognise Corded Ware because of these shared practices (Bourgeois and Kroon 2017), which also correlate with steppe ancestry of the individuals buried in accordance with them (Furholt 2020 pp. 9–10).

The names of the typical Corded Ware grave goods (e.g. battle axe, dagger) suggest these items are weapons, and this naming colours our interpretations of migrating groups (cf. Heyd 2021; see Ch. 1). However, Wentink (2020) has recently shed new light on the grave goods in Dutch Corded Ware burials. He shows the use wear on the axes and battle axes points to a role in cutting down and uprooting trees. The majority of the flint daggers do not feature well-developed use wear but may have been tokens of distant exchange relations (Wentink 2020 p. 136). Similarly, he argues many of the beakers may not have been usable or used, but are specially produced for the funeral (Wentink 2020 pp. 73; 82). Therefore, Wentink (2020 pp. 229–32) argues these items do not signal martial prowess, but an idealised representation of the deceased which emphasises long-distance travel and contacts.

The funerary sites and practices described above make up Corded Ware in the Netherlands. Studies of Corded Ware ceramics in the Netherlands are discussed below (for typochronology) and in Chapter 7 (for ceramic technology). Drenth *et al.* (2008) also discuss a number of potential Corded Ware settlement sites in the Netherlands. These sites are not discussed in detail here, because most of them are mere artefact scatters which have little to no information value. The more convincing settlement sites are those in the coastal area, but these are actually misclassified Vlaardingen settlements (see above).

The last point in this section on Corded Ware is about the transition from Funnel Beaker West to Corded Ware. We revisit the evidence for this transition in detail below, hence a brief overview of the discourse is relevant.

In general, Corded Ware is seen as younger than, and distinct from, Funnel Beaker West due to the differences in ceramic style and funerary practice (see above). However, there has been debate on the possibility of continuity between these two entities. So-called 'contact finds' were the crux of this debate. These finds are archaeological cases in which Corded Ware finds appear in Funnel Beaker West contexts, and vice versa. For example, Funnel Beaker West flat grave no. 14 at Angelslo, which contained Corded Ware ceramics (Bakker and Van der Waals 1973), or the Corded Ware vessels deposited in Funnel Beaker West megaliths (Bakker 1992 pp. 58–9). These finds were taken to indicate a degree of contemporaneity, or continuity between Funnel Beaker West and Corded Ware (Bakker and Van der Waals 1973; Fokkens 1986, 1998; Van der Waals 1984). However, this evidence has since been sidelined on the basis of typochronology.

The crucial publications in this development are those by Brindley (1986b p. 105), Drenth and Lanting (1991 p. 42), and Lanting and Van der Plicht (2000 pp. 32, 68, 79). These authors combine the typochronologies for Funnel Beaker West and Corded Ware with radiocarbon dates to suggest both the end date for Funnel Beaker West and the start date for Corded Ware fall around 2800 BCE. They argue this leaves little to no overlap between both archaeological cultures. Combined with the differences in ceramic style and funerary practices between Funnel Beaker West and Corded Ware, this interpretation of the radiocarbon evidence led to the idea of a rapid, disruptive transition, or 'replacement' of Funnel Beaker West communities around 2800 BCE (cf. Fokkens 2012 p. 23). Consequently, archaeologists dismissed 'contact finds' as later re-use or erroneous interpretation (e.g. Bakker 2010 p. 15; Lanting and Van der Plicht 2000 p. 66). This line of thought is the *status quo* on the transition from Funnel Beaker West to Corded Ware. The notion of a rapid, disruptive transition around 2800 BCE also feeds directly into interpretations of the interactions between migrating and indigenous communities in Northwest Europe (cf. Heyd 2021 p. 405 on the "northern corridor").

Crucially, doubts have since emerged about the strength of the radiocarbon evidence behind this interpretation of the transition between Funnel Beaker West and Corded Ware (Fokkens *et al.* 2016 pp. 284–5; Furholt 2003 pp. 98–100). Therefore, the next two sections are a critical deep dive into the two main arguments for a rapid transition: the typochronology (Section 2.2) and the radiocarbon evidence (Section 2.3). In specific, the role of the culture-historical perspective in these two arguments is discussed.

2.2 Rise and Fall

Cultural history is a prominent part of our knowledge about the third millennium BCE in the Netherlands, and European Prehistory in general. This perspective not only considers similarities in material culture as an indicator for past cultural groups or phenomena (cf. Furholt 2020 p. 3), but also makes these groups and phenomena the subjects of history (Trigger 2006 pp. 240, 310–3). Archaeological evidence becomes a means to trace the history of, for example, Corded Ware groups or the Bell Beaker phenomenon.

Crucially, archaeologists structure such histories along a particular narrative (cf. White 1973, 2014), namely the emergence, rise, decline, and fall of groups or phenomena. Consider the overview of Funnel Beaker groups presented in Section 2.1. These groups developed out of older groups in Central Europe around 4500-4400 BCE (*emergence*), spread across the North European plain, constructing megaliths and fashioning highly similar ceramics (*rise*). However, this initial similarity gradually gave way to regionalised styles, and the construction of megaliths stopped altogether in some areas (*decline*). Ultimately, Funnel Beaker groups disappeared with the arrival of Corded Ware groups (*fall*). This example shows how archaeologists fit various pieces of evidence into a rise-and-fall narrative. Funnel Beaker West is not an exception in this respect. The same applies to Corded Ware (see below). In essence, the culture-historical perspective envisions the entire past as an endless cycle of the rise and fall of specific groups.

The argument in this section is not that using such narrative structures disqualifies the facts but that the narrative structure took over from the facts in some cases. I argue that the typochronologies for Funnel Beaker West and Corded Ware in the Netherlands follow this narrative structure of rise and fall. Moreover, this narrative structure has coloured interpretations of the radiocarbon evidence and the transition between these two archaeological cultures.

The narrative structuring of the Funnel Beaker West typochronology along a rise-and-fall trajectory is evident from depictions of this chronology (cf. Bakker 1979 Fig. 27a; Van Gijn and Bakker 2005 Fig. 13.2; Van Ginkel *et al.* 1999 p. 40). These depictions show modestly decorated ceramics in the earliest horizons. The decorations become more lavish and complex, climaxing during horizons 3 and 4. Only to diminish again in complexity during horizons 5 and 6, and ultimately vanish, leaving plain ceramics in horizon 7. This narrative structuring, whereby the complexity of decorations indicates the rise and fall of a cultural entity, has deep roots in studies of Funnel Beaker West.

The classification of Funnel Beaker West vessels in accordance with a rise-and-fall narrative is visible in Van Giffen (1927 pp. 402; 417), who describes early Funnel Beaker West vessels as mere derivatives of older cultures. However, these vessels develop into Early Havelte, which he describes as the pinnacle of Funnel Beaker West achievement, and connects to the most elaborate forms of megalithic architecture. After this phase, Havelte "*begint te verloopen*" (=starts to expire). Knöll (1959) co-opts and emphasises this narrative structure. He repeatedly speaks of decoration "receding" as time progresses, of shapes (barely) clinging on during later phases, and of an ultimate "*völliger Verfall von Form und Verzierung*" (= complete decay of shape and decoration).

More recent studies step away from the explicit terminology above, but inherit the narrative structure by leaving the typological development unchanged. Bakker (1979) retains the above narrative structure as he recombines the typologies of Knöll (1959) and Van Giffen (1927). In addition, Bakker (1979 p. 66) too writes about "more complicated" Late Drouwen ceramics, "elegant" Early Havelte ceramics (ibid. p. 61), and "reduced" complexity in younger phases (ibid. p. 72).

This brings us to the current typochronology of the Funnel Beaker West. Brindley (1986b p. 101) outwardly rejects the terminology of earlier authors, but does inherit the underlying narrative structure as she only slightly modifies Bakker's (1979) typochronology. This inheritance is visible in descriptions of decorations as increasingly diversified in horizon 3 (Brindley 1986b p. 96), and "more simplified" in horizon 5 (ibid. p. 99). Consequently, the narrative structuring of Funnel Beaker West along a rise and fall trajectory shapes the typochronology to the present day.

A similar narrative structure is present in the Corded Ware typochronology. For present purposes, only the emergence of Corded Ware is relevant, so a brief discussion suffices here. Van der Waals and Glasbergen (1955 p. 8; Lanting and Van der Waals 1976 p. 4) reconstruct a development towards increasingly elaborate and complex decorations from early 1a beakers to later 1b beakers. The early beakers also feature a "well-developed" protruding foot. A "logical devolution" then sets in with 1c beakers and leads to the ultimate loss of complex decorations and typical elements such as protruding feet in 1e beakers (Van der Waals and Glasbergen 1955 pp. 11-2; 15-6). The narrative structure of emergence, rise, decline, and fall is evident from these descriptions. Similar to Funnel Beaker West, subsequent typochronologies, among others the one put forward by Drenth and Lanting (1991), inherited this structure (cf. Beckerman 2012 for an overview).

The above observations do not, by themselves, disqualify the typochronologies for Funnel Beaker West and Corded Ware. It may well be possible to organise these ceramics into the above sequences. Whether these sequences are chronological is a different matter (see below). However, highlighting the narrative structure brings to the fore a key, tacit argument for a rapid transition between indigenous Funnel Beaker West and migrating Corded Ware groups. Namely, the suggestion that Funnel Beaker West was already making for the door when Corded Ware arrived on the scene. A quick, chronological succession between the two entities becomes self-evident because archaeologists construe them along this cyclical rise-and-fall narrative.

The same narrative structure also shapes the absolute chronology of the third millennium BCE. Brindley (1986b p. 105), Drenth and Lanting (1991 p. 42), and Lanting and Van der Plicht (2000) reject young radiocarbon dates for Funnel Beaker West, and old dates for Corded Ware, precisely because they believe the decline of Funnel Beaker must set in prior to the emergence of Corded Ware (cf. Mennenga 2017 for a similar interpretation of radiocarbon dates from Northwestern Germany). This is a circular argument which imposes the narrative structure from the Funnel Beaker West and Corded Ware typochronology onto the absolute chronology.

The next section shows that, if we ignore the narrative structure from culture history, address several other issues in the absolute chronology, and apply a formal Bayesian model, the available radiocarbon evidence does not support the current typochronology, nor a rapid transition. Instead, a different image of the third millennium BCE emerges in which Funnel Beaker West and Corded Ware communities co-exist.

2.3 Re-examining the Absolute Chronology of the Third Millennium BCE

The second crucial argument for a rapid transition between Funnel Beaker West and Corded Ware is the absolute chronology from Lanting and Van der Plicht (2000). This chronology leaves little to no temporal overlap between the youngest date for Funnel Beaker West and the oldest date for Corded Ware. This section is a re-examination of this argument which tests the absolute chronology and the proposed rapid transition against the available radiocarbon evidence by means of Bayesian chronological modelling.

Bayesian chronological modelling is an application of Bayesian statistics to radiocarbon evidence (Bayliss 2015; Bronk Ramsey 1995). Bayesian statistics evaluate a prior belief against available data to produce a revised or posterior probability which is indicative for the state of the prior (Tijms 2018 p. 79). In archaeology, the prior is often a site stratigraphy (e.g. Dreshaj *et al.* 2023) or chronology (e.g. Brunner *et al.* 2020), the available data a body of radiocarbon dates, and the posterior probability an indication of the support for the prior. As such, Bayesian chronological modelling has gained traction as a formal method for testing and developing chronologies which can integrate multiple lines of evidence (Bayliss 2015; Hamilton and Krus 2018).

A re-examination of the radiocarbon evidence is necessary, not only because of the circular argument discussed above but also because of three other issues with the absolute chronology (cf. Beckerman 2012; Fokkens *et al.* 2016; Furholt 2003; Mennenga 2017). Firstly, Lanting and Van der Plicht (2000) do not calibrate the radiocarbon dates, which is a critical oversight given the platforms in the calibration curve during the third millennium BCE (cf. Furholt 2003 in specific). Secondly, the dated material frequently exhibits uncertain or indirect associations with the dated events. For example, Lanting and Van der Plicht (2000 p. 65) incorporate a radiocarbon date for Funnel Beaker West ceramics which was performed on charcoal particles from the infill of a pit presumed to be contemporaneous with the construction of an adjacent megalith which in turn contains ceramics from various horizons (cf. Beckerman 2012 for similar issues with dates for Corded Ware). Such uncertain associations are a poor basis for an absolute chronology. Lastly, the quality of the data reporting is low, especially to modern standards (cf. Bayliss 2015). Lanting and Van der Plicht (2000) provide good context information for the radiocarbon dates but crucial information about (f.e.) laboratory treatment of samples and fractionation is absent. The quality of data reporting also continues to be a problem in archaeological publications about this period (cf. Fokkens *et al.* 2016).

These three issues already led Furholt (2003 pp. 98–100), Beckerman (2012), and Fokkens *et al.* (2016) to express doubts about the resolution of the absolute chronology, but these publications stop short of testing and outright contradicting the chronology.

Fully resolving the three above-mentioned issues is beyond the scope of this study. This would require a comprehensive radiocarbon dating programme for the Netherlands and Northwestern Germany with the aims of establishing a new and continuous influx of high-quality radiocarbon dates with good associations and context data, as well as sophisticated statistical modelling of boundaries (cf. Bayliss 2015; Bronk Ramsey 2009b, 2009a, 2017; e.g. Djakovic *et al.* 2022). Instead, this dissertation presents an intermediate solution: compiling a new overview of available radiocarbon dates, excluding radiocarbon dates which lack good associations, (re-)calibrating all dates with the latest calibration curve, and formulating Bayesian chronological models to test whether the resulting dating ranges support the chronologies which are based on these dates.

Data Selection and Data

The point of departure is a survey of radiocarbon dates for Funnel Beaker West and Corded Ware in existing overviews (e.g. Fokkens *et al.* 2016; Lanting and Van der Plicht 2000) and more recent excavation reports (e.g. Bouma and Van der Velde 2022: see Appendix

A for all used sources). Chronometric hygiene (cf. Spriggs 1989) was applied during this survey to select radiocarbon dates for quality and to ensure the validity of further steps in the analysis.

Various proposals exist for evaluation criteria when applying chronometric hygiene to radiocarbon dates, ranging from qualitative systems (e.g. Gragson and Thompson 2022) to semi-quantitative point-based systems (e.g. Pettitt *et al.* 2003). In this case, a qualitative selection criterion was applied due to the poor quality of data reporting in the source publications (see above).

The evaluation criterion was the strength of the association between the dated event and the dated materials. The overview of radiocarbon dates in Appendix A includes only those radiocarbon dates for which the dated material exhibits good association with Funnel Beaker West or Corded Ware ceramics (or in the case of Corded Ware other material culture such as battle axes) which can be dated by means of the typochronology. If multiple, reliable dates on independent samples were available from the same context (e.g. separate dates on different parts of a wooden structure in a burial pit), the youngest of these dates has been retained in Appendix A. If multiple reliable dates were available for the same organism (f.e. two dates on skeletal remains of a single individual) the measurement values of these dates have been combined with the R-combine function in OxCal (Bayliss 2015 pp. 688–9; cf. Bronk Ramsey 2009b).

In total, 62 radiocarbon dates were selected for further analysis during the survey. Appendix A is a complete overview of these dates with all available information formatted according to the recommendations by Bayliss (2015). A breakdown of these radiocarbon dates by dated material and typochronological phase is shown in Table 2.1. Three observations about these selected radiocarbon dates warrant further discussion here.

Firstly, a large number of the radiocarbon dates, especially for Corded Ware, was performed on charcoal (see Tab. 2.1). These radiocarbon dates were retained only if the charcoal had a direct association with the dated event (see above). For example, a radiocarbon date on a charred coffin in a burial with ceramics would be included in Appendix A, but not a radiocarbon date on a charred post from a timber circle around the burial mound which was potentially contemporaneous with the burial. Nevertheless, the amount of charcoal dates is bound to raise concerns about old wood effects (cf. Fokkens *et al.* 2016 p. 280; Furholt 2003 p. 20).

However, the reliability of radiocarbon dates on charcoal is more complex than generally assumed. In some cases, dating charcoal is actually preferable over dating food crusts or skeletal remains, for example when marine or freshwater reservoir effects are expected for other organic material (Kidder and Grooms 2023; Phlippsen 2013). The true problem is that studies generally report insufficient data about dated charcoal to prove or disprove the presence of old wood effects. For example, the number of radiocarbon dates on charcoal for which species determinations, plant anatomy (seeds, branches, sapwood, heartwood, etc.), or other factors which enable assessment of longevity were reported is low (see Tab. 2.1; Appendix A). In addition, the same problems apply to the 'more acceptable' radiocarbon dates on human bone and food crusts. These dates were generally published without the stable isotope data or biomarker data needed to check for potential reservoir effects (cf. Hart *et al.* 2018; Heron and Craig 2015; Lanting and Van der Plicht 1998; Phlippsen 2013; see Appendix A). Therefore, if any conclusion can be drawn from this dataset, it is about the absolute need and urgency for archaeologists in

Dated material		Charcoal		Human bone		Food crust	Total
Group	**Phase**	**Det.**	**Indet.**	**Cremation**	**Unknown**		
Funnel Beaker West	1/3	0	1	0	0	0	**1**
	2/6	0	0	0	2	0	**2**
	3/4	0	0	1	0	0	**1**
	3/5	1	0	0	0	0	**1**
	4	3	1	0	1	0	**5**
	5	8	1	1	0	0	**10**
	6	0	1	1	0	2	**4**
	7	0	2	16	0	2	**20**
	Subtotal	12	6	19	3	4	**44**
Corded Ware	1/2	0	1	0	0	0	**1**
	2	0	2	0	0	0	**2**
	3/4	0	2	0	2	0	**4**
	4	0	4	1	0	4	**9**
	AOO	0	2	0	0	0	**2**
	Subtotal	0	11	1	2	4	**18**
Total		**12**	**17**	**20**	**5**	**8**	**62**

Table 2.1: Overview of radiocarbon dates for Funnel Beaker West and Corded Ware in Appendix A. The radiocarbon dates are grouped by horizon or phase (rows) and by dated material (columns). Det. = species determination reported for charcoal; Indet. = no species determination reported for charcoal. The table only shows the phases or horizons for which reliable dates could be found.

the Netherlands and Germany to re-engage with absolute chronology and to be rigorous about chronometric hygiene.

The second observation about the radiocarbon dataset in Appendix A relates to the availability of radiocarbon dates for certain phases in the typochronology. As shown in Table 2.1, the survey yielded no reliable radiocarbon dates for the early horizons (1-3) of the Funnel Beaker West typochronology and phases 1 and 3 of the Corded Ware typochronology. This means a formal test of these phases by means of a Bayesian chronological model is impossible (see below). However, it equally indicates no reliable evidence exists for the absolute ages of these phases and horizons as proposed in the current typochronologies.

Lastly, there is a pattern in the radiocarbon evidence for Funnel Beaker West. The radiocarbon dates for earlier horizons (4-5) tend to stem from charred timber constructions in burials, whereas those for later horizons (6-7) more often stem from human skeletal remains in cremation burials (see Appendix A; Tab. 2.1). We will return to this pattern below.

Prior to the formulation of all Bayesian chronological models, all dates in Appendix A have been recalibrated in OxCal v4.4.4 with the IntCal20 curve (Bronk Ramsey 2021; Reimer *et al.* 2020). The resulting dating ranges for Funnel Beaker West are shown in Figures 2.2 to 2.4, and for Corded Ware in Figure 2.5. The sections below discuss the patterns visible in these calibrated radiocarbon dates, the Bayesian chronological models formulated to test the typochronologies of Funnel Beaker West and Corded Ware, as well as the proposed rapid transition between these two entities around 2800 BCE.

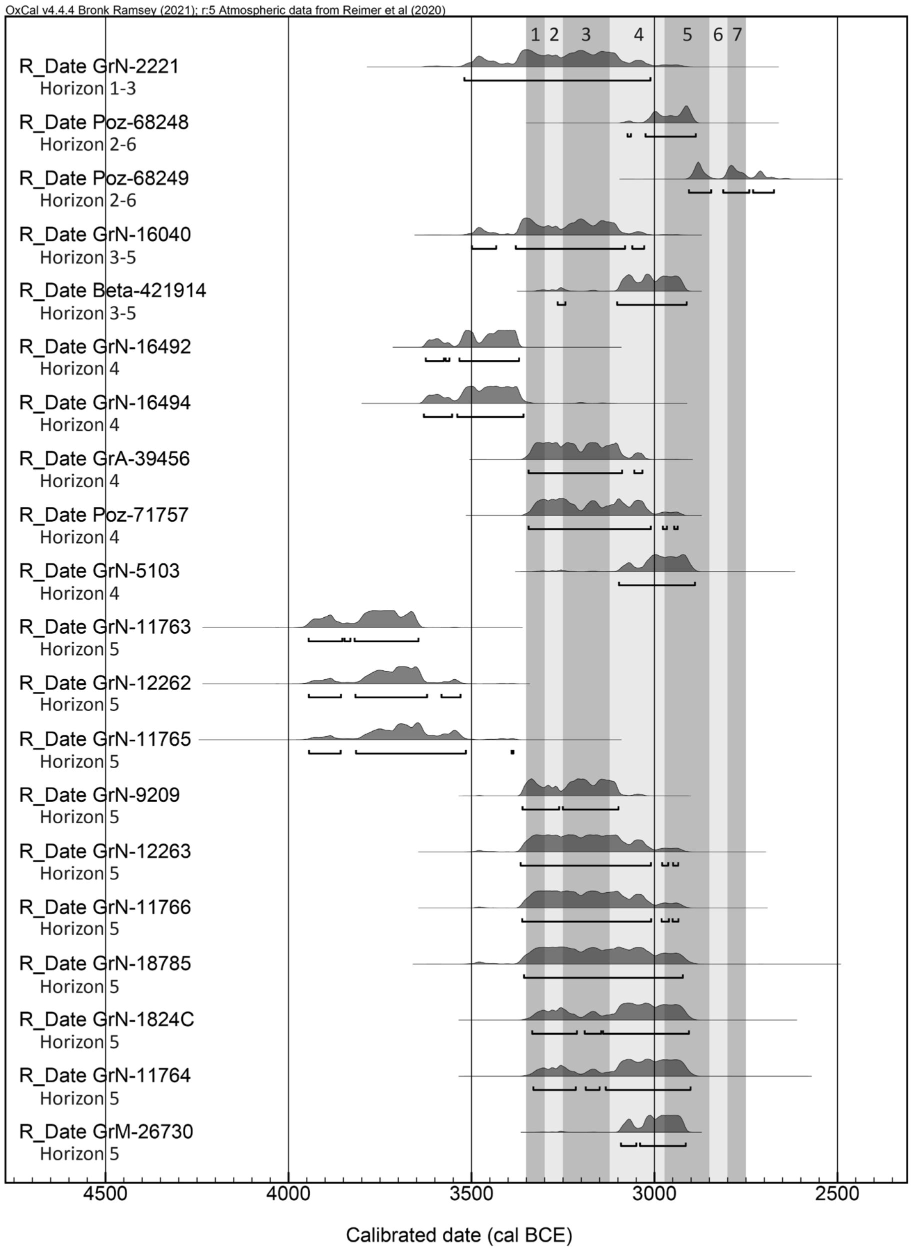


Figure 2.2: Calibrated radiocarbon dates (2-sigma values) with good associations to Funnel Beaker West ceramics from horizons 1-5 (see Appendix A). Recalibrations using IntCal 2020 (Reimer *et al.* 2020) in OxCal v4.4.4 (Bronk Ramsey 2021). The labels report the typological classifications of the associated ceramics according to Brindley's (1986b) typochronology. The shaded and numbered vertical bars indicate the proposed dates for the corresponding horizons (see top; cf. Brindley 2022 p. 112). There are no reliable radiocarbon dates for the first three horizons. The 2-sigma values for radiocarbon dates associated with ceramics from horizons 4 and 5 ceramics fluctuate greatly between ca. 4000 and 2900 cal BCE.

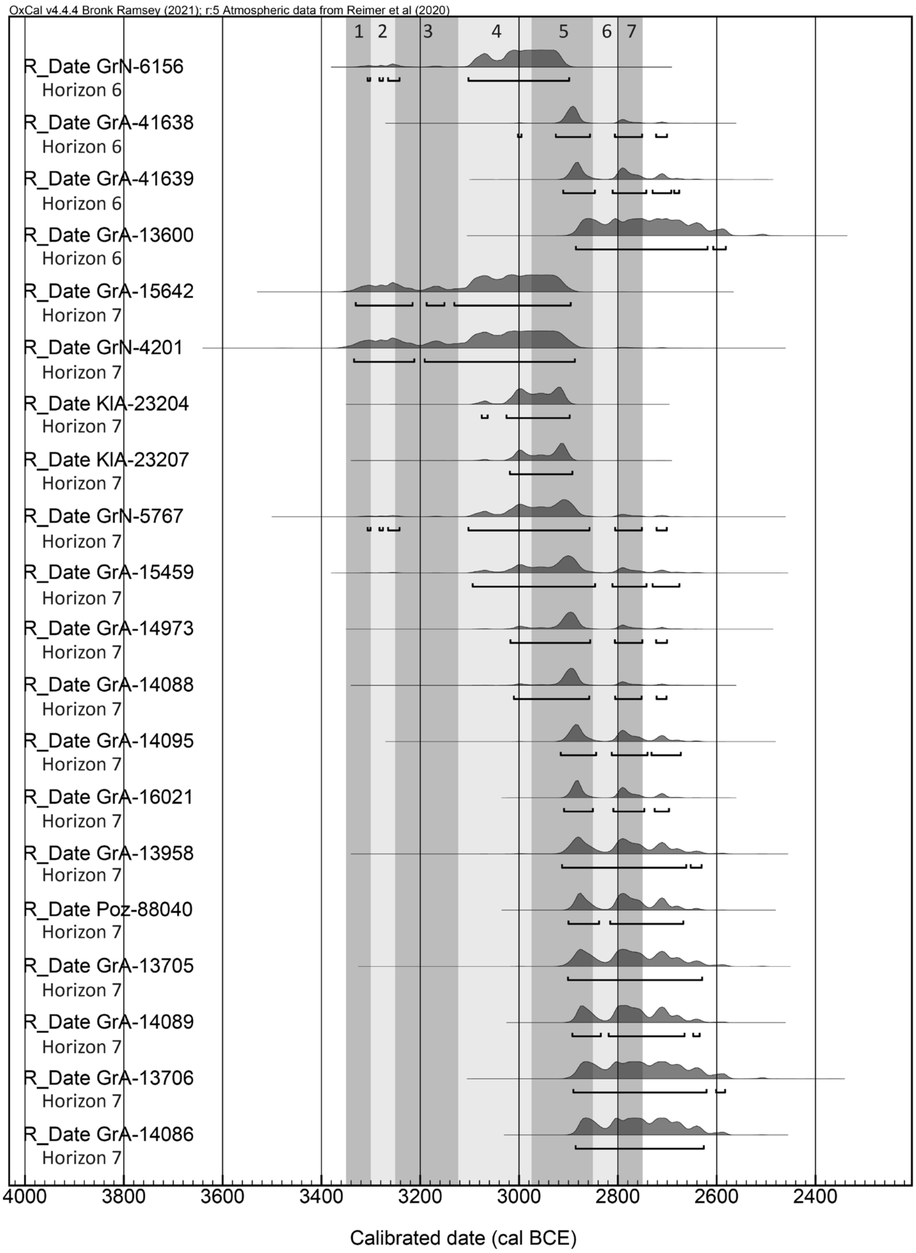


Figure 2.3: Calibrated radiocarbon dates with good associations to Funnel Beaker West ceramics from horizons 6 and 7 (see also Fig. 2.4; Appendix A). The labels indicate the typological classification of these ceramics according to Brindley (1986b). Re-calibrations of the radiocarbon dates at 2-sigma confidence intervals using IntCal 2020 (Reimer *et al.* 2020) in OxCal v4.4.4 (Bronk Ramsey 2021). The numbered and shaded vertical bars indicate the duration of the seven typochronological horizons of the Funnel Beaker West according to Brindley (2022 p. 112). The dates for ceramics from horizon 6 and 7 show no match with the proposed dates for the horizons. However, a substantial number falls between ca. 2900-2600 cal BCE.

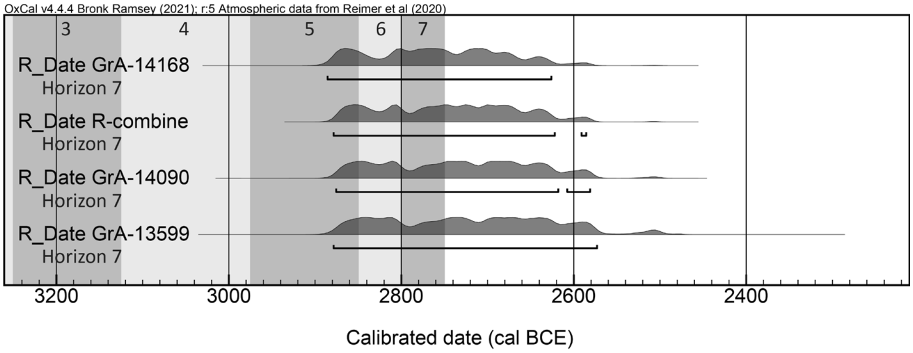


Figure 2.4: 2-sigma ranges for calibrated radiocarbon dates with good associations to horizon 7 ceramics (see also Fig. 2.3; Appendix A). Recalibrations using IntCal 2020 (Reimer *et al.* 2020) in OxCal v4.4.4 (Bronk Ramsey 2021). The labels show the typological classifications of the associated ceramics according to Brindley (1986b). Numbered and shaded vertical bars indicate the proposed dates for the corresponding horizons (see top; cf. Brindley 2022 p. 112). All radiocarbon dates shown here for horizon 7 ceramics fall between ca. 2900-2600 cal BCE, well outside the proposed dating range of this horizon.

Assessing the Validity of the Typochronologies

The calibrated radiocarbon dates in Figures 2.2 to 2.5 show that the typochronologies proposed by Brindley (1986b) and Drenth and Lanting (1991) are not supported by the radiocarbon evidence. This was known for Corded Ware (cf. Beckerman 2012; Furholt 2003) but not for Funnel Beaker West. Hence, the findings for the Funnel Beaker West typochronology are discussed in more detail below.

The current typochronology for Funnel Beaker West stems from Brindley (1986b), who distinguishes seven horizons based on ceramic typology (cf. Brindley 2022 p. 112 for the dates of these horizons). A visual inspection of the absolute dates associated with ceramics from specific horizons suggests these dates do not correspond to this detailed subdivision. There are no reliable dates for ceramics from the first three horizons to begin with (see above; Fig. 2.2), and the two-sigma ranges of dates for ceramics from all other horizons tend to span 3 or 4 of the proposed horizons (see Fig. 2.2-4). This strongly suggests that the absolute dates do not support a division of Funnel Beaker West into seven distinct phases.

A Bayesian chronological model of the radiocarbon dates in OxCal v4.4.4 (Bronk Ramsey 2021) confirms this interpretation of Figs. 2.2-4. The model used only the radiocarbon dates from Appendix A which are associated with a single Funnel Beaker West horizon. This meant only dates for horizons 4-7 were available (see Tab. 2.1). These dates were organised as four uniform, contiguous phases within one sequence (cf. Bronk Ramsey 2009a; see Appendix A for model code). These model parameters are appropriate because Brindley (2022, 1986b) classifies Funnel Beaker West vessels into seven discrete phases with each phase sharing a start and end date with adjacent phases.

Running the Bayesian model for the Funnel Beaker West typochronology in OxCal results in an error because the Markov Chain Monte Carlo (MCMC) sampling process cannot find an order for the dates which satisfies all constraints in the model (Bronk Ramsey 2009a, 2021). This concurs with the visual inspection of the calibrated radiocarbon dates discussed above: the absolute ages of the ceramics do not conform a strict subdivision into seven distinct phases, nor the relative ages proposed for these horizons in Brindley (2022 p. 112). Given this outcome, the detailed subdivision of Funnel Beaker West into seven horizons is not followed in this study.

However, this does not apply to some of the broader patterns. The majority of the radiocarbon dates associated with ceramics from horizons 6 and 7 do fall after ca. 2900 cal BCE (see Fig. 2.3-2.4), whereas dates for preceding horizons (4-5) fall prior to this date (see Fig. 2.2). These dates do not cluster into discrete chronological phases, but do suggest a general trend exists. We return to this trend in Section 2.4.

The same conclusion applies to the Corded Ware typochronology from Drenth and Lanting (1991). A visual inspection of the calibrated radiocarbon dates shows these do not support the detailed chronological distinctions between various typochronological phases (see Fig. 2.5), as Furholt (2003) and Beckerman (2012) have already shown (cf. Wentink 2020).

The recalibrated radiocarbon dates also do not appear to support the distinction between Corded Ware beakers and so-called All-Over Ornamented beakers. According to the typochronology, All-Over Ornamented beakers should appear toward the end of the Corded Ware period and lead up to Bell Beakers (Drenth and Lanting 1991; Lanting and Van der Waals 1976; Van der Waals and Glasbergen 1955). However, the calibrated ranges for these ceramics overlap entirely with those of Corded Ware vessels (see Fig. 2.5; cf. Beckerman 2012). Wentink (2020 pp. 36–8) further demonstrates that burials with All-Over Ornamented beakers are not distinct from Corded Ware burials in terms of funerary practices. This suggests there is no argument to distinguish All-Over Ornamented beakers from Corded Ware.

This hypothesis can be substantiated with a formal Bayesian chronological model in OxCal v4.4.4 (Bronk Ramsey 2021). The Bayesian model in this analysis is more complex than the one for the Funnel Beaker West typochronology (see above) because Drenth and Lanting (1991) base typological dates on combinations of multiple artefacts. Single artefacts may span multiple phases, in particular an early stage (phase 1-2) and a late stage (phase 3-4; cf. Lanting and Van der Plicht 2000; see also Appendix A). As such, the Bayesian chronological model has a nested design with two contiguous, uniform phases (early and late Corded Ware) each with two further contiguous, uniform phases within them (phase 1 and 2, and phase 3 and 4 respectively; cf. Bronk Ramsey 2009a). All-Over Ornamented dates have been placed in the late Corded Ware phase of the model, which closely matches the proposed relative age of these ceramics in the typochronology (see Fig. 2.5; cf. Lanting and Van der Plicht 2000 p. 81). Phase 1 and 3 have been left out of the model due to the absence of available radiocarbon dates (see Tab. 2.1). The code for this model can be found in Appendix A.

The outcomes of the Bayesian chronological model again confirm the outcomes of the visual inspection of Fig. 2.5. Similar to the Bayesian chronological model for the Funnel Beaker West typochronology, the MCMC Sampling process in OxCal is unable to find an order for the dates which satisfies all constraints in the model. This means the radiocarbon dates cannot support the typochronological subdivisions proposed by Drenth and Lanting (1991; cf. Lanting and Van der Plicht 2000). Therefore, the Corded Ware typochronology is not used in this dissertation.

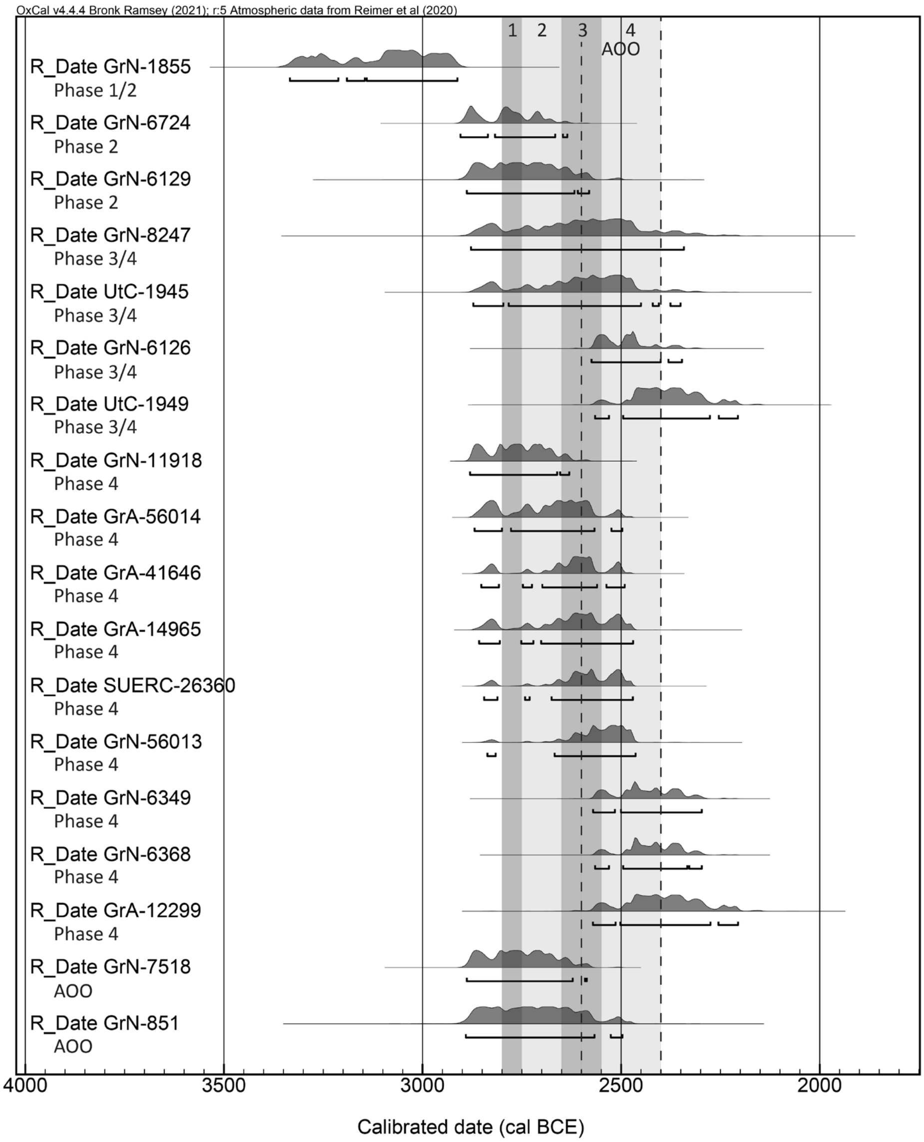


Figure 2.5: Selected, calibrated radiocarbon dates for Corded Ware (see Appendix A). 2-sigma ranges from calibrations using IntCal 2020 (Reimer *et al.* 2020) in OxCal 4.4.4 (Bronk Ramsey 2021). The shaded vertical bars (see top) are the proposed dates for sub-phases of Corded Ware in the Netherlands; the area between the dotted lines is the date for All-Over Ornamented (AOO) beakers (Drenth and Lanting 1991; Lanting and Van der Plicht 2000 pp. 35, 81). Labels on the right indicate the typochronological phase of the material associated with the date. The recalibrated dates do not match up with the proposed dates in the typochronology, and generally suggest an earlier starting date for Corded Ware (ca. 2900 cal BCE) with an exception extending into the fourth millennium BCE. The youngest calibrated ranges fall around 2200 cal BCE.

Assessing the Validity of a Rapid Transition

The recalibrated radiocarbon dates in Figures 2.2-2.5 warrant a reconsideration of the start and end dates for Funnel Beaker West and Corded Ware. These new dates have major implications for the transition between these archaeological cultures.

A visual inspection of Figures 2.2-4 shows the earliest and latest possible calibrated radiocarbon dates for Funnel Beaker West differ from the conventional start and end dates of this group (cf. Brindley 2022 p. 112; see also Section 2.1). The earliest possible dates fluctuate sharply. Some dates would agree with the conventional starting date around 3400 cal BCE, others extend towards 4000 cal BCE. However, the cut-off point for the youngest possible Funnel Beaker West dates appears consistent in Figures 2.2-4. This cut-off point lies around 2600 cal BCE, at least 150 years after the conventional end date for Funnel Beaker West between 2800 and 2750 cal BCE (cf. Brindley 2022 p. 112).

Similarly, the calibrated radiocarbon dates for Corded Ware in Figure 2.5 do not match the conventional start and end dates for this group, which lie at 2800 BCE and 2400 BCE respectively (Lanting and Van der Plicht 2000 p. 35; 81). The bulk of the dates has an earliest possible range around 2900 cal BCE with one exception extending into the fourth millennium BCE (see Fig. 2.4). Similarly, the youngest possible dates fall between 2300 and 2200 cal BCE, potentially 200 years after the conventional end date for Corded Ware (cf. Beckerman 2012 pp. 63–4).

Bayesian chronological modelling can be applied to infer the most likely start and end dates for Funnel Beaker West and Corded Ware on the basis of the radiocarbon evidence (cf. Bourgeois *et al.* in press.). In this case, the model incorporates all reliable radiocarbon dates for Funnel Beaker West and Corded Ware from Appendix A into two separate sequences. The two separate sequences are necessary because we cannot assume Funnel Beaker West and Corded Ware to be contiguous phases within the same sequence (see Section 2.2; cf. Bronk Ramsey 1995, 2009a). Next, the model uses the *KDE_Plot* function to summarise the calibrated dating ranges and infers the start and end date for both Corded Ware and Funnel Beaker West (Bronk Ramsey 2017). The code for and raw output of this model can be found in Appendix A. Figure 2.6 is a summary of the output (cf. Bourgeois *et al.* in press.).

The Bayesian chronological model of the radiocarbon dates confirms the informal observations about the radiocarbon dates in Figures 2.2-5. The mean estimated start date for Funnel Beaker West falls at 3711 BCE with a two-sigma range from 3802 BCE to 3645 BCE. The estimate for the mean end date is 2669 BCE with a two-sigma range from 2761 BCE to 2581 BCE (see Fig. 2.6; Appendix A). The mean estimated start date for Corded Ware is 2976 BCE with a two-sigma range from 3089 BCE to 2899 BCE. The mean estimated end date for Corded Ware falls at 2371 BCE with a two-sigma range between 2474 BCE and 2243 BCE (see Fig. 2.6; Appendix A).

These outcomes of the Bayesian chronological model imply a substantial period of overlap between Funnel Beaker West and Corded Ware communities. Even the most conservative scenario (i.e. the youngest possible start date for Corded Ware minus the oldest possible end date for Funnel Beaker West) would result in an overlap of 138 years, more than double the 50 years which is currently seen as the maximum overlap (cf. Lanting and Van der Plicht 2000 pp. 68; 79). The most likely scenario is an even longer overlap of 307 years, based on the mean start date of Corded Ware and the mean end date of Funnel Beaker West (see Fig. 2.6; Appendix A; cf. Bourgeois *et al.* in press.); and the maximum duration of the overlap is 508 years, based on the oldest possible start date for Corded Ware and the youngest possible end date for Funnel Beaker West (see Fig. 2.6).

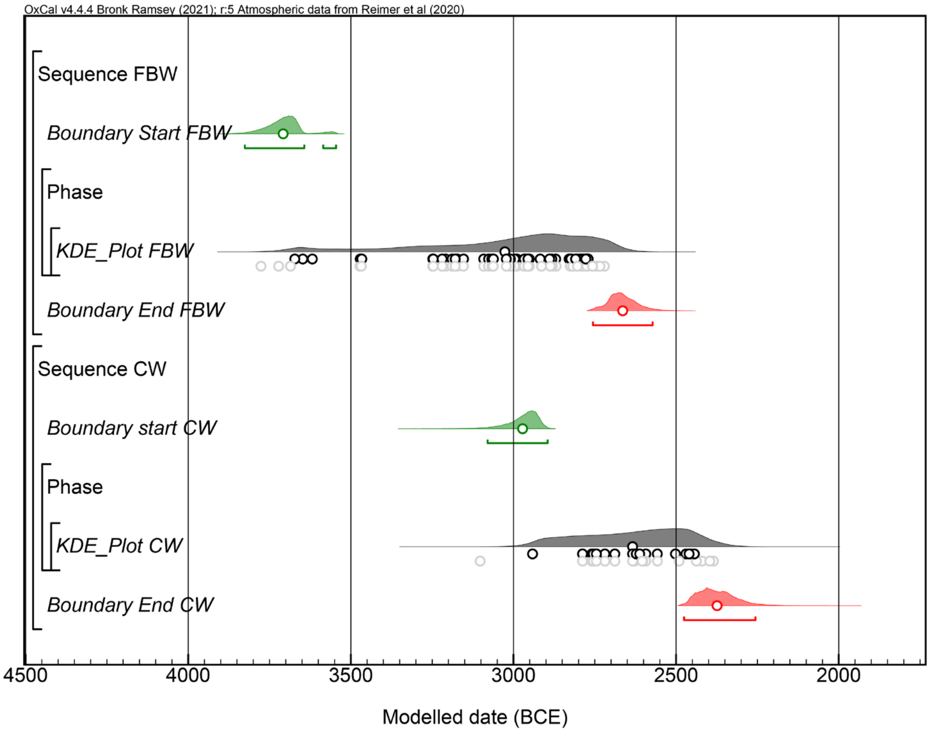


Figure 2.6: Bayesian analysis of the start and end date of Funnel Beaker West and Corded Ware on the basis of the radiocarbon dates in Appendix A. The dates were calibrated in OxCal v4.4.4 (Bronk Ramsey 2021) with the IntCal20 calibration curve (Reimer *et al.* 2020). The kernel density plots are in grey, the inferred starting dates in green, and the inferred end dates in red. Transparent rings indicate the mean likelihood of individual calibrated radiocarbon dates, solid rings the mean posterior probability of dates and posterior probability distributions. The brackets and functions on the left show the build-up of the model in OxCal. For raw output, see Appendix A. Agreement of the model is good (Amodel = 113.1), as is the agreement (Aoverall = 111.6) of the individual calibrated dates (see Appendix A; cf. Bronk Ramsey 1995 for threshold values).

Consequently, the renewed analysis of the radiocarbon evidence demonstrates no rapid transition from Funnel Beaker West to Corded Ware occurred around 2800 BCE. This interpretation is an artefact of the culture-historical perspective, which led researchers to assume Funnel Beaker West and Corded Ware are distinct successive entities and to ignore contrary evidence from radiocarbon dating. A formal analysis of the absolute dates points towards an overlap of ca. 150-500 years between Corded Ware and Funnel Beaker West communities in the first half of the third millennium BCE (cf. Bourgeois *et al.* in press.; Furholt 2003 pp. 98–9). Instead of a rapid transition, we are looking at a co-existence.

In the next sections, it is argued the above two conclusions are not merely potential scenarios on the basis of radiocarbon dates. The two groups of radiocarbon dates for Funnel Beaker West in Figures 2.2 to 2.4 resonate with changes in the funerary practices of Funnel Beaker West. Moreover, a co-existence between Funnel Beaker West and Corded Ware can explain a number of archaeological cases which are problematic exceptions for proponents of a rapid transition.

2.4 Funnel Beaker West Chronology: What Can We Know?

The aim of this section is to shed new light on the chronology of Funnel Beaker West. As shown in Figures 2.2-2.4, the radiocarbon dates for Funnel Beaker West fall into two groups. Crucially, all these dates stem from closed contexts, namely flat graves (see Appendix A). The argument below is that these two groups document the gradual development of a specific funerary practice in these flat graves, namely an increasing focus on certain grave goods and the cremation of the deceased. Typochronological studies picked up on this trend, but overstated it (see also Section 2.2). As shown below, this development is not a gradual decline of Funnel Beaker West but a phenomenon in its own right. The development does not divide the data into distinct phases but does offer a foothold for a re-engagement with Funnel Beaker West chronology.

Early Flat Graves

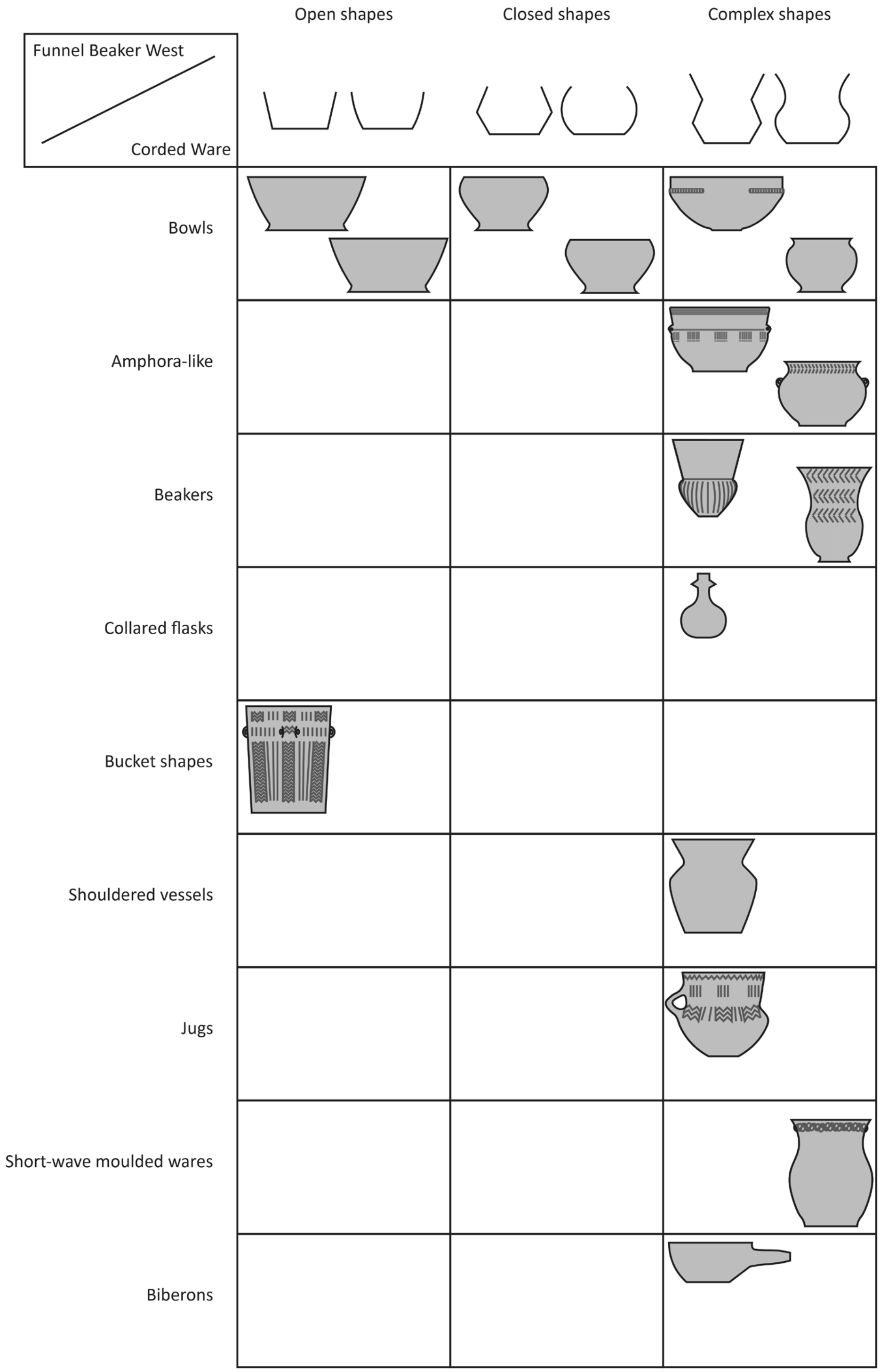
The first group of radiocarbon dates from flat graves falls between ca. 4000 and 2900 cal BCE (see Figs. 2.2-2.3; see below for exact dates). The older ranges fluctuate considerably and the dates are too sparse to draw a lower boundary. However, the cut-off point around ca. 2900 cal BCE is consistent (see Section 2.3). In addition to their absolute dates, these flat graves share several other characteristics.

Firstly, flat graves in this group yield traces of burnt structures in the burial pit, but rarely of cremations. Hence most dates in this group stem from charcoal (see Tab. 2.1; Appendix A). Several excavators argue this charcoal stems from wooden coffins or structures with beams inside the grave which were set ablaze during the burial, without resulting in the cremation of the deceased (cf. Bouma and Van der Velde 2022; Finke 1983). Recent excavations show such traces might only occur in a small portion of burials in flat grave cemeteries (cf. Bouma and Van der Velde 2022 pp. 38; 40–1 on Dalfsen; Kossian 2000 pp. 50–2; 135 on Northwest Germany).

The second shared characteristic relates to the vessel shapes found in these burials. Open shapes such as bowls, as well as larger amphora-like shapes make up the bulk of the vessels (see Fig. 2.7; 2.8; Tab. 2.2; cf. Brouwer 2014 pp. 43–6 on Baalder Es; Van Giffen 1937 on Kruidhaarsveld). This contrasts with megalith inventories which show both a broader range of vessel shapes and different proportions of these shapes (see Fig. 2.8; Tab. 2.2).

There are exceptions to the above pattern (see Figs. 2.2-3; Tab. 2.1). For example, the Funnel Beaker West site at Uddelermeer yields multiple features with heated bone and ceramics in addition to flat graves (cf. Bakker 1979 pp. 194–5; Holwerda 1909 p. 42).

Figure 2.7 (opposite page): Overview of vessel types and shapes in Funnel Beaker West and Corded Ware referred to in this dissertation. Funnel Beaker West vessels appear in the upper left corner of each cell, Corded Ware vessels in the lower right corner. An extensive body of literature on type definitions exists for both Funnel Beaker West (Bakker 1979 p. 177, Tab. VI; Brindley 1986b Fig. 1) and Corded Ware (Drenth and Lanting 1991 pp. 44–5; Van der Waals 1964; Van der Waals and Glasbergen 1955). However, the Bayesian chronological models do not support the chronological distinctions between these types (see Section 2.2 and 2.3), hence the simplified scheme presented here. All bowls (regardless of lugs, feet, pedestals, shoulders, necks, etc.) become bowls. Amphora-like vessels include the related shapes amphorae, tureens, and tureen-amphorae. Beaker replaces all sub-types of this shape in Funnel Beaker West and Corded Ware. Bucket shapes replace pails. Collared flasks, shouldered vessels, jugs, short-wave moulded wares (SWMs), and biberons are distinctive and so retain their respective names.


Open shapes
Closed shapes
Complex shapes
Funnel Beaker West
Corded Ware
Bowls
Amphora-like
Beakers
Collared flasks
Bucket shapes
Shouldered vessels
Jugs
Short-wave moulded wares
Biberons

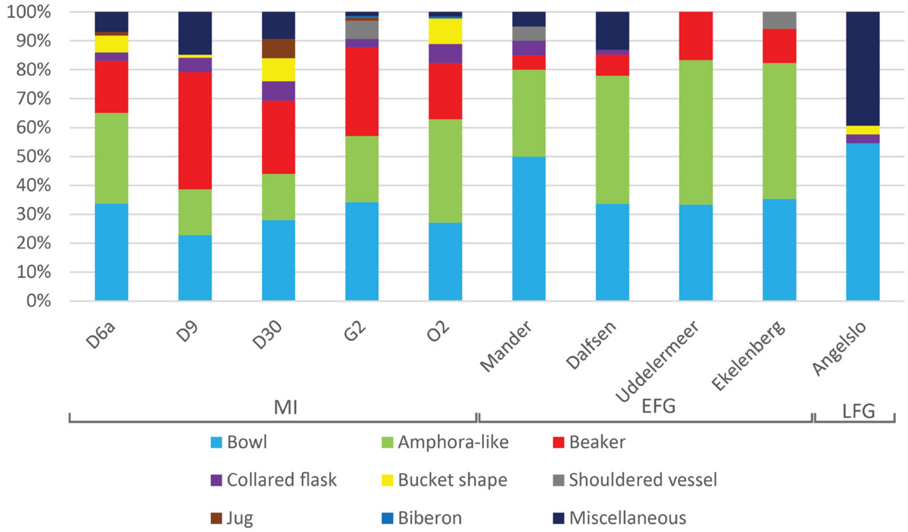


Figure 2.8: Relative proportion of vessel types reported in Funnel Beaker West megalith inventories (MI), early flat grave cemeteries (EFG), and late flat grave cemeteries (LFG; see Tab. 2.2 for raw data; Fig. 2.7 for vessel types). Megalith inventories exhibit a broader range of vessel types than early and late flat grave cemeteries. Moreover, early flat graves show a strong preference for bowls and amphora-like vessels. The late flat grave cemetery at Angelslo is an extreme of this development which starts with early flat graves: bowls dominate the assemblage.

These features have been interpreted as refuse pits from a nearby settlement (cf. Bakker 1979 p. 195). However, upon examining the ceramics from this cemetery, I had the opportunity to submit these heated bone fragments to Dr. R. Schats and Dr. S.A. Schrader from the Laboratory for Human Osteoarchaeology. According to both, the heated bone fragments likely stem from multiple, cremated human individuals. Consequently, the 'refuse pits' at Uddelermeer are likely cremation burials. A radiocarbon date on one of these bone fragments falls among the first group (see Fig. 2.2; GrM-26730: 4387 ±27 BP, 3092-2915 cal BCE). This example shows cremation does occur in Funnel Beaker West burials before ca. 2900 cal BCE, but rarely so.

To summarise, the older dates in Figures 2.2 and 2.3 exhibit associations with a particular funerary practice. This practice involves the burning of wooden structures in the burial pit but rarely cremation, and the selection of specific vessel types such as bowls and amphora-like vessels as grave goods. I refer to these flat graves as *early flat graves*. The funerary practices in these early flat graves contrast with those in the younger group of radiocarbon dates in Figures 2.3-4.

Late Flat Graves

The radiocarbon dates in the younger group of flat graves consistently fall between ca. 2900 and 2600 cal BCE (see Fig. 2.2-4; see below for exact dates). Contrary to the first group, most radiocarbon dates in this younger group stem from cremated human remains (see Tab. 2.1; Appendix A). These cremation burials feature ceramics classified as horizons 6 and 7. In essence, this implies a sharper selection of vessels suitable as grave goods: mourners almost exclusively deposit large, complex bowls with the deceased (see Fig. 2.8; Tab. 2.2; Bakker 1992 p. 93; cf. Bakker and Van der Waals 1973 on Denekamp and Angelslo).

Site type	Site		Beaker	Bowl	Amphora-like	Collared flask	Bucket shape	Shouldered vessel	Jug	Biberon	Misc.	Total
Megaliths	D6a	*n*	31	58	54	5	10	0	2	0	12	**172**
		%	18	33.7	23.9	2.9	5.8	0	1.2	0	7	**100**
	D9	*n*	41	23	16	5	1	0	0	0	15	**101**
		%	40.6	22.8	15.8	5	1	0	0	0	14.9	**100**
	D30	*n*	19	21	12	5	6	0	5	0	7	**75**
		%	25.3	28	16	6.7	8	0	6.7	0	9.3	**100**
	G2	*n*	112	125	84	11	0	23	4	2	5	**366**
		%	30.6	34.2	23	3	0	6.3	1.1	0.5	1.4	**100**
	O2	*n*	60	83	110	20	27	0	0	2	5	**307**
		%	19.5	27	35.8	6.5	8.8	0	0	0.7	1.6	**100**
Early Flat Graves	Mander	*n*	1	10	6	1	0	1	0	0	1	**20**
		%	5	50	30	5	0	5	0	0	5	**100**
	Dalfsen	*n*	9	41	54	2	0	0	0	0	16	**122**
		%	7.4	33.6	44.3	1.6	0	0	0	0	13.1	**100**
	Uddelermeer	*n*	2	4	6	0	0	0	0	0	0	**12**
		%	16.7	33.3	50	0	0	0	0	0	0	**100**
	Ekelenberg	*n*	2	6	8	0	0	1	0	0	0	**17**
		%	11.8	35.3	47.1	0	0	5.9	0	0	0	**100**
Late Flat Graves	Angelslo	*n*	0	18	0	1	1	0	0	0	13	**33**
		%	0	54.5	0	3	3	0	0	0	39.4	**100**

Table 2.2: Vessel types in assemblages from Funnel Beaker West megaliths and flat grave cemeteries. The table reports absolute numbers and percentages from recently published Funnel Beaker West sites. The megaliths are: D6a (Brindley *et al.* 2002 p. 76), D9 (De Groot 1988), D30 (Brindley and Lanting 1992), G2 (Brindley 1986a p. 37), and O2 (Ufkes 1993 p. 31). The flat grave cemeteries are: Mander (Lanting and Brindley 2004), Dalfsen (Brindley 2022 p. 142), Uddelermeer (Bakker 1979 p. 195), Ekelenberg (Bakker 1979 pp. 197–8), and Angelslo (Bakker and Van der Waals 1973). See Fig. 2.7 for vessel type definitions.

The focus on large, complex bowls and cremation in funerary practices is not an isolated instance in Dutch Funnel Beaker West, but also occurs in Germany (Kossian 2000 pp. 50–2; 135). Furthermore, a near exact, contemporary parallel of this funerary practice exists in Central Germany in the shape of the Schönfelder Kultur (cf. Schwarzberg 1994; Wetzel 1979 pp. 90–2). As such, this development in funerary ritual is not a local 'degeneration' (see Section 2.2), but a phenomenon in itself. The late flat graves are part of a broad trend in Funnel Beaker funerary practices across the North German Plain and the Netherlands, likely shaped by interactions between mourners in this area (cf. Bourgeois and Kroon 2017). This trend starts at some point in the fourth or early third millennium BCE, and becomes especially salient in the third millennium BCE.

Given the strong association between these funerary practices and relatively young radiocarbon dates, this group of flat graves and the associated ceramics are distinct from the early flat graves. I refer to them as *late flat graves* and treat these ceramics as a separate subset of Funnel Beaker West in later analyses.

A Bayesian Chronological Model of Early and Late Flat Graves

The chronological trend in Funnel Beaker West flat graves which is described above on the basis of a visual inspection of the radiocarbon dates (see Fig. 2.2-4) can be substantiated with a formal Bayesian chronological model (see Fig. 2.9).

This model takes all Funnel Beaker West dates from Appendix A and places them into two groups. The first group consists of all radiocarbon dates associated with inhumations with a broad range of vessel shapes and burnt wooden structures (i.e. early flat graves). The second group of dates consists of all dates associated with late flat graves, including burnt human skeletal remains and food crusts on the typical large, complex bowls. These two groups are modelled as separate uniform phases because a visual inspection of the data shows some cremation burials may be contemporaneous with early flat graves (see

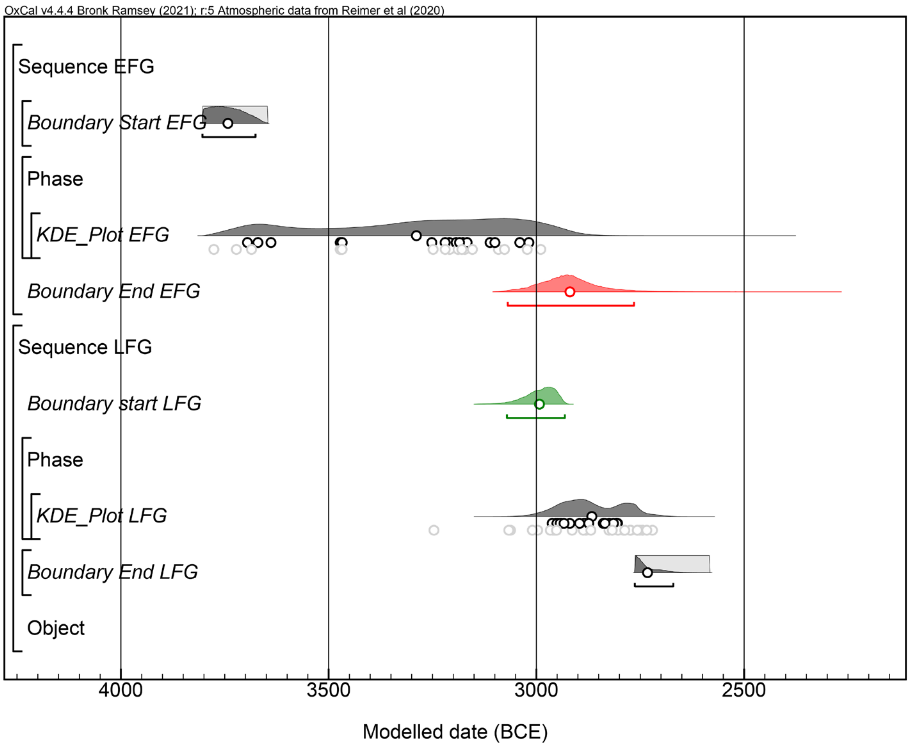


Figure 2.9: Bayesian chronological model of the start and end dates for Funnel Beaker West early flat graves (EFG) and late flat graves (LFG) on the basis of the radiocarbon dates in Appendix A. The dates were calibrated in OxCal v4.4.4 (Bronk Ramsey 2021) with the IntCal20 calibration curve (Reimer *et al.* 2020). The kernel density plots are in grey, the inferred end date of EFG in red, and the inferred start date of LFG in green. The start and end dates for Funnel Beaker West (in grey) are input from the model in Figure 2.6 as uniform likelihoods. Transparent rings indicate the mean likelihood of individual calibrated radiocarbon dates, solid rings the mean posterior probability of dates and posterior probability distributions. The brackets and functions on the left show the build-up of the model in OxCal. For raw output, see Appendix A. The model has an agreement of (Amodel=) 95.1 and an agreement of the individual dates of (Aoverall=) 98.4. OxCal rejects one date (GrN-16040 4550 ±60 BP; 3500-3029 cal BCE; A=5.9%) on a cremation burial due to low agreement with the model, but no stable isotope date is available to evaluate whether this is data is (f.e.) affected by reservoir effect (see Appendix A; cf. Bronk Ramsey 1995 for threshold values).

above). As such, treating the two groups of dates as contiguous phases in the model is unwarranted (Bronk Ramsey 1995, 2009a). The two-sigma ranges for the start date and end date of Funnel Beaker West from the Bayesian chronological model in Figure 2.6 are input in this model as a uniform likelihood for the start date of early flat graves and the end date of late flat graves respectively (cf. Bronk Ramsey 2021 OxCal manual on Operations and Models). This is primarily for consistency as splitting the data and leaving these boundaries undefined would result in too much contraction of modelled dates relative to the original distribution (cf. Fig. 2.6). Moreover, the focus of this Bayesian chronological model are the start date of late flat graves and the end date of early flat graves, not the start and end date of Funnel Beaker West.

The model uses the *KDE_Plot* function to summarise the radiocarbon dates in both groups (Bronk Ramsey 2017) and then calculates the end date for the group of radiocarbon dates associated with early flat graves and the start date for the group of radiocarbon dates associated with late flat graves (Bronk Ramsey 1995, 2009a). The outcomes of the model are summarised in Figure 2.9. For raw output of the model, see Appendix A.

The output of the Bayesian chronological model validates the observations on the calibrated radiocarbon dates and provides a formal estimate of the start and end dates of early and late flat graves (see Fig. 2.9). The mean estimated end date for early flat graves falls at 2920 BCE with a two-sigma range from 3070 to 2766 BCE. The mean estimated start date for late flat graves falls at 2993 BCE with a two-sigma range from 3071 to 2932 BCE. These outcomes confirm the development described above. The funerary practice associated with early flat graves are generally older than those associated with late flat graves (see Fig. 2.9). This means there is a chronological development in Funnel Beaker West burial rites from a (comparatively) broad range of vessel shapes and types as grave goods and a practice of setting wooden structures in the burial pit ablaze to a more restricted range of ceramic vessels included as grave goods and cremation burials. In addition, these two practices do not form distinct phases but overlap during at least the first century of the third millennium BCE but possibly longer.

Future studies of the burial practices found in Funnel Beaker West flat graves may further refine this outcome. For present purposes, the Bayesian chronological model consolidates the distinction between early and late flat graves as proposed here.

Megalith Inventories

Lastly, a brief note on megalith inventories. No reliable radiocarbon dates could be found for the vessels in these assemblages (see Appendix A). In addition, megalith inventories feature cremated human remains and large, complex bowls associated with late flat graves (cf. Bakker 1992 p. 93) side-by-side with vessel types found in early flat graves, as well as additional variation in vessels (see Fig. 2.8; Tab. 2.2).

The precise cause for this high variation in megalith inventories is unclear. On the one hand, megaliths are open contexts in which material accumulates over time and is reworked (e.g. Lanting and Brindley 2004 on O2; cf. Cummings *et al.* 2015 p. 831; Sjögren 2015 p. 1012 for a broader discussion). This is evident from the side-by-side appearance of materials associated with early and late flat graves. On the other hand, megaliths may not be burial places for local communities as is assumed based on ceramic style (cf. Voss 1982), but public gathering places with a broader, regional significance, as has been argued by Midgley (2008 pp. 199–200, 1992 pp. 352–3).

Either way, megalith inventories, as open contexts, should not be at the basis of the Funnel Beaker West chronology (*contra* Bakker 1979; Brindley 1986b). Instead, the focus should be on techniques to acquire direct dates from these vessels (e.g. Casanova *et al.* 2018, 2020, 2021, 2022), or the relations between assemblages from flat graves and megalith inventories. This dissertation follows the latter road because a radiocarbon dating programme is beyond the scope of this project (see Section 2.3). This means the typical vessels associated with late flat graves are extracted from megalith inventories and added to the subset for late flat graves. The other vessels in megalith inventories are treated as contemporaneous with early flat graves in the sample design (see Ch. 5).

2.5 Funnel Beaker West in the Third Millennium BCE

The second conclusion from the re-examination of the absolute chronology is a co-existence of ca. 150-500 years between Funnel Beaker West and Corded Ware communities at the start of the third millennium BCE (see Section 2.3). There is broader evidence for such a co-existence in the archaeological record. Specifically, several archaeological cases exist, including the so-called 'contact finds' from Section 2.1, in which evidence appears for contemporaneity between Funnel Beaker West and Corded Ware communities (cf. Bourgeois *et al.* in press.). These cases are anomalous within the framework of a rapid transition but fit a co-existence of Funnel Beaker and Corded Ware communities.

The archaeological cases fall into two groups: 1) a case in which Corded Ware precedes Funnel Beaker West, and 2) cases in which Corded Ware conforms to Funnel Beaker West funerary practices.

Corded Ware before Funnel Beaker West

The best-known anomaly for a rapid transition between Funnel Beaker West and Corded Ware is flat grave no. 14 at Angelslo. This cremation burial is part of a late flat grave cemetery (cf. Bakker and Van der Waals 1973). Crucial for the argument below, this late flat grave cemetery itself is, in turn, part of an alignment along with two Funnel Beaker megaliths and several Corded Ware burials (Arnoldussen and Scheele 2012 p. 159; Bakker and Van der Waals 1973; Van der Waals 1967 pp. 210–2). This alignment is an excellent example of the second group of anomalies, but the contents of flat grave no. 14 merit separate discussion.

Bakker and Van der Waals (1973 pp. 24–5) attribute flat grave no. 14 to the last stages of Funnel Beaker West based on the grave goods. These grave goods consist of fragments of Funnel Beaker West ceramics, some showing signs of heating. However, a Corded Ware sherd occurs alongside the Funnel Beaker West material. Crucially, the excavators state there is no evidence for a younger disturbance of the burial (*contra* Lanting and Van der Plicht 2000 p. 66). The Corded Ware sherd is either part of the backfill or one of the grave goods. Either way, the inclusion of this Corded Ware sherd implies it pre-dates the construction of the Funnel Beaker West cremation burial.

Two radiocarbon dates are available for this burial (see Appendix A). The first was performed on charred branches intermingled with the ceramics (GrN-5070: 4100 ±30 BP, 2864-2500 cal BCE) and the second on the heated human bone in the burial (GrA-16021: 4230±60 BP, 3000-2585 cal BCE). Both dates fall well within the temporal range of Corded Ware, as well as the temporal range of late flat graves (see Section 2.3; 2.4; Fig. 2.6; 2.9; Appendix A).

This outcome is all the more intriguing because the alignment flat grave no. 14 is part of consists of several unmarked flat graves attributed to Corded Ware and Funnel Beaker West (cf. Arnoldussen and Scheele 2012 p. 157). This alignment signals these burials were positioned in the landscape following the same structuring principle, which indicates coordination and communication between Corded Ware and Funnel Beaker West mourners.

To my knowledge, there are no other burials like flatgrave no. 14. However, more cases of Corded Ware and Funnel Beaker West funerary contexts being located in close proximity or as part of alignments do exist (cf. Arnoldussen and Drenth 2015). Examples are Anlo (Bakker 1979; Bakker and Van der Waals 1973 p. 36; Jager 1985 pp. 190–1; Waterbolk 1960), Ekelenberg (Van Giffen 1937; Van Giffen 1937), Dalfsen (Van der Velde 2022 p. 198), Noordbarge, and Uddelermeer (Bakker 1979; Holwerda 1909, 1911, 1912). Unfortunately, these sites often lack radiocarbon dates to determine the chronological relations between the Corded Ware and Funnel Beaker West burials.

Flatgrave no. 14 at Angelslo is a telling but ultimately unique case for the contemporaneity of Funnel Beaker West and Corded Ware. Most cases fall into the second category: continuity in Corded Ware and Funnel Beaker West funerary practices.

Spooky Action at a Distance?

The first example of archaeological cases in this group is discussed in the previous section: The alignment of late Funnel Beaker West and Corded Ware interments at Angelslo. This specific case is part of a recurring phenomenon in which funerary practices of Corded Ware and Funnel Beaker West appear continuous. Proponents of a rapid transition often cite vague forms of continuity in practice as explanations for these cases or dismiss them as later re-use (e.g. Brindley and Lanting 1992 p. 135; hence the title of this section). Below, I discuss the strongest case for such continuity, namely the inclusion of Corded Ware vessels in megaliths, and argue these 'vague continuities' can only be explained if we accept that the people who deposited Corded Ware vessels learned, and adhered to, Funnel Beaker West practices.

Corded Ware vessels appear regularly in Funnel Beaker West megaliths (cf. Bakker 1992 pp. 58–9; see Tab. 2.3). Their occurrence is often explained as the re-use of megaliths after Funnel Beaker West activity ceased (e.g. Brindley and Lanting 1992 p. 117). However, the deposition of these vessels goes beyond the mere inclusion of some Corded Ware material.

Bakker (1992 p. 59) argues the types of Corded Ware vessels found in megaliths differ from those found in Corded Ware burials. Corded Ware burials feature a highly standardised funerary practice, which involves (among others) preferential use of certain vessel types as grave goods (cf. Bourgeois and Kroon 2017). Wentink (2020 pp. 48–9, Tab. 4.1) presents an overview of ceramic vessels in Corded Ware funerary contexts in the Netherlands. This overview shows a clear preference for beakers: 78.7% of the ceramics found in Corded Ware burials are beakers, while amphora-like vessels and short-wave moulded wares together constitute less than 3% of the vessels deposited as grave goods. However, the Corded Ware vessels in megaliths break with this preference. Beakers constitute only 46% of the Corded Ware vessels in megaliths. The majority of the ceramics are amphora-like vessels and short-wave moulded wares. These vessel types make up ca. 54% of the Corded Ware vessels in megalith inventories (see Tab. 2.3). Therefore, the

Vessel type	Beaker	Amphora-like	SWM	Total	Source
Site	*n*	*n*	*n*	*n*	
D6a	1	0	0	1	Brindley *et al.* (2002 p. 78)
D9	2	1	1	4	De Groot (1988 p. 92)
D21	1	0	0	1	Bakker (1992 p. 48)
D26	0	2	0	2	Bakker (1992 pp. 49–50)
D28	2	0	1	3	Bakker (1992 p. 49)
D30	3	0	0	3	Brindley and Lanting (1992 p. 137)
D32a	1	0	4	5	Taayke (1985 p. 42)
D32d	1	0	0	1	Taayke (1985 p. 48)
D40	1	0	1	2	Brindley and Lanting (1992 p. 123)
G2	0	3	0	3	Brindley (1986a p. 49)
G3	0	1	0	1	Brindley (1983 p. 222)
Total *(n)*	**12**	**7**	**7**	**26**	
Total *(%)*	**46.2**	**26.9**	**26.9**	**100**	

Table 2.3: Overview of Corded Ware vessels in recently published megalith inventories (see Fig. 2.7 for vessel types). The table follows the classifications in these publications (see rightmost column). The only exception is D32a. Taayke (1985 p. 42) reports three rim sherds from SWMs or amphora-like vessels. The depicted sherds feature the typical decoration by modelling of SWMs, hence their classification as such here.

Corded Ware vessels included in megaliths constitute a clear break with otherwise well-defined Corded Ware funerary practices.

Bakker (1992 p. 59) suggests the break with Corded Ware burials indicates a special status for the Corded Ware individuals interred in megaliths. However, the inclusion of these amphora-like vessels also conforms to Funnel Beaker West funerary practices. Tallies of Funnel Beaker West vessels in funerary contexts show similar, large amphora-like vessels occur in high proportions relative to beakers (see Tab. 2.2, Fig. 2.8), especially in flat grave cemeteries (see Section 2.4). This means Funnel Beaker West funerary practices involve preferential selection of amphora-like vessels as grave goods. Therefore, the high percentage of Corded Ware amphora-like vessels in Funnel Beaker West megaliths not only breaks with Corded Ware funerary practice but conforms to Funnel Beaker West practices on the selection of ceramic grave goods.

Such a continuous practice is anomalous for a rapid, disruptive transition. The current chronology suggests a gap of a century between the primary use of megaliths from horizons 3-5 and the emergence of Corded Ware (see Section 2.3 for dates of the horizons). Moreover, there would be little interaction with megaliths during intervening horizons 6 and 7 (Brindley and Lanting 1992 pp. 137–40). Yet the above cases demonstrate that whosoever deposited these Corded Ware vessels in megaliths was fully aware of Funnel Beaker West funerary practices, which implies first-hand knowledge of these practices exists in the third millennium BCE. This completely contradicts the notion of a rapid, disruptive transition and later 're-use'. However, it is consistent with a co-existence of Funnel Beaker West and Corded Ware: the persons who deposited these Corded Ware vessels could learn these funerary practices from contemporary Funnel Beaker West communities.

Beyond the Netherlands

The co-existence of Funnel Beaker West and Corded Ware communities in the Netherlands is by no means exceptional within a broader European framework. Various studies of the Corded Ware transition point towards overlap between Corded Ware and 'preceding' groups. Examples of such overlap are Globular Amphora in Poland (Włodarczak 2017 pp. 286; 300–1), Salzmünde and Bernburg (Müller 2001 p. 252) as well as Schönfeld (Wetzel 1979; see above) in Central Germany, and Vlaardingen in the Netherlands (Beckerman 2015 p. 214; Kroon *et al.* 2019). In addition, recent studies of Pitted Ware and Corded Ware ceramics in Sweden demonstrate patterns of interaction between the two groups (Holmqvist *et al.* 2018; Larsson 2009 pp. 260–1). Furholt (2003 p. 123, 2021) discusses further examples based on radiocarbon evidence. These studies show the Corded Ware transition, as a rule, is not a rapid supplanting of previous groups, but a long juxtaposition of indigenous and migrating groups.

Among the regions with evidence of a co-existing Corded Ware and previous groups, Denmark stands out as a close analogue of the Netherlands. The transition from Funnel Beaker North to Corded Ware in Denmark is well-attested and complex, with regional variation (cf. Iversen 2014, 2019, 2020 for recent overviews of the debate on this transition). Iversen (2014 p. 25) argues the last phase of Funnel Beaker North, the Store Valby phase, lasts until at least 2600 cal BCE, and overlaps with Corded Ware for at least 250 years. Furthermore, he demonstrates a complex intertwining of Funnel Beaker North, Pitted Ware, and Corded Ware during this time. Iversen (2014 p. 189, 2015 p. 61, 2020 pp. 127–8) refers to this process as cultural creolisation and argues it results in a pidgin of Funnel Beaker practices performed with Corded Ware and Pitted Ware material culture. Moreover, he argues that palisaded enclosures and megaliths play key roles in this process as gathering places which facilitate interaction between multiple communities. This role is reflected in the deposition of Funnel Beaker North, Pitted Ware, and Corded Ware items at these sites. Both the prolonged co-existence of Funnel Beaker North and Corded Ware, as well as the central role of megaliths are analogues to the Netherlands (see above).

To conclude, a long transition between Corded Ware and Funnel Beaker West in the Netherlands is not an exception relative to other regions, but part of a rule. The introduction of Corded Ware is not a rapid transition, but a long co-existence of 'prior' groups and Corded Ware communities throughout the first half of the third millennium BCE.

2.6 Overview

Five conclusions stand out from this chapter. These conclusions, and their roles in the following chapters, are highlighted here.

Firstly, a critical re-examination of the radiocarbon evidence with Bayesian chronological modelling shows neither the Funnel Beaker West, nor the Corded Ware typochronology is borne out by radiocarbon dates (see Section 2.2; 2.3). Therefore, these typochronologies are not used in this dissertation.

Secondly, the same re-examination does show a chronological trend within Funnel Beaker West (see Sections 2.3; 2.4). Two temporal clusters are visible in the radiocarbon dates for flat graves: early flat graves which pre-date ca. 2920 BCE and may extend as far back as ca. 3711 BCE, and late flat graves which date between ca. 2993 and 2669 BCE (see fig. 2.6; 2.9). These two groups resonate with a trend in funerary practices towards a narrower selection of vessels as grave goods, and cremation of the deceased rather than inhumation. For convenience, the dates from the Bayesian chronological models in Figure 2.6 and 2.9 are rounded off to 25 years. This results in: Funnel Beaker West (3700-2675 BCE), early flat graves (3700-2925 BCE), and late flat graves (3000-2675 BCE). No radiocarbon dates are available for megalith inventories, but it is possible to filter out ceramics associated with late flat graves. As such, the sample design for Funnel Beaker West works with these three subsets of Funnel Beaker West vessels (see Ch. 5): megalith inventories, early flat graves, and late flat graves.

Thirdly, the re-examination of the radiocarbon dates by means of Bayesian chronological modelling does not support chronological distinctions between Corded Ware vessels and All-Over Ornamented beakers. Rather, these two types of vessels appear contemporaneous (see Section 2.3). As such, All-Over Ornamented beakers are incorporated with Corded Ware vessels in the sample design (see Ch. 5).

Fourthly, the available radiocarbon evidence points towards a substantial period of co-existence between Funnel Beaker West and Corded Ware. A Bayesian chronological model of these dates yields an estimated mean end date of 2669 BCE (two-sigma range: 2761-2581 BCE) for Funnel Beaker West. The same model returns a mean estimated start date of 2976 BCE (two-sigma range: 3089-2899 BCE) for Corded Ware (see Section 2.3; Fig. 2.6). This implies an overlap of 138-508 years between migrating and indigenous communities in the Netherlands at the start of the third millennium BCE. Again, these dates will be rounded off to 2675 BCE (end date Funnel Beaker West) and 2975 BCE (start date Corded Ware) with an overlap of 150-500 years or simply several centuries in upcoming Chapters.

Such an overlap is not unique to the Netherlands: similar cases have been made for Germany, Denmark, Sweden, Poland, and the coastal area of the Netherlands. Therefore, the transition between Funnel Beaker West and Corded Ware is not a rapid, disruptive process, but a long co-existence (see Section 2.5). This conclusion becomes pivotal in Chapters 12 and 13.

Lastly, a long co-existence better explains several anomalous archaeological cases in which Corded Ware pre-dates Funnel Beaker West, co-opts locations and alignments of Funnel Beaker West cemeteries, or adheres to Funnel Beaker West practices for the deposition of vessels in megaliths (see Section 2.5). Proponents of a rapid transition scenario dismiss these cases as erroneous interpretations or as vague forms of continuity, but a co-existence means migrating could simply learn these practices from Funnel Beaker West groups. These funerary practices feature again in Chapters 12 and 13.

In sum, the crucial ingredients of the third millennium BCE are the co-existence of migrating and indigenous communities, and learning events which cross the culture-historical boundary between them. The next two chapters are a presentation of the comparative method for ceramic technology developed here to study these processes. The aim of this method is not to create homogeneous groups representative of a people or tradition, but to detect long-term variability and potential overlaps which result from learning.

3

An Archaeology of Learning

This chapter is the first of two chapters which present the theoretical framework of this dissertation. This framework revolves around the following question: how to reconstruct learning from ceramics in the archaeological record?

The point of departure is a critique of current approaches to ceramic technology in archaeology (see Section 3.1). These approaches harness knowledge transmission to identify and track past groups. A broader perspective is necessary because the connection between groups and learning specific knowledge is not straightforward.

The second section of this chapter is a proposal for such a broader perspective. The cornerstone of this perspective is the concept of *technical repertoire*: the knowledge of potters is not monolithic, but dynamic and encompasses diverse, alternate techniques. Therefore, variability is a crucial concern for studies of learning. This implies we should look at large samples which capture the variation in ceramic technology for a given region and period. I design a method to compare such samples in Chapter 4. The last section of this chapter (Section 3.3) is a summary of the key points.

3.1 Beyond Group Detection

Ceramic technology enjoys increasing popularity as a means to write cultural history, primarily as an alternative to ceramic style (Dietler and Herbich 1998; Roddick and Stahl 2016; Roux 2019a p. 217; Stark 1998). The idea behind such applications is that the transmission of technical knowledge relates to group boundaries. For example, master and apprentice potters might share the same language, or belong to the same community of practice. Consequently, spatial or temporal (dis)continuities in the distribution of ceramic production techniques become indicative of the presence or absence of a group and can help to reconstruct the historical trajectory of that group (cf. Derenne *et al.* 2020, 2022; Kroon *et al.* 2019 for examples in the third millennium BCE). Hence, these approaches are referred to here as culture-historical (see Ch. 2).

Culture-historical approaches to ceramic technology have two problematic aspects. Both problems relate to the connection between groups and homogeneous ceramic technology.

Firstly, ethnographic evidence shows ceramic technology does not stick to group boundaries. For example, Gosselain (2008a p. 169) discusses a case in which potters on either side of an ethnic boundary know, use, and teach the techniques found on the other side of that boundary. Similar cases are widespread in ethnographic studies of ceramic technology (cf. Gosselain 1998 p. 92; Mahias 1993 p. 160; Mayor 2010 p. 13;

Wallaert 2012 pp. 34–7). These studies show knowledge transmission cuts across the social, linguistic, ethnic, and economic boundaries which archaeologists wish to reconstruct from ceramic technology.

The second problem relates to the role of learning in the creation of group identity. Archaeologists use concepts such as community of practice to argue learning technical skills is an important aspect of acquiring group membership. For example, learning the Corded Ware production process would mean integration into a Corded Ware community (cf. Beckerman 2015; Kroon *et al.* 2019; Larsson 2009; Roux 2019a). However, a connection between bounded social groups and learned techniques does not follow from the definition of community of practice. On the contrary, Lave and Wenger (1991 pp. 35–6; 98; Wenger 1998 p. 154) state members of a community of practice are not bound by spatial, cultural, or social proximity. Lave (2019 p. 143) explicitly stresses groups are not essential to the concept of community of practice.

In brief, groups do not make for homogeneous ceramic technology, nor does homogeneous ceramic technology make for groups. This lack of a straightforward connection between groups and ceramic technology means cultural history does not enjoy general validity as a perspective on knowledge transmission. For example, there is no straightforward connection between the wholesale replacement of *chaînes opératoires* and the migration of past groups (cf. Roux 2019a pp. 301; 306). Naturally, such cases do exist (e.g. Gosselain 2000 on the Bantu expansion), but so do cases in which ceramic technology persists despite the devastating impact of migration (e.g. Arnold 2018; Ernst 2021 on indigenous ceramic technology in the Americas). These complexities indicate a broader view of ceramic technology is necessary. Archaeologists need to let go of the connection between past groups and ceramic technology and focus on learning in itself.

3.2 From Sherds to Learning

Learning is the driving force behind the similarities we see in the archaeological record (Sørensen 2015). It also involves deeply social and meaningful interactions between people (Lave 2011). Studying learning in itself means we prioritise these interactions in our understanding of archaeological ceramics and look at the aggregate effect of countless such interactions.

The central assumption in this section is that no potter is an island. The techniques a potter chooses to apply are all learned from and/or communicated with other potters around them. These acts of learning may take various forms. Some may be apprenticeship, others might simply consist of a potter seeing and copying a finished vessel, or experimenting (cf. Gosselain 2016, 2017; Wallaert 2012). When potters put this learned knowledge into practice to make pottery, their actions may in turn constitute learning events for their apprentices or other potters who come upon their vessels. Every vessel in the archaeological record, however modest, is bound up in these learning processes (cf. Bloch 2005 pp. 97–8, 2012 p. 21; Bourdieu 1977 pp. 72; 78).

The central question in this section is as follows: How do we get from the broken vessels in the archaeological record to the aggregate effect of these learning events 5,000 years ago? The answer given below is that it requires large datasets, and attention for the variability introduced by various forms of learning. Two crucial concepts are defined in the discussion below: *technical repertoire* and *body of knowledge*.

Prehistoric ceramics typically survive in a partial, fragmented state (see Fig. 3.1). The *chaîne opératoire* approach is applied to these fragments to reconstruct their production process. An in-depth discussion of this approach and the exact study protocol can be found in Chapters 4 and 5, respectively. For present purposes, it suffices to state this approach enables archaeologists to look at production traces on these sherds, and to reconstruct the sequence of techniques, or *chaîne opératoire*, which went into the production of this vessel (see Fig. 3.1). Each technique in this sequence is a gesture performed by a potter on the clay body with or without a tool (cf. Roux 2019a). Both these techniques and their ordering in the sequence are learned technical knowledge which has been put into practice by a potter 5,000 years ago. The crucial point here is that this specific *chaîne opératoire* we reconstruct for a vessel is probably not the only one that potter knew.

Ethnographic studies show potters tend to know multiple, alternative ways to produce ceramics. For example, Gosselain (2008a pp. 164; 169) mentions potters who know how to produce vessels by moulding with a convex mould, but also by hammering wet clay (cf. Roux 2019a p. 61 for a description of these techniques). Consequently, these potters can produce multiple, different *chaînes opératoires*. The above case is not an exception, but part of a broader pattern (see Section 3.1; Dietler and Herbich 1998 p. 254; Gosselain 1998 p.

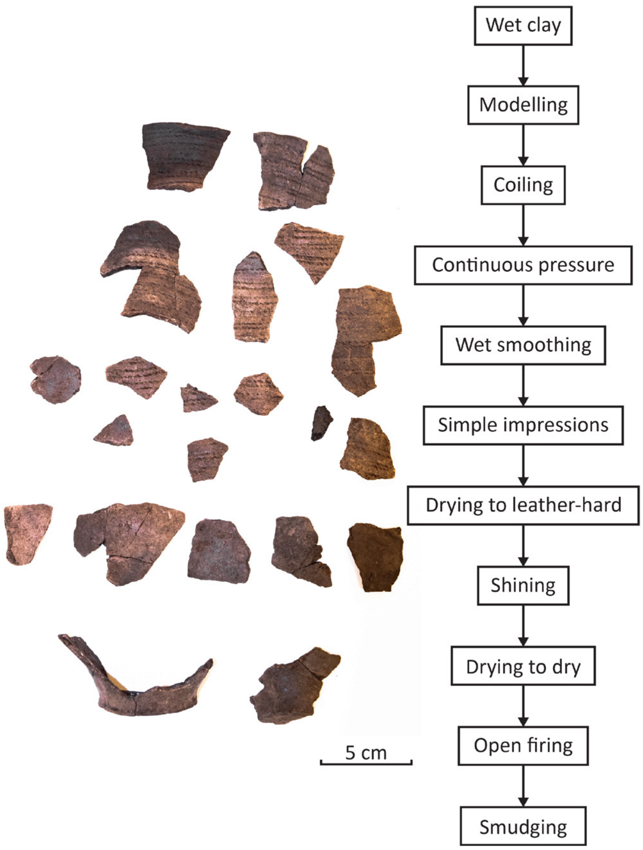
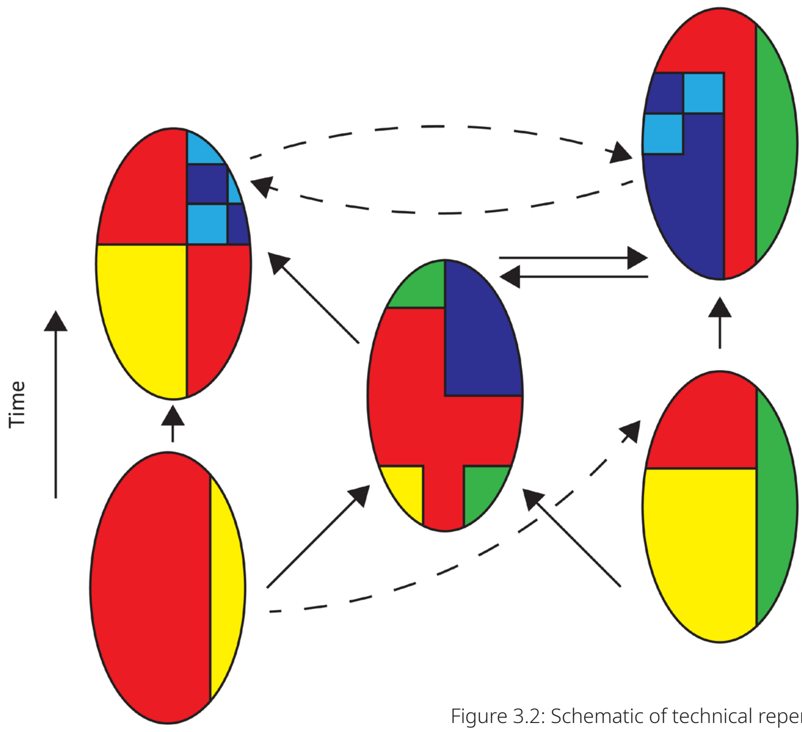


Figure 3.1: Overview of the sherds which make up vessel 175 and the *chaîne opératoire* of the vessel. The fragmented, partial state of this vessel is typical for archaeological ceramics. Yet, traces on these sherds enable a reconstruction of its *chaîne opératoire* (for the diagnostic traces, see Ch. 7, Appendix C, D).

92; MacEachern 1998; Mahias 1993 p. 160; Mayor 2010 p. 13; Wallaert 2012 pp. 34–7). Therefore, we should not think of potters as working within a single technical tradition (see Section 3.1), but as disposing over a *technical repertoire*: a range of alternate techniques which can be combined into many different *chaînes opératoires*.

How do potters come by these alternate techniques in their technical repertoires? The answer lies with learning, both during apprenticeship and afterwards.

Anthropological studies of learning in craft communities show apprenticeship is more complex than a simple one-to-one knowledge transfer from master to apprentice (Lave 2011, 2019; Lave and Wenger 1991). Lave (2011) shows such knowledge transfer does occur, but apprentices also have these interactions with other masters and fellow apprentices in their surroundings (cf. Lave and Wenger 1991). Moreover, masters leave apprentices to experiment (under supervision) and to self-correct, which further emphasises creativity. Competence in these communities, argues Lave (2011), is not just the ability to replicate a certain set of techniques, but the ability to absorb new techniques and improvise as needed (cf. Barth 1987 in a broader context; Kuijpers 2018 on skill).



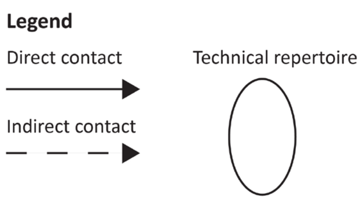


Figure 3.2: Schematic of technical repertoires and learning. Each technical repertoire encompasses multiple, alternate techniques, indicated by different colours. Technical repertoires change over time as potters learn new techniques in direct and indirect interactions with other potters. Further sources of knowledge could be experience, creativity, and innovation. The nett result is an enormous potential for variation in *chaînes opératoires* even from the same hand.

Apprenticeship does not transfer a single technical tradition, but continuously creates partially overlapping technical repertoires (see Fig. 3.2).

In addition, apprenticeship is not the only moment during which potters learn (Gosselain 2017, 2018). Potters continue to acquire new technical knowledge throughout their lives from direct, personal interactions with other potters (and apprentices) as well as from indirect interactions such as observing finished vessels at markets or other meeting places (cf. Gosselain 2000, 2016, 2017; see Fig. 3.2). These interactions may well cross social boundaries (see Section 3.1). Wallaert (2012) provides examples of potters who go through multiple apprenticeships, and over their lifetimes expand their technical repertoire to include several technical traditions. Just as an example of the complex shapes such post-learning events can take: Wallaert (2012 pp. 32–3) discusses a case in which potters, by interacting with archaeologists, learn and adopt a production process from ceramics which date back several centuries. In sum, technical repertoires are not static from apprenticeship onward, but dynamic as potters continue to learn new (and old) techniques from within and across social boundaries. Learning knows no bounds.

The key point here is that, given the complexity of learning, one potter might produce many different *chaînes opératoires*. This insight has major implications for the interpretation of the *chaîne opératoire* from vessel 175 (see Fig. 3.1). This singular *chaîne opératoire* cannot be representative for the knowledge of the potter(s) involved. Instead, it is best thought of as an actualisation of the potters' technical repertoire (cf. Deleuze 1991 p. 70): a translation of the potter's technical knowledge at that point in time into one among many possible operational sequences. We would need many different *chaînes opératoires* to determine the extent of even one technical repertoire.

At this point, the challenge of reconstructing learning from archaeological ceramics becomes apparent. If we study multiple vessels, we are bound to find variation in the *chaînes opératoires*, but there is no way to determine the connections between this variation. For example, the potter(s) who fashioned vessels 175 and 136 chose to apply different techniques (see Fig. 3.3). Vessel 136 shows signs of scraping, simple incisions, and burnishing, techniques which do not appear in the *chaîne opératoire* of vessel 175. Moreover, the simple impressions were made with different tools, namely a cord in vessel 175, and a spatula in vessel 136 (cf. Roux 2019a for the definition of these techniques; for the diagnostic traces, see Ch. 7; Appendix C, D). Does this variation result from differences in technical knowledge, or from alternative choices in a technical repertoire? The archaeological record yields no additional information to resolve this unclarity. For all we know, these vessels could have been made centuries apart, or on the same day (see Ch. 2). Therefore, archaeologists need a workaround to get from this fragmentary state of the evidence to learning in the past.

The workaround proposed here is based on the assumption that learning may cause variation, but not randomness. Potters learn and apply techniques used by other potters around them (see above). This means the variation in the *chaînes opératoires* they produce likely falls within a certain bandwidth when we look at multiple production processes.

As an example, consider the *chaînes opératoires* in Fig. 3.3. These feature different decorative techniques, but these different techniques have been applied at the same point in the *chaîne opératoire*. The potters first smoothed the vessel wall while it was wet, then applied decorative techniques, and allowed the vessel to dry to a leather-hard state before applying surface treatment (see Ch. 7; Appendix C, D for diagnostic traces). There is variation, but also

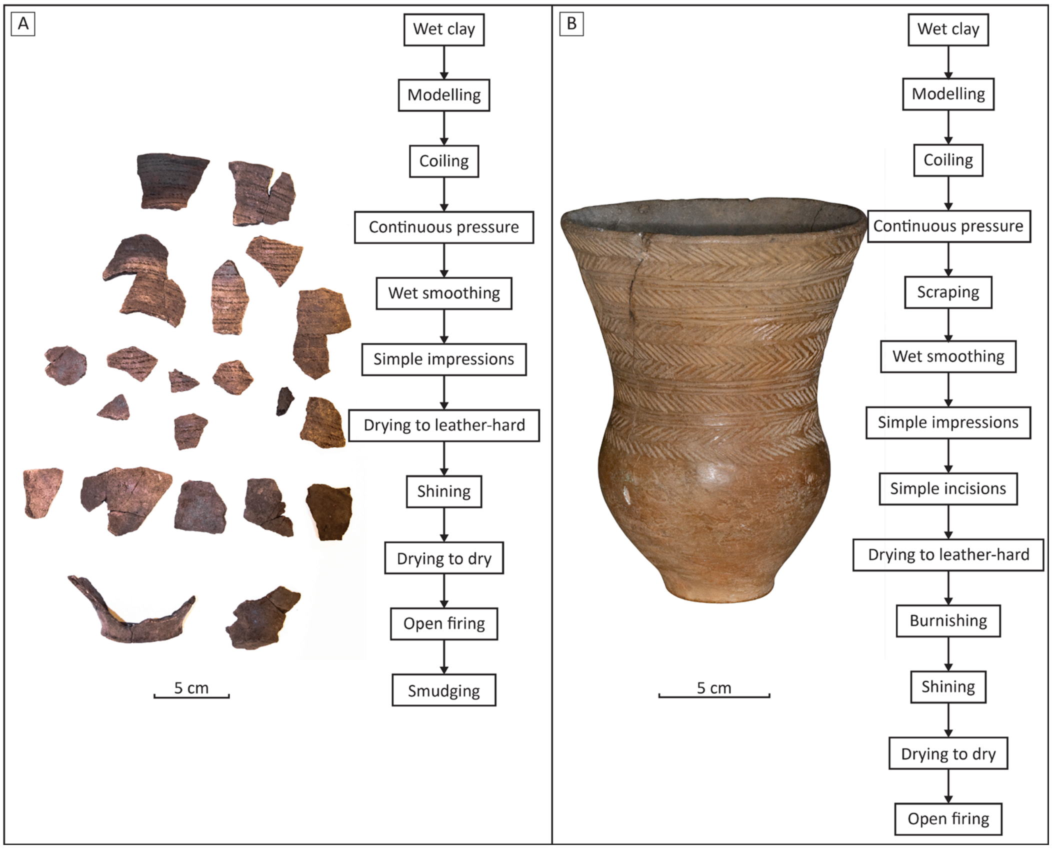


Figure 3.3: Two vessels and their *chaînes opératoires*: A) vessel 175, and B) vessel 136. The two *chaînes opératoires* of these vessels differ in multiple respects (for diagnostic traces, see Ch. 7; Appendix C, D). For example, the decorative techniques of vessel 175 are simple impressions with cord on wet clay, whereas the decorative techniques on vessel 136 are simple impressions with a spatula, and simple incisions, both on wet clay. Are these differences the result of alternate choices in the same technical repertoire, or of two different technical repertoires?

structure. Many different combinations of those techniques are feasible: One could first dry the vessel to a leather-hard state, then burnish, dry the vessel to a dry state, and only then make simple incisions. However, the potter(s) did not do this, indicating they learned and put into practice a similar production process. This tells us that whenever and wherever these potters may have lived and worked, similar knowledge and ideas on how to produce ceramics were in circulation around them (cf. Bloch 2012 p. 21; Sørensen 2015 pp. 89–90).

The fact that knowledge transmission leads to variation within a certain bandwidth implies we can take a sample which is representative for that variation. This sample has to encompass many different *chaînes opératoires*, purposefully collected from a given period and region to capture the variation in (combinations of) techniques for this context. Such a sample is not representative of any one technical repertoire per se, but shows the extent of the technical knowledge which was in circulation at the time. It is an aggregate of many learning events.

Such a sample is referred to here as a *body of knowledge*. This term stems from Wenger and Wenger-Trayner (2015 p. 13) and refers to the combined knowledge of all practitioners in a certain line of work. For example, the body of knowledge for lawyers would consist of all the jurisprudence, law codes, etc. these lawyers work with on a daily basis. Similarly, a body of knowledge for ceramic *chaînes opératoires* should aim to represent all the techniques, procedures, and tools potters in a certain region and period were familiar with.

Bodies of knowledge play a crucial role in this dissertation. The central aim of the sampling strategy is to construct bodies of knowledge for Corded Ware and Funnel Beaker West (see Ch. 5). These bodies of knowledge are overviews of the technical knowledge among potters in indigenous, and migrating communities during the third millennium BCE. The next steps in the process are to determine the *chaînes opératoires* of these ceramics (see Ch. 6-8), and to compare these bodies of knowledge (see Ch. 9-10). Did potters among migrating and indigenous communities learn the same techniques and procedures? If so, this is a strong indication potters in these communities interacted and learned from each other, because learning the exact gestures, tools, raw materials, and their ordering into a production sequence requires potters to be in the same room and to observe each other at work (cf. Arnold 2018; Gosselain 2018; Mayor 2010; Roux 2019a; Wallaert 2012). If, on the other hand, such interactions never took place, we might find little overlap in the techniques, production methods, raw materials, and tools. As such, a comparison of two bodies of knowledge can shed light on learning events 5,000 years ago.

A comparison between bodies of knowledge needs to take two things into account: learning, and variability.

Firstly, learning is critical for thinking about differences between bodies of knowledge. Say we encounter a technique in Corded Ware ceramics which does not appear in Funnel Beaker West *chaînes opératoires*, for example simple impressions with cord. This difference matters in the comparison, after all it is a difference in learned technical knowledge. However, there is no reason to assume indigenous potters could not learn this technique. As shown above, potters can, and do, learn new techniques throughout their lives, including those used across social boundaries (see Section 3.1). Therefore, we should approach these differences as a matter of probability: the more pronounced the differences in techniques, the smaller the likelihood of potters learned from each other, but we should never rule out this possibility entirely.

The second factor to take into account when comparing bodies of knowledge is variability. Consider the *chaînes opératoires* of vessels 136 and 175 in Figure 3.1. These vessels exhibit a certain amount of variation in (f.e.) surface treatment: the potters were familiar with the techniques of shining, burnishing, and smudging (cf. Roux 2019a for definitions). If we found a third vessel which was only burnished during surface treatment, then this vessel sits outside the variation seen in vessels 136 and 175. However, we have established that the potter(s) who made vessels 136 and 175 knew the burnishing technique. Therefore, they could produce this new *chaîne opératoire* simply by making an alternate choice in their technical repertoire. This example shows that rather than comparing the exact (combinations of) techniques (i.e. the variation), we should evaluate what other *chaînes opératoires* potters could produce given the techniques they were already familiar with (i.e. variability). Could potters in Funnel Beaker West communities make Corded Ware vessels with a few simple adjustments to the production process they were already familiar with?

The above two points on variability and learning are crucial in the next chapter. These points are reworked there into a probabilistic comparison for ceramic *chaînes opératoires*.

3.3 Overview

This chapter argues for a new perspective on ceramic technology, which studies knowledge transmission in itself, rather than as a proxy for past groups. This is because learning can cut across group boundaries (see Section 3.1). Moreover, by focussing on learning, we foreground the social, and meaningful interactions between people during which knowledge was transmitted.

The *chaîne opératoire* approach is the bridge between ceramics in the archaeological record and the knowledge of past potters. A *chaîne opératoire* is an ordered sequence of production techniques which can be deduced from technical traces on finished vessels. These sequences are part of the learned, technical knowledge of potters.

Crucially, anthropological studies show potters do not simply reproduce the same production process throughout their entire lives, but continuously learn new techniques, resulting in a dynamic technical repertoire. A single potter can produce many different *chaînes opératoires* by recombining the techniques in this technical repertoire. However, this variation in *chaînes opératoires* is not random or unlimited, but based on the technical knowledge in circulation around the potter.

Consequently, archaeologists should look at large, diverse samples of ceramic *chaînes opératoires*. These samples, or bodies of knowledge, do not reflect the knowledge of any one potter, but are an aggregate which serve to determine the extent of the technical knowledge which was in circulation in a given area and period.

The next chapter is an outline of a probabilistic comparison for such bodies of knowledge. This comparison can infer whether different *chaînes opératoires* result from potters learning similar production processes but making different choices, or from potters learning different production processes and not interacting. As such, this probabilistic method enables me to establish whether the potters who made Corded Ware and Funnel Beaker West vessels learned from each other.

4

A Probabilistic Analysis of Ceramic Technology

Putting knowledge transmission at the heart of archaeological studies in ceramic technology requires a method which compares variability in ceramic *chaînes opératoires* (see Ch. 3). This chapter is an outline of the method I have developed for this purpose. The basis of the method is a conceptualisation of the ceramic *chaîne opératoire* as a network (Section 4.1), and a re-casting of this network as a probability space (Section 4.2). This creates a probabilistic method which considers the *chaîne opératoire* of a single vessel as one of many alternate paths through a network, and compares these alternatives in an inferential, quantitative manner. The final section of this Chapter (Section 4.3) is a comparison of this probabilistic approach to the qualitative, abductive approach commonly found in studies of ceramic technology.

4.1 The *Chaîne Opératoire* as a Network

The *chaîne opératoire* approach is crucial for tracking past knowledge in this dissertation (see Section 3.2). This section starts with an introduction to this approach, followed by a re-conceptualisation of it through network analysis, with specific attention to the concept syntax.

The term *chaîne opératoire* derives from Leroi-Gourhan (1964, 1965), but some debate exists regarding the history of the approach (cf. Audouze *et al.* 2017; Delage 2017a, 2017b). Initial applications of the *chaîne opératoire* are best known from analysis of lithic technology (cf. Creswell 1972; Pelegrin *et al.* 1988; Tixier 1967), but the approach is currently commonplace in archaeological analyses of various materials (e.g. Jørgensen *et al.* 2018; Kuijpers 2018; Miller 2009). Key works for the ceramic *chaîne opératoire* are Balfet (1965), Rye (1981), and Roux (2017, 2019a). The vocabulary from the latter publication by Roux (2019a) is adopted here to describe ceramic technology.

Leroi-Gourhan (1964 p. 164, 1965 pp. 132–3) envisions the *chaîne opératoire* as a dialogue between tools, gestures, and materials (cf. Lemonnier 1992 p. 1; Mauss 1936 for the definition of technique). This dialogue is ordered into a logical sequence from raw material to finished product by a syntax. The dialogue can be read from traces left on manufactured items as a sequence of techniques (cf. Roux 2019a for ceramics). This definition of the *chaîne opératoire* as a sequence of techniques which obeys a syntax is crucial for the definition of the network below.

The *chaîne opératoire* approach is not universally accepted. Ingold (2010, 2013) criticises the approach for leading to a conceptualisation of production processes as rigid, linear sequences (cf. Sofaer 2018 for ceramics). As shown below, the network representation can overcome this critique by showing this critical conceptualisation and the classic notion of the *chaîne opératoire* outlined above are two sides of the same coin.

The sections below are a re-conceptualisation of the *chaîne opératoire* through network analysis. Network visualisations of the (ceramic) *chaîne opératoire* are common (e.g. Gosselain 2018 Fig. 1; Lemonnier 1992; Miller 2009 p. 108; Roux 2019a Fig. 2.42), but these networks seldom serve as analytical tools (cf. Brysbaert *et al.* 2012; Kuijpers 2018). In this respect, the network approach developed below pushes beyond the existing use of networks in studies of past technology.

Defining the Basic Elements of the Network

A network is a mathematical abstraction which shows the structure of relationships between entities. The abstraction presents the entities as nodes, and their relations as edges (cf. Newman 2010 p. 1). The network representation developed here takes the inventory of techniques defined by Roux (2019a; e.g. coiling, scraping, and burnishing) as nodes. An edge between two techniques in the network indicates a technique can follow up another technique. For example, the network below has nodes for the roughing-out technique modelling and the preforming technique scraping. An edge joins these nodes, because a potter can follow up a modelling operation by scraping the surface of the rough-out. I argue below these edges are directional, but first two brief remarks on the choice of nodes in the network.

Firstly, the equation of nodes to techniques is not a necessary feature. Provided the arguments below regarding the directional edges in the network holds, the same analysis can be applied at coarser resolutions (e.g. stages of the *chaîne opératoire*, such as roughing out, preforming, and surface treatment) and at finer resolutions, such as modalities of techniques like coiling by spreading or coiling by pinching (cf. Roux 2019a pp. 41–2 for definitions).

The choice to employ techniques rather than stages or modalities of techniques is a balancing act. For reasons outlined below, the optimal data for the probabilistic comparison consist of complete *chaînes opératoires* from start to end. Obtaining such complete *chaînes opératoires* is nearly always possible for archaeological ceramics at the level of stages, which implies all ceramics can be included in the analysis (high representativity). However, the outcomes would be generic (low specificity), because the sequence of stages is nearly always the same in ceramic *chaînes opératoires*, regardless of the context. Vice versa, obtaining complete *chaînes opératoires* at the level of modalities of techniques would enable highly specific results at the cost of low representativity, as few complete *chaînes opératoires* can typically be reconstructed at this level of resolution from fragmented archaeological assemblages. In other words, the higher the resolution of the nodes, the more specific the outcomes but the lower the representativity due to the smaller amount of data, and vice versa. As such, performing the network analysis at the level of techniques is not a necessity, but offers a practical balance between specificity and representativity.

The second remark is about the absence of nodes for specific raw materials and paste preparation processes in the networks below. Similar to the choice to employ techniques as nodes, the absence of these two stages is not a necessity, but a practical choice relating to two factors.

Firstly, there is a difference in detection methods and sampling strategy (see Ch. 5). This study uses ceramic petrography to study raw materials and paste preparation, and relies mostly on macroscopy with some input from ceramic petrography for the detection of other production techniques. Contrary to macroscopy, ceramic petrography is a destructive method, and not all vessels studied through macroscopy could also be sampled for thin sections. Consequently, the two datasets differ in size and composition (see Ch. 5).

The second issue relates to classification and is the chief problem. Ceramic petrography revolves around geological classifications of sediments and rocks. The relation between these classifications and emic classifications of raw materials is not straightforward (cf. Arnold 1971, 2018). The construction of perceptive categories for raw materials could overcome this issue (cf. Kuijpers 2018), but such an undertaking is beyond the scope of the present study. The matter lies differently for pottery production techniques which are well-attested in ethnographic and archaeological studies (cf. Roux 2019a).

Given the issues with classification and differences in samples, correlation between the datasets on raw materials use and preparation and the dataset on techniques is more prudent than direct integration through probabilistic analysis. Hence the absence of nodes for raw materials choice and preparation in the networks below.

Following these two remarks on the definition of nodes, let us look at the nature of the edges in the network. The key point in the next section is that the edges between nodes are directional because of the syntax of the ceramic *chaîne opératoire*. Directionality is a crucial element for the probabilistic analysis, and enables incorporation of complex patterning in ceramic technology.

From Syntax to Directional Network

Syntax is a key element in the definition of the *chaîne opératoire*, but plays a minor role in applications and comparisons. This section presents an argument for a formal connection between syntax and hydric states in ceramic production. Network analysis can incorporate and compare this syntax by making the edges between nodes directional.

Leroi-Gourhan (1964, 1965) uses the term syntax as a metaphor for the logic which binds tools, gestures, and materials into a coherent sequence. Lemonnier (1980 p. 9, 1992 pp. 21–2) elaborates on the concept syntax by proposing *chaînes opératoires* consist of strategic and flexible steps. Strategic steps cannot be postponed, cancelled, or reversed, because they are crucial elements within the syntax of a production process. Flexible steps on the other hand can occur at any time, or be ignored, altered, and reversed. Following this definition, Gosselain (2018) identifies acquisition and processing of clay, shaping, drying, and firing as strategic parts of the ceramic *chaîne opératoire*. The discussion below picks up on the connection between the latter two items on this list. We return to raw materials and shaping at a later stage. For now, let us say pottery production self-evidently requires clay and temper (raw materials), as well as roughing-out techniques which transform these raw materials into a vessel.

Gosselain (2018) states drying and firing are strategic steps in the ceramic *chaîne opératoire*. Both steps relate to hygrometry, which is a measure of the humidity of a body (cf. Roux 2019a p. 43). The hygrometry of a clay body affects its mechanical properties. For our purposes, the chief mechanical property affected is plasticity: the capacity for permanent deformation under applied force. A clay body with high humidity is plastic and can be shaped by hand, whereas shaping by hand is impossible for a clay body rendered rigid and brittle by low humidity. Consequently, the application of the various ceramic production techniques depends on the hygrometry of the clay body, because of this relation between hygrometry and plasticity (cf. Roux 2019a p. 43).

The relation between hygrometry and the application of techniques is a key element for the directionality of the network. Hygrometry is a continuous variable: The clay paste dries up gradually during the production process as a result of deliberate drying or ambient temperatures. Moreover, a successful ceramic production process always develops from high humidity to low humidity (cf. Roux 2019a p. 43) even if this does not necessarily imply time pressure (cf. Sofaer 2018). The directional nature of the production process necessarily follows from this continuous nature of hygrometry: any two techniques form a sequence because the clay ever so slightly dries as the production process goes on, and because the application of techniques depends on the hydric state of the clay body. For example, a potter can go from coiling to burnishing, because burnishing requires a drier clay body than coiling. However, the inverse order is impossible because that would require the clay body to become moister over time.

Sofaer (2018) argues hygrometry is not irreversible in a strict sense. Potters may opt to soak and dissolve a dry vessel, or re-humidify a vessel surface during production. These observations are valid, but over-stated. Re-humidification of vessel surfaces, for example during softening, does result in traces which are distinct from those left by operations on wet clay (cf. Lepère 2014; Roux 2019a pp. 200–1). Moreover, dissolving a dry vessel into wet clay and re-doing the production process implies erasing all traces of the techniques preceding the dissolution. Therefore, any finished vessel will exhibit a directional development from high to low humidity regardless of such operations. As such, the directionality of ceramic production processes holds.

Despite the continuous nature of hygrometry, archaeologists generally distinguish four discrete hydric states for clay bodies (Roux 2019a p. 43). From high to low humidity the hydric states are: wet, leather-hard, dry, and fired. Crucially, ceramic production processes always pass hydric states in the above order. None of the hydric states can be skipped: Firing a leather-hard vessel would result in failure (Roux 2019a pp. 43; 110). The (sequence of) hydric states in ceramic production should not be considered the product of modern measurement techniques. The fact that prehistoric potters produced vessels automatically implies their awareness of the crucial role of hygrometry in ceramic production. These hydric states can probably be precisely replicated by means of perceptive categories (sensu Kuijpers 2018) given the differences hygrometry induces in surface appearance, malleability, and texture of a clay body (cf. Rye 1981 pp. 20–1; 24).

The above paragraphs argue hygrometry *is* the syntax of the ceramic *chaîne opératoire*. The relation between hygrometry and plasticity of a clay body implies hygrometry orders the application of techniques during the production process, because techniques can only be applied to clays with certain degrees of plasticity. Moreover, the directional development from high to low humidity in the ceramic production process can be influenced by potters, but not altered, postponed, cancelled, or reversed in a successful production process.

The network representation of the ceramic *chaîne opératoire* captures the syntax of the production process by making the edges between nodes directional. Two techniques form a sequence because the clay is ever so slightly drier after the application of each technique. The directionality of the edges reflects this continuous, progressive change in the hygrometry of the clay body. The network acknowledges the influence of potters over hygrometry by also including nodes for drying to leather-hard and dry consistency, as well as firing of vessels. This puts the drying of clay vessels on equal footing with other deliberate operations, such as coiling and painting. The first node in the network is 'wet clay', in which the prepared clay paste has the highest hygrometry. This node necessarily leads onto roughing-out techniques from where a multitude of alternate sequences become possible. Hence the designation of roughing-out techniques as strategic by Gosselain (2018). Roughing-out techniques are simply the first stop on the route.

Given the relation between hygrometry and plasticity, each technique in the network also exhibits a 'tolerance' which indicates the hydric states in which application of said technique is feasible. For example, the tolerance of modelling is the hydric state wet, whereas the tolerance for burnishing are the hydric states leather-hard or dry. The information about the tolerance of techniques is based on the overview in Roux (2019a).

The discussion on the tolerance of nodes completes the definition of the network conceptualisation of the *chaîne opératoire*. The resulting network with techniques as nodes, directional edges to capture the syntax, and with specific tolerances attached to each technique is presented in Fig. 4.1. This network representation allows for the distinction of two key terms for understanding and comparing *chaînes opératoires*: total and specific *chaînes opératoires*.

Total and Specific *Chaînes Opératoires*

In this section, I propose a terminological nuance which paves the way for the probabilistic analysis and addresses recent critiques of the *chaîne opératoire* approach.

Present use of the term *chaîne opératoire* can both refer to the abstract whole of ceramic technology, and to a singular production process reconstructed from traces on a specific vessel. The network representation above enables a distinction between these two conceptualisations.

The abstract whole of ceramic technology is referred to as the *total chaîne opératoire*. The total *chaîne opératoire* consists all possible ceramic production techniques, and, crucial for the probabilistic approach below, all possible combinations of these production techniques allowed within the syntax of the *chaîne opératoire*. The network in Figure 4.1 represents this total *chaîne opératoire* for ceramic technology.

By contrast, the production process of a vessel which one can reconstruct from technical traces on the vessel is a *specific chaîne opératoire*. Given that a specific *chaîne opératoire* is a sequence of techniques, and that the total *chaîne opératoire* is the overview of all possible combinations of techniques, all possible specific *chaînes opératoires* exist as paths through the network in Figure 4.1. In graph theory, a path is a list of nodes in which each node on the list exhibits an incoming link from the previous node (Newman 2010 p. 136). The relation between network and path is a direct analogy for the relation between total and specific *chaînes opératoires*.

The relation between path and network is the cornerstone of the probabilistic approach developed in the next section. In addition, the distinction between specific and total *chaîne opératoire* reconciliates recent criticisms of the *chaîne opératoire* approach as overly rigid and linear (cf. Ingold 2010, 2013; Sofaer 2018) with classic conceptualisation of the concept (cf. Lemonnier 1992). The classic conceptualisation of the *chaîne opératoire* as a

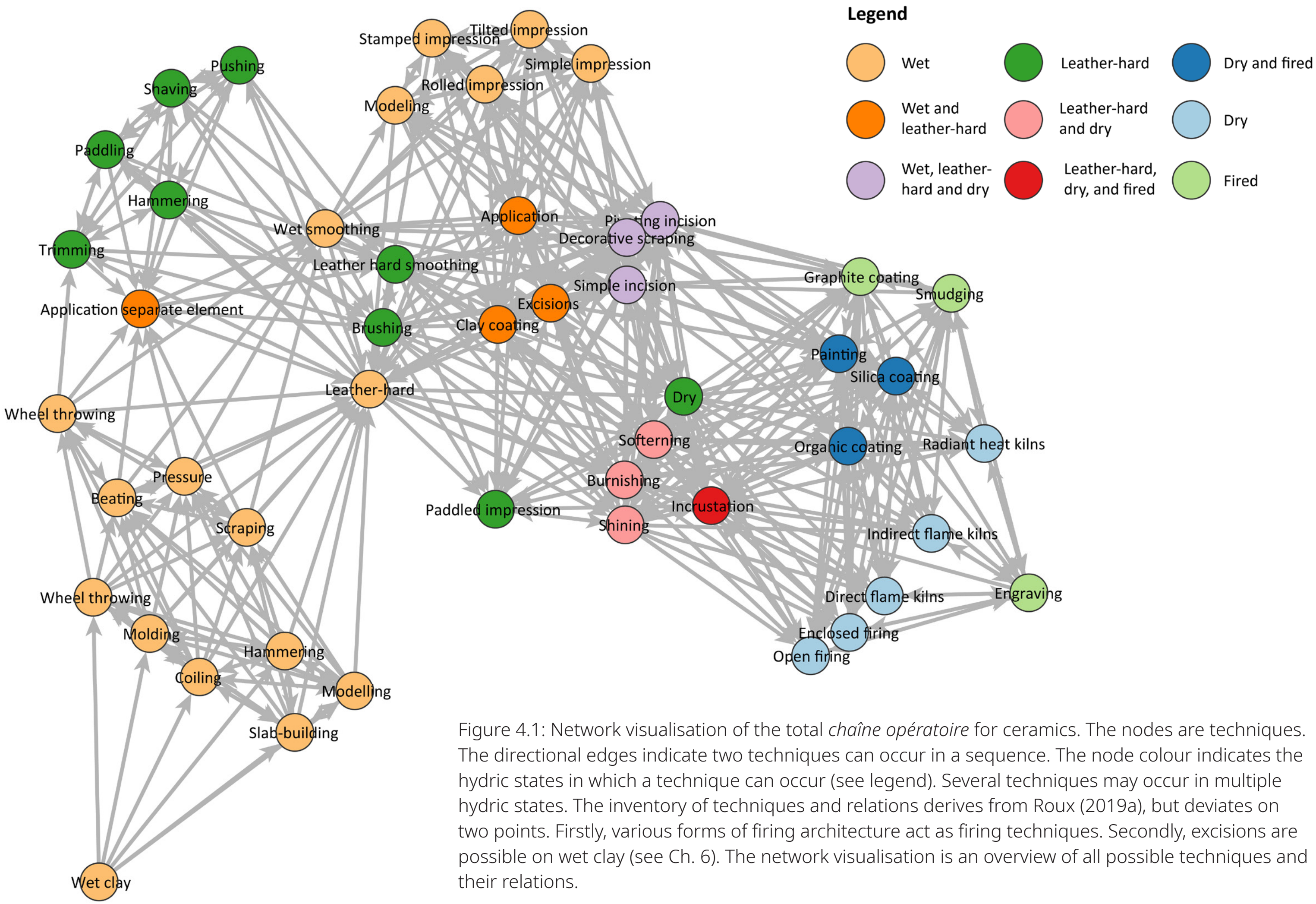


Figure 4.1: Network visualisation of the total *chaîne opératoire* for ceramics. The nodes are techniques. The directional edges indicate two techniques can occur in a sequence. The node colour indicates the hydric states in which a technique can occur (see legend). Several techniques may occur in multiple hydric states. The inventory of techniques and relations derives from Roux (2019a), but deviates on two points. Firstly, various forms of firing architecture act as firing techniques. Secondly, excisions are possible on wet clay (see Ch. 6). The network visualisation is an overview of all possible techniques and their relations.

sequence of techniques is about specific *chaînes opératoires* or paths through the network. However, the above-mentioned critics look at the total *chaîne opératoire*, the network as a whole, which indeed offers the possibility of many alternate, cyclical, and varying specific *chaînes opératoires*. Hygrometry connects these two different views: the directionality of the edges which results from hygrometry, from the behaviour of clay, implies all specific *chaînes opératoires* ultimately appear as linear sequences from high to low hygrometry through the more complex total *chaîne opératoire*. As such, the network representation resolves the contradiction between the classic and critical conceptualisations of the *chaîne opératoire* approach.

Re-conceptualising the *chaîne opératoire* also opens up possibilities for new approaches to ceramic technology. The next section is an outline of such a new approach with the network in Figure 4.1 as the point of departure.

4.2 The Total *Chaîne Opératoire* as a Probability Space

The previous section is a re-conceptualisation of the *chaîne opératoire* approach through network analysis. A key feature of the network approach is that any specific *chaîne opératoire* exists as one among many possible paths in the total *chaîne opératoire*. This insight allows for the formulation of a probabilistic comparison of specific *chaînes opératoires*. The first step in this formulation is to show the total *chaîne opératoire* can be thought of as a probability space.

Fundaments of a Probabilistic Conceptualisation

The term probability space derives from Kolmogorov (2018) and is a formal model for chance processes. A probability space consists of three elements: a sample space, an event space, and a probability function. The sample space is an overview of all possible outcomes of a given chance process, whereas the event space is a set of specific outcomes. The last element, the probability function, assigns a probability to each outcome (Chow and Teicher 1988 pp. 19–20; Sazanov 2002). The network conceptualisation of the *chaîne opératoire* above can be understood as a probability space.

The total *chaîne opératoire* is a direct analogue for a sample space. The network representation shows all possible outcomes of the ceramic production process in the form of paths through the network (see the discussion about sound, valid, and invalid paths below). A specific *chaîne opératoire* is a direct analogue for an event: one specific outcome within the sample space. Returning to the definitions laid down in Chapter 3, a body of knowledge, or any set of specific *chaînes opératoires*, can be thought of as an event space.

The crux of the approach is the definition of the probability function. No direct analogue for this element exists in ceramic technology. Instead, the approach below uses relative frequency distributions of specific sequences of techniques as a probability function (see Fig. 4.2). It works as follows. We take a body of knowledge for (f.e.) Funnel Beaker West. Every specific *chaîne opératoire* in that body of knowledge consists of a number of choices to follow up one technique with another. The total *chaîne opératoire* is an overview of all possible choices, presented as edges between nodes (see Section 4.1). We give each edge in the network a value which is equal to the percentage of specific *chaînes opératoires* from the Funnel Beaker West body of knowledge which features that choice. For example, if 90% of these specific *chaînes opératoires* saw the application of simple impressions during decoration followed up by drying the vessel to a leather-hard consistency, but the other 10% first underwent simple incisions after the simple impressions, then the edge between the nodes 'simple impression' and 'leather-hard' receives a value of 90, and the edge between the nodes 'simple impression' and 'simple incision' a value of 10. We interpret these numbers as an indication of the procedures with which potters were familiar, and the commonness of these procedures. As such, they become the probability function which assigns a likelihood to a particular choice (in the example above, simple impressions are more likely to be followed by drying to leather-hard than by simple incisions). Doing this systematically for all choices in the specific *chaînes opératoires* results in a network which captures the variability in Funnel Beaker West ceramic technology in a quantitative fashion. The most common combinations of techniques become the busiest paths through the network, while alternate options or exceptional choices branch off or form local detours. The power of this analogy with a probability space is the ability to formally compare this variability between bodies of knowledge.

A Method for Probabilistic Comparison

Building on the analogies above, a probabilistic comparison between bodies of knowledge becomes possible. This procedure consists of three steps.

The first step plots all specific *chaînes opératoires* in a given body of knowledge, say body of knowledge A, as paths through the network in Fig. 4.1. The comparison then extracts all edge weights in the network as a probability distribution (see Fig. 4.2). Relating back to Section 4.1, the probability distribution not only captures the occurrence of specific techniques (i.e. nodes) but also the syntax of the production process because it extracts all combinations of techniques (i.e. edges) in the network simultaneously (see Fig. 4.2). By repeating step 1 for a second body of knowledge (body of knowledge B) we get two such probability distributions.

The second step consists of a formal comparison between the probability distributions for body of knowledge A and B. The Wasserstein distance is employed for this comparison (see SciPy documentation 2023 for the algorithm). The Wasserstein distance is a non-parametric method to compare two probability distributions which exist in the same metric space. The comparison computes the minimal amount of work required to transform one distribution into the other (Ramdas *et al.* 2017; Villani 2009 pp. 93–4 for the exact definition). The more dissimilar the two distributions are, the more work is necessary to complete the transformation, and therefore the larger the Wasserstein distance between them (and vice versa). Viene da Trasporto Ottimo

In the context of comparing specific *chaînes opératoires*, the Wasserstein distance informs us about the minimum number of alternate choices potters would need to make, or new techniques they would need to learn, in body of knowledge A (f.e. Funnel Beaker West) to arrive at the specific *chaînes opératoires* observed in body of knowledge B (f.e. Corded Ware). If Funnel Beaker West and Corded Ware specific *chaînes opératoires* share many sequences of techniques, for instance, if only one surface treatment technique differs, then the comparison returns a small Wasserstein distance. The distance increases if frequently observed sequences of techniques in the Funnel Beaker West body of knowledge are marginal, or do not appear, in Corded Ware. As such, we can think of the Wasserstein distance as the odds that alternate choices within the Funnel Beaker West body of knowledge would produce the specific *chaînes opératoires* in the Corded Ware body of knowledge. The greater the distance, the more changes in the choices

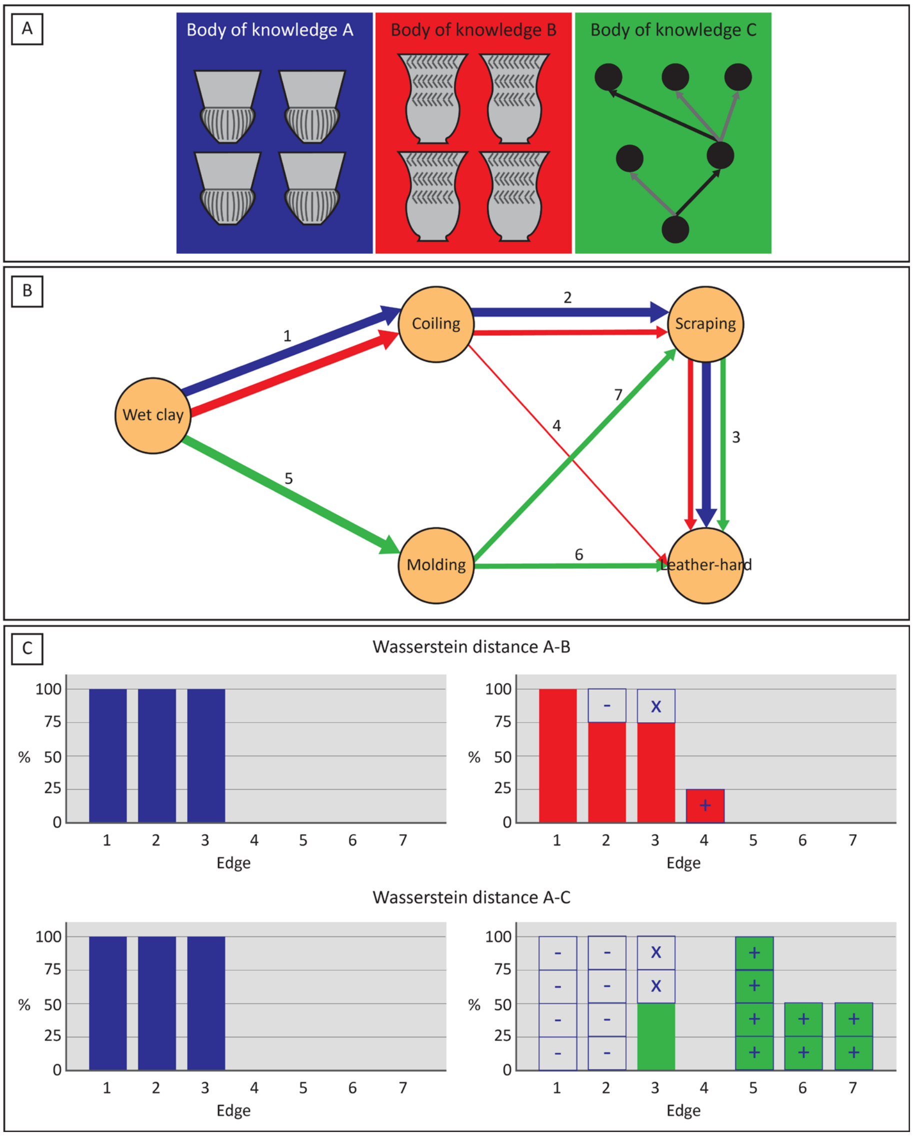


Figure 4.2: Method for probabilistic comparisons of ceramic *chaînes opératoires* in three steps (A-C). A: The method requires three bodies of knowledge (A, B, and C) at minimum. It is unknown whether the potters behind bodies of knowledge A and B learned from each other, but the potters who made body of knowledge C must not share knowledge with those behind body of knowledge A. B: The comparison represents the specific *chaînes opératoires* within these bodies of knowledge (see colours) as paths through the total *chaîne opératoire*. The numbers in the graph are labels for the edges. The thickness of the edges indicates the relative number of specific *chaînes opératoires* which run along the edge. C: The edge weights in the entire network then become a probability distribution. The Wasserstein distance calculates the minimal effort required to transform the probability distribution of body of knowledge A into those for body of knowledge B and C. Effort, in this context, means making alternate choices and learning new techniques. In this example, it requires less effort to transform body of knowledge A into B, than to transform it into an unrelated body of knowledge C. As a result, we may conclude the technical variability in bodies of knowledge A and B likely results from potters sharing a certain amount of technical knowledge (see Tab. 4.1).

and knowledge of potters required, and the less likely these potters learned the same production processes. Crucially, the Wasserstein distance is never infinite: there will be a distance, even if two bodies of knowledge do not feature even one shared technique, but this distance will simply be large. As such, the probabilistic approach always allows for the possibility, however remote, that potters learn and integrate completely new techniques (see Section 3.2).

This sensitivity of the Wasserstein distance to differences in edge weights is also why working with complete specific *chaînes opératoires* is preferable. If one works with fragments of specific *chaînes opératoires*, the overrepresentation of (e.g.) decorative and surface treatment techniques relative to roughing-out techniques skews the Wasserstein distance. Working with fragments of specific *chaînes opératoires* is possible but requires additional steps (see discussion on guided random path generation).

The third and last step in the comparison consists of interpreting the Wasserstein distance between body of knowledge A and B. What Wasserstein distance would warrant the conclusion that the potters involved did, or did not, learn the same production process? In order to tackle this question, we shall use a procedure which is analogous to *f*-statistics in genetics (cf. Patterson *et al.* 2012; Peter 2016) and polarisation in phylogenetics (Wiley and Lieberman 2011 pp. 10–1). A direct application of these algorithms is not possible because both procedures rely on the random nature of genetic mutations to convert the number of divergent mutations between two organisms or genomes into intervening generations (i.e. the more differences, the longer ago the last shared ancestor). The same principle does not apply to ceramic technology: mutations, or rather different technical choices, are not purely stochastic and recombination of 'different strands of knowledge' is common (see Section 3.2). However, the same base procedure can be applied. This procedure interpolates the relation between two groups through a comparison with a third, unrelated group.

The interpretation of Wasserstein distances requires at least three bodies of knowledge. For the first two bodies of knowledge, A and B, we do not know if potters shared knowledge (f.e. Funnel Beaker West and Corded Ware). For the third body of knowledge C, we know the potters learned a different production process than those who made the vessels in body of knowledge A (f.e. pottery production in modern India). All bodies of knowledge must consist of events within the sample space (hence the total *chaîne opératoire* must represent all specific *chaînes opératoires*). The Wasserstein distance between bodies of knowledge A and C then enables a conclusion about the Wasserstein distance between bodies of knowledge A and B (see Tab. 4.1; Fig. 4.2). After all, we know the distance between A and C is an indication of the learning and alternate choices potters would need to conduct a production process completely unrelated to what they themselves have learned.

Bello spunto per comparare o avere una distanza distanza o una threshold motivata

In the above example, if the distance between Funnel Beaker West and Corded Ware *is equal to*, or *larger than*, the distance between Funnel Beaker West and pottery production in modern India, one may assume potters among Funnel Beaker West and Corded Ware communities never shared any knowledge. On the other hand, if the distance *is smaller than* that between Funnel Beaker West and pottery production in modern India, the results imply that the potters who made Corded Ware and Funnel Beaker West vessels did learn similar production processes (see Tab. 4.1). In this case, we can examine how much knowledge is shared between these potters. For example, by repeating step 3 with a fourth body of knowledge, such as specific *chaînes opératoires* from Funnel Beaker North, for

Outcome	Description	Interpretation
Wasserstein distance A-B < Wasserstein distance A-C	The variability in body of knowledge A requires fewer alternate choices and new techniques to produce the specific *chaînes opératoires* in body of knowledge B, than to produce the unrelated ones in body of knowledge C.	The potters who fashioned these vessels learned similar techniques.
Wasserstein distance A-B ≥ Wasserstein distance A-C	Within the variability of body of knowledge A, the amount of alternate choices and new techniques needed to produce the unrelated specific *chaînes opératoires* from body of knowledge C is equal to, or higher than those needed to produce body of knowledge B.	The potters who fashioned these vessels did not share technical knowledge.

Table 4.1: Potential outcomes of a probabilistic comparison of two bodies of knowledge. It is unknown whether the potters who made bodies of knowledge A and B shared knowledge, the potters who fashioned vessels in bodies of knowledge A and C are known to have learned different production processes. A comparison between A and C acts as a check for the relation between A and B.

which we know potters learned and used some of the same techniques as Funnel Beaker West (cf. Wiley and Lieberman 2011 p. 10 for a similar procedure in cladistics).

The sections above are a basic outline of a probabilistic approach to comparing specific *chaînes opératoires*. This outline suffices to interpret the analyses in this dissertation. However, there are also hints at a number of additional complexities in relation to the method. These complexities are discussed below in an in-depth account of the algorithms and assumptions involved in the comparisons.

Unlike Anything: Generating Random *Chaînes Opératoires*

As stated in the previous section, a comparison requires at least three bodies of knowledge. Two of these bodies of knowledge must have been fashioned by potters who did not learn similar techniques. To my knowledge, no such comparative data exists at present because the study protocol is novel. Therefore, this study relies on the random generation of specific *chaînes opératoires* to create bodies of knowledge for which we can be sure no shared knowledge exists with prehistoric potters. This section outlines the algorithm which generates these random specific *chaînes opératoires*. A more complex version of the same algorithm performs other tasks in this study (see Tab. 4.2). Hence the discussion of this version before the more complex version.

The generation of random *chaînes opératoires* is another affordance of the network representation of the total *chaîne opératoire*. This representation enables the use of a modified Markov chain (Duoc *et al.* 2010; Gagniuc 2017; see Tab. 4.3 for the algorithm). The modifications are necessary due to the complexities of ceramic production processes, but they also set the algorithm apart from a proper Markov chain.

Similar to a Markov chain, the algorithm for generating random specific *chaînes opératoires* constructs paths through a chance process. The algorithm takes the last node on the path and then determines the next node on the path by randomly selecting one of the neighbours of this node in the network. The algorithm appends this neighbour to the list and repeats the procedure (see Tab. 4.2). The random selection itself uses the *choice()* algorithm in Python (see Python documentation 2022 for the exact algorithm). The algorithm departs from a Markov chain in four ways: a fixed starting point, a memory,

Method	Random path generator	Guided random path generator
Network	Total *chaîne opératoire*	Total *chaîne opératoire*
Edge weight distribution	Uniform, all edge values equal 1.	Based on a body of knowledge, a seed, or uniform.
Edge weight modifier	None.	Depends on observed edges, and/or a set factor for non-observed edges.
Starting input	List with: 1) initial path state, 2) and initial node.	List with: 1) initial path state, 2) and initial node.
Step 1	List all neighbours of last node on list.	List all neighbours of last node on list.
Step 2	From the list in step 1, eliminate all neighbours which: 1) do not match path state in terms of tolerance, 2) already occur on the list.	From the list in step 1, eliminate all neighbours which: 1) do not match path state in terms of tolerance, 2) already occur on the list.
Step 3	Select one remaining neighbour at random, and append it to the list.	Select one remaining neighbour, and append it to the list. The odds of selection are proportional to the weight of the edge to the neighbour.
Step 4	Depending on new node, update path state. Return to step 1.	Depending on new node, update path state. Return to step 1.
Termination conditions	1) No neighbours available for selection in step 3: if path state is fired, save path as valid; if path state is not fired, discard path and re-start. 2) After passing a node for firing, equal chance of saving path as valid, or returning to step 1 when at step 4.	1) No neighbours available for selection in step 3: if path state is fired, save path as valid; if path state is not fired, discard path and re-start. 2) After passing a node for firing, chance of saving path as valid, or returning to step 1 when at step 4. Odds for either depend on observed post-firing techniques. Upon saving, split path in node pairs and adjust the weight of the respective edges by +1.
Output	Specific *chaînes opératoires*.	Specific *chaînes opératoires* and/or an edge weight distribution.

Table 4.2: Overview of base data, procedures, and output of two algorithms for the random generation of specific *chaînes opératoires*.

loop prevention, and a set of termination conditions. All four changes relate to ceramic technology, and in particular to syntax.

Firstly, the algorithm has a fixed starting point. Following the discussion in Section 4.1, all ceramic production processes start with the node ‘wet clay’, and in the hydric state ‘wet’. Therefore, the algorithm starts with a list with two pieces of information. The first is a path state, namely ‘wet’ (see below), and the second is the starting node ‘wet clay’. The selection of further nodes for the list is subject to the other three modifications.

The second modification relative to Markov chains relates to hydric states. Given the structuring role of the hydric states in ceramic production (see Section 4.1), the path has a separate variable which records its present hydric state. This variable is initially set to ‘wet’ (see above). The algorithm updates this variable when the nodes for ‘drying to leather-hard’, ‘drying to dry’, and ‘firing’ are appended to the list. The variable for the hydric state also plays a role in the selection of neighbours. Prior to randomly selecting a neighbour, the algorithm screens all candidates and removes all neighbours which do not feature the current hydric state of the path in their tolerance (see Tab. 4.2). This modification prevents violations of the hydric state in randomly generated paths: if the path state is ‘wet’, only techniques with the tolerance ‘wet’ can be selected as next nodes on the path.

The third modification governing the selection of nodes is loop prevention. Prior to selecting a neighbour, the algorithm removes all candidate nodes which are already in the path from the list of available neighbours (see Tab. 4.2). This prevents the algorithm from continuously selecting the same small set of nodes in a well-connected set.

Loop prevention is artificial, because loops do occur in ceramic technology (see examples below). However, most of these loops are a matter of splitting or lumping. For example, one can count the application of each coil as a distinct instance of coiling (see Sofaer 2018 on De La Fuente 2011), or group all of these actions without losing information.

There are also loops for which lumping is more problematic. For example, a potter may apply simple incisions to a vessel in a wet state, and later on return to add new incisions while the clay body is dry. In this example, loop prevention is definitely artificial, but it is preferable over allowing for loops for two reasons. Firstly, allowing for loops would only introduce more artificial decisions. It would necessitate rules which prevent the algorithm from ending up in an endless loop. In the above example, one would need to specify the maximum number of times simple incisions can occur in a specific *chaîne opératoire*, as well as the conditions in which this maximum number (or any other number) of loops is allowed. As such, one artificial decision to prevent loops is preferable over the many artificial decisions needed to allow for them.

In addition, allowing for loops would result in long, unwieldy randomly generated *chaînes opératoires*, because the chance of randomly selecting a node which advances the production process (such as drying or firing) among many, well-connected nodes for decorative techniques is small. These long randomly generated specific *chaînes opératoires* might end up being incomparable to human made ones, simply because potters have things to do other than endlessly applying decorations. As such, loop prevention is also preferable in terms of the computation and accuracy of the outcomes. However, loop prevention remains a choice between two evils.

The last modification of the algorithm relative to Markov chains is the implementation of termination conditions (see Tab. 4.2). The algorithm terminates a path under two conditions. The first condition is a lack of neighbours available for the selection procedure. In this case, the algorithm checks if the path state is 'fired' and stores the path if this is the case or discards the path if this is not the case. Secondly, after passing a node for firing, the algorithm applies a check prior to each new iteration (see Tab. 4.2). The check has an equal chance of terminating and storing the path or proceeding with a new iteration. Similar to loop prevention above, the aim of this change is to render the outcomes of random path generation more comparable to actual specific *chaînes opératoires*. Without the termination conditions, the algorithm would always produce paths with all post-firing treatments and only terminate after running out of nodes to append.

To return to the over-all algorithm, the fixed starting point, influence of hydric states, loop prevention, and termination conditions all act as a 'memory' during random path generation. Such a memory is a departure from Markov chains (cf. Duoc *et al.* 2010; Gagniuc 2017), but vital for generating credible specific *chaînes opératoires*.

All of the above modifications relate to a single principle, namely the distinction between sound, valid, and invalid paths. What do these terms mean? The total *chaîne opératoire* allows for a great number of paths. These paths fall into either of the above three categories on the basis of the following criteria. Sound and valid paths do not violate the syntax of ceramic production: these paths follow the hydric states in the order from high to low humidity, do not apply techniques suited for a particular hydric state outside of this state, and do not form endless loops. In other words, valid and sound paths are credible specific *chaînes opératoires*. They would work if a potter tried them. The difference between valid and sound paths lies in verification: valid paths follow the above rules, sound paths follow the rules and are attested within the ethnographic or archaeological record. Invalid paths on the other hand, are possible within the network but violate one or more of the above rules, and would therefore be unworkable as ceramic production processes. As such, the purpose of the modifications is to improve the efficiency of the algorithm. The modifications lead to the exclusion of invalid paths, and the generation of valid paths which are suitable for comparisons against sound paths.

It is possible to create a network in which only valid paths exist. However, this network is far less efficient and elegant than the network in Fig. 4.1. The network would essentially be a directed a-cyclical graph in which each node is a branching point for all possible valid paths which feature that node in that position. This graph essentially repeats all possible future branches for each branching point, resulting in a large, unwieldy network. The elegance and efficiency of the network in Fig. 4.1 lie precisely in the compression of all these alternate paths, but come at the cost of additional limitations on the algorithm (see above).

Why create an algorithm to generate random paths? Bodies of randomly generated specific *chaînes opératoires* are an ideal control group when checking for shared knowledge between archaeological datasets. A collection of randomly generated *chaînes opératoires* can, by definition, not be based on the same learned information as a body of knowledge. Therefore, the distance of an observed body of knowledge to a random body of knowledge is always a measure of the distance to a completely different ceramic production process (see Tab. 4.1). Randomly generated specific *chaînes opératoires* fulfil this role as the ultimate out-group in Chapter 10.

However, the use of randomly generated specific *chaînes opératoires* also necessitates considerations about robusticity. The randomly generated specific *chaînes opératoires* differ with each iteration of the algorithm. Random path generation can, by chance, result in a set of specific *chaînes opératoires* which resemble a body of knowledge. Therefore, a large number of randomly generated specific *chaînes opératoires* is needed to ensure a representative outcome. Following recommendations by Ripley (1987 p. 116), each body of randomly generated specific *chaînes opératoires* encompasses 1,000 paths; more than 5 times the size of the largest body of knowledge with observed specific *chaînes opératoires* (see Ch. 5). This volume ensures adequate reflection of randomness without excessive cost in terms of computation.

Random path generation enables the creation of bodies of knowledge which do not resemble extant data. In some instances, the opposite procedure may be necessary: the generation of paths which closely resemble a body of knowledge. For example, such a procedure can buffer sparse datasets. The next section is an outline of an algorithm for such a procedure.

Simulation and Guided Random Paths

The probabilistic approach has a second crucial affordance: the ability to simulate paths based on observed data. This application features prominently in Chapter 10. The algorithm involved is a more complex variant of random path generation. The complexity stems from the incorporation of edge weights in the selection of neighbours and the ability to perform a recursive process. This algorithm is referred to as guided random path generation or simulation.

The crucial modification occurs in step 3 of the algorithm (see Tab. 4.2). In guided random path generation, the chance of selecting a neighbour is proportional to the weight of the edge to this neighbour. Let us recall the edge weight stems from observed specific *chaînes opératoires* in a body of knowledge (see above). As a result, guided random path generation replicates the choices of potters to combine certain techniques. Furthermore, it is possible to adjust these edge weights or manipulate certain edge weights so as to increase or decrease the error rate of this replication process.

The second change to the base algorithm for random path generation occurs in the termination of the paths. The algorithm for guided random generation does not only store valid paths but can break up the valid path into node pairs and increase the weight of the corresponding edges by one (see Tab. 4.2). As such, the simulation can become recursive: the outcome of each iteration feeds into subsequent iterations.

Both changes enable guided random path generation to exhibit complex behaviour. This mode of path generation is able to perform various tasks. For present purposes, it serves to reconstruct bodies of knowledge from sparse data. As mentioned above, datasets with complete specific *chaînes opératoires* are rare. However, there are studies which describe fragments of specific *chaînes opératoires* for a given region and period. Guided random simulation can reconstruct complete specific *chaînes opératoires* from these fragments by joining the most prevalent (i.e. most likely) path segments together. This procedure is applied in Chapter 10 to simulate (i.a.) a dataset for Funnel Beaker North, which in turn helps to interpret the Wasserstein distance between Funnel Beaker West and Corded Ware (see above). Guided random path generation could also help to reconstruct complete specific *chaînes opératoires* from highly fragmented ceramics.

Lastly, guided random path generation opens up several new opportunities to apply computer sciences in studies of ceramic technology. For example, it could also simulate developments in ceramic technology by running multiple iterations with a given error rate. As such, this algorithm may prove crucial for studies of long-term developments and evolutionary trajectories in ceramic technology.

4.3 Final Considerations: Why Go Probabilistic?

This chapter is an outline of a probabilistic comparison of ceramic technology in two steps. The first step consists of envisioning ceramic production processes as paths (specific *chaînes opératoires*) through a network (the total *chaîne opératoire*). In the second step, these paths and the network are reconceptualised as analogues to a probability space. This analogy enables a comparison of the variability within bodies of knowledge possible, but also the generation of random and guided random specific *chaînes opératoires* which can serve as a check for shared knowledge. As such, this probabilistic method is tailored for the purposes of this study (see Ch. 3). However, the method also has advantages over current methods for comparing ceramic technology and can complement these approaches.

The most common method to compare specific *chaînes opératoires* is abductive in nature. The term abductive refers to the reconstruction of a single, narrative account of the *chaîne opératoire* from large numbers of pottery fragments and vessels. These narrative accounts list the techniques applied during each stage of the *chaîne opératoire*, and these lists can then be compared (see protocols in Gosselain 2018; Roux 2019a, e.g. 2019b).

The primary advantage of the abductive approach over the probabilistic approach outlined above is flexibility. The narrative account does not restrict the analysis to a specific resolution (e.g. techniques) nor require complete specific *chaînes opératoires* to conduct comparisons. For example, one could have a detailed account for roughing out of the lower body based on one group of sherds and a more general account of roughing-out techniques for the upper body which draws on a different set of sherds. By contrast, the probabilistic approach works best with complete specific *chaînes opératoires* at a consistent level of resolution. Consequently, the abductive approach is more flexible than the probabilistic approach outlined here.

However, the flexibility of the abductive approach comes with three disadvantages relative to the probabilistic approach. The first disadvantage relates to variability. The abstract narrative account produced during the abductive approach poorly accommodates assemblage variability, especially in comparisons between assemblages. Instead, the use of the abductive approach tends to lead to the detection of binary oppositions in specific stages. For example, researchers might state that traces of coiling are either present or absent during the roughing out of the lower body. Such binary oppositions do not tell us whether particular technical choices are common or rare, nor do they allow for the possibility that potters might learn or be familiar with multiple techniques. The probabilistic approach, on the other hand, is capable of incorporating variability in a more nuanced, quantitative fashion as multiple alternate paths with different intensities through the same network. Moreover, it makes no assumptions about the (in)ability of past potters to learn a given technique: it only increases the distance as potters need to learn more new techniques.

The second disadvantage of the abductive approach is unclarity with regard to what is compared. The abducted narratives may be based on ceramic assemblages with different properties. For example, one assemblage may feature a large number of wall sherds with traces of surface treatment but few bases with traces of roughing out, and vice versa for another assemblage. Yet the abductive approach would present the same narrative for both assemblages, despite these differences. How do these two narratives relate at all then? The advantage of the probabilistic comparisons lies in the explicit, quantifiable assumptions, base data, and output. Every datapoint is a specific *chaîne opératoire* which follows from traces on vessels, and has a measurable impact on the outcomes of the comparisons. As such, the probabilistic approach enjoys better verifiability than the abductive approach. This advantage is crucial for a deep time perspective on phenomena as complex as knowledge (cf. Mesoudi 2011).

The last disadvantage is the inability of the abductive approach to capture the syntax of the production process. The syntax is a crucial element in the definition of the *chaîne opératoire*: the ordering of the techniques is as important as the techniques used (see Section 4.1). The abductive approach loses sight of the syntax because it splits the *chaîne opératoire* into discrete steps and stages, which are compared separately. By contrast, the probabilistic approach can capture and compare these orders of techniques as well as the techniques themselves because it departs from network analysis which is based precisely on the connections between entities (see Section 4.1).

To conclude, both comparative methods have different strengths. The abductive approach provides flexibility, whereas the probabilistic approach can provide nuanced, quantifiable assessments of variability, which takes the syntax of the production process into account. Despite the methodological differences, both methods are ultimately compatible. Chapters 9 and 10 apply the abductive and probabilistic methods, respectively, to compare Funnel Beaker West and Corded Ware bodies of knowledge. The outcomes of both comparisons are similar and even complementary (see Ch. 12, 13).

5

Sample Design

This chapter outlines the sampling strategy and analytical techniques for reconstructing ceramic technology in Funnel Beaker West and Corded Ware vessels. The chapter has three parts. Section 5.1 is a discussion of the overarching aims behind the selection of vessels, and Section 5.2 of the research methods and study protocols to reconstruct specific *chaînes opératoires* from these vessels. Lastly, an overview of the sites and vessels included in the sample is given in Section 5.3, along with arguments that the sample is representative of the variability in ceramic technology among Funnel Beaker West and Corded Ware in the Netherlands. A summary of the chapter is available in Section 5.4.

5.1 Sampling Strategy

Two goals shape the sampling strategy. Both relate to the discussion on ceramic technology in Chapters 3 and 4.

The first goal is to incorporate variation in ceramic production. This goal stems from the notion that potters dispose over a technical repertoire which allows for the production of many alternate specific *chaînes opératoires* (see Section 3.2). The archaeological record does not allow us to observe individual technical repertoires or developments therein. However, it is possible to look at the aggregate effect of many such technical repertoires by taking into account the breadth of variation in ceramic technology for a given region and period. This more general point of view is a body of knowledge (see Section 3.2). Consequently, the overarching aim behind the sampling strategy is to construct such bodies of knowledge for Funnel Beaker West and Corded Ware ceramic technology in the Netherlands.

The second goal relates to the completeness of the specific *chaînes opératoires*. The probabilistic comparison from Chapter 4 works best with complete specific *chaînes opératoires*. Working with fragmented specific *chaînes opératoires* is possible, but would require both careful sample control to prevent overrepresentation of certain techniques (e.g. decorative techniques), and guided random path generation to join these fragments into probable paths (see Section 4.2). The results from such a procedure would always imply additional inferences when compared to an analysis with complete specific *chaînes opératoires*. Therefore, this study uses exclusively complete specific *chaînes opératoires*.

In sum, the sampling strategy has two goals. The primary aim is to cover the variation in Funnel Beaker West, and Corded Ware ceramic production. The second aim is to select vessels for which complete, specific *chaînes opératoires* can be reconstructed. The next section covers the analytical techniques for this reconstruction.

5.2 Analytical Techniques

Two complementary research methods are applied in this study for the reconstruction of specific *chaînes opératoires*: macromorphology and ceramic petrography. This section motivates the use of these tools and discusses the applied study protocols.

Macroscopic Analysis

Macroscopic analysis of ceramics is the backbone of this study. Macroscopy refers to the analysis of ceramics with the naked eye or under low magnification. The protocol for macroscopy applied here derives from Roux (2019a; see Tab. 5.1 for an overview). This protocol is applicable for reconstructing all stages of the *chaîne opératoire* from roughing out to post-firing treatments. Moreover, it has three advantages relative to prior protocols for the study of ceramic technology, such as Rye (1981).

The first advantage is a strong empirical focus. The protocol revolves around the detection of technical traces and the interpretation of these traces through comparisons against experimental and ethnographic materials with a known production process (Roux 2019a pp. 140–1). The back and forth between detected traces and traces with a known origin benefits the accuracy of interpretations.

Parameters	Variables	
Relief *describes changes in wall thickness for the entire vessel wall (profile) or local zones (topography). These changes often (but not exclusively) relate to roughing-out and preforming techniques.*	Profile (Roux 2019a pp. 142–3).	-
	Topography (Roux 2019a pp. 143–4, Fig. 3.8).	Hollows (Roux 2019a pp. 144–5, Fig. 3.9-10).
		Protrusions (Roux 2019a p. 145, Fig. 3.11-2).
Type of fracture *refers both to preferential orientation of breaks and appearance of the break in cross-section (profile). Both factors relate to roughing-out techniques.*	Orientation (Roux 2019a p. 146).	-
	Profile (Roux 2019a Fig. 3.13).	-
Surface *describes the appearance of vessel surfaces, which relates to a great number of production techniques from roughing out to post-firing treatments. The variables for describing vessel surfaces include patterns in surface colour, appearance of gloss, relations between inclusions and surface, smoothness, and the appearance of striations.*	Colour (Roux 2019a p. 146).	-
	Shine (Roux 2019a p. 148, Fig. 3.14).	-
	Granularity (Roux 2019a pp. 149–50, Fig. 3.15).	-
	Microtopography (Roux 2019a pp. 150–2, Fig. 3.16).	-
	Striation (Roux 2019a pp. 152–3).	Dimensions
		Layout
		Microrelief (edge and base; Roux 2019a Figs. 3.17-8).
Decorative traits *refer to the appearance of decorative elements, which is indicative of decorative techniques and the hygrometry of the paste at the time of application.*	Morphology (Roux 2019a p. 154).	Microrelief (edge and base; Roux 2019a Figs. 3.17-8).
Radial section *refers to the sequence of colours on breaks from outer margin, to core, and inner margin. This parameter is indicative of firing atmospheres.*	Colour (Roux 2019a p. 154; Rye 1981 pp. 114–8, Fig. 104).	-

Table 5.1: Variables for the description of technological traces on ceramics (after: Roux 2019a Tab. 3.1). Descriptions of the parameters in italics with relevant page numbers.

The second advantage of the protocol from Roux (2019a) is verifiability. The protocol emphasises the documentation of technical traces through photography and standardised terminology. This documentation enables independent evaluation and verification of results, which are essential lacunae in older studies of ceramic technology (see also Sections 6.1, 7.1).

The final advantage is the holistic, broad scope of ceramic technology in the protocol. Roux (2019a) provides an overview of production traces from all stages of the ceramic production process based on ethnographic, experimental, and archaeological case studies from across the world. Moreover, she proposes a unified, standardised vocabulary for the description of these traces. This broad scope greatly facilitates comparisons across different regions and periods, which aligns with the central aims of this study.

The exact research protocol applied here deviates from the protocol by Roux in two respects. The first difference is relatively minor: there are no measurements of hardness (see Tab. 5.1; cf. Roux 2019a Tab. 3.1). This omission relates to the origins of the vessels studied here. Most vessels stem from museum collections. Therefore, systematic application of destructive hardness tests is not possible. Moreover, the information value of these hardness tests is negligible. Hardness relates to firing temperatures, but this relation is not straightforward, and proper reconstruction of firing temperatures would require more advanced study protocols (cf. Gliozzo 2020).

The second difference relates to the synthesis of macroscopic data. Roux (2019a p. 209) recommends documentation of individual production traces on all ceramics in an assemblage, followed by a synthesis of all these traces at the assemblage level to reconstruct a single, abstracted production process. This abstracted production process then feeds into the comparisons (see Section 4.3 on the abductive approach). The synthesis of production traces is placed at a lower level here, namely at the level of specific *chaînes opératoires* (see Ch. 4). In turn, larger groups of specific *chaînes opératoires* form bodies of knowledge which feed into the comparison. This difference in the position of the reconstruction relates to the differences between the abductive and probabilistic comparisons discussed in Section 4.3. Working with specific *chaînes opératoires* enables me to work with quantified data and to incorporate both the variability in and syntax of the production process. Hence this deviation from the protocol presented by Roux (2019a)

Petrographic Analysis

The second analytical tool is ceramic petrography. This analysis follows the seminal protocol from Withbread (1989, 1995) with the modifications proposed by Quinn (2013 p. 79; see Tab. 5.2). All analyses were performed with a Leica DM 2700P microscope with a HC plan s10x/2mm eye piece and three lenses: Hi plan 4x/0.10 pol, Hc pl Fluotar 10x/0.30 -/D1, Hcx pl Fluotar 20x/0.50 pol 0.17/D1.15.

The petrographic analyses characterise the matrix, inclusions, and voids of a fabric. For the matrix, the information pertains to the homogeneity, composition, (interference) colours, and optical activity (cf. Quinn 2013). The description of the inclusions looks at the relative abundance, type, sphericity, angularity, maximal and modal size, sorting, and grain size distribution (cf. Quinn 2013). The rock and mineral inclusions are identified by comparing their optical properties to petrographic atlases (chiefly, Adams *et al.* 2014; MacKenzie *et al.* 1982; MacKenzie and Adams 1994; MacKenzie and Guilford 2013; Yardley *et al.* 1990). Lastly, the descriptions of voids mention void shapes and sizes (cf. Quinn 2013). The term microstructure refers to the relations between these three elements, such as a joint orientation

<table>
<tr><td>Group</td><td colspan="3">Descriptive name of the petrographic group</td></tr>
<tr><td>Sample</td><td colspan="3">Identifier of the sample</td></tr>
<tr><td rowspan="3">Microstructure

All visible structural elements.</td><td>Voids</td><td colspan="2">Relative abundance, size, and void type (cf. Whitbread 1995 p. 380).</td></tr>
<tr><td>C:f:v</td><td colspan="2">Relative abundance of the coarse fraction of the inclusions, the fine fraction of the inclusions, and the voids.</td></tr>
<tr><td>Orientation</td><td colspan="2">Alignment of voids and/or inclusions relative to the margin of the sample.</td></tr>
<tr><td rowspan="8">Groundmass

Description of the matrix and inclusions.</td><td>Homogeneity</td><td colspan="2">Describes the degree of homogeneity in a sample (cf. Quinn 2013 p. 94).</td></tr>
<tr><td rowspan="5">Micromass

The equivalent of the clay matrix.</td><td colspan="2">Score from more calcareous or to more ferruginous (cf. Quinn 2013 pp. 93–4).</td></tr>
<tr><td>Optical state</td><td>States whether the matrix exhibits optical activity (cf. Whitbread 1995 p. 382).</td></tr>
<tr><td rowspan="2">Colour</td><td>Colour of the matrix in cross polarised light at 4x magnification.</td></tr>
<tr><td>Colour of the matrix in plane polarised light at 4x magnification.</td></tr>
<tr><td colspan="2">Description of variations in colour, if present.</td></tr>
<tr><td rowspan="2">Inclusions</td><td colspan="2">Relative abundance, sphericity, maximal size of all inclusions. Spacing of the inclusions. Characterisation of grain size distribution. Sorting of the particles (cf. Quinn 2013 pp. 89–93).</td></tr>
<tr><td>Texture</td><td>In case of a bimodal fabric (cf. Quinn 2013 pp. 85–9).

Coarse fraction

Relative abundance of the inclusions, upper boundary-lower boundary in millimetres

For mineral and organic inclusions:

Relative abundance, Inclusion type; sphericity, angularity, largest size, modal size. Other relevant characteristics.

For grog:

Relative abundance, Inclusion type; sphericity, angularity, largest inclusion size, modal inclusion size. The number of types present and for each type:

Colour. List of inclusion and void types. Optical activity. Microstructure. Presence of shrinkage voids. Other relevant characteristics.

For clay lumps (cf. Quinn 2013 pp. 91–3):

Relative abundance, sphericity, angularity, largest particle size, modal size. Colour. Optical density. Type of boundaries. Concordance. Internal composition.

Fine fraction (in case of bimodal fabric)

Percentage of the inclusions, upper boundary-lower boundary in millimetres (always 0.01mm)

Relative abundance, inclusion type</td></tr>
<tr><td>Comments</td><td colspan="3">Brief description of the fabric, including an interpretation of the characteristics described above (cf. Quinn 2013 pp. 100–2).</td></tr>
<tr><td>Picture</td><td colspan="3">Photomicrographs of representative parts of the fabric in plain and cross polarised light.</td></tr>
</table>

Table 5.2: Form for the description of thin sections (after: Kroon 2016), based on Whitbread (1989, 1995) and Quinn (2013). Explanatory notes in italics. Relative abundances are estimations based on comparator charts (cf. Quinn 2013 p. 82).

and relative abundance (cf. Quinn 2013). The description of each thin section also comes with a brief interpretation, and two representative photomicrographs (see Tab. 5.2).

In this study, ceramic petrography is the primary source of information on the choices past potters made in the selection and preparation of raw materials. The identification and description of inclusions and clays through ceramic petrography are more accurate than macroscopic observations. Additionally, the microstructure of a fabric may yield information on paste homogenisation (cf. Ho and Quinn 2021), as well as complementary information on various other stages of the specific *chaîne opératoire*, such as surface treatment. Moreover, ceramic petrography can help to narrow down potential sources of clay and other raw materials sources (cf. Quinn 2013; Roux 2019a). As such, ceramic petrography is complementary to macroscopic analysis.

The disadvantage of ceramic petrography is the destructive nature of the analysis. For this study, the thin sections derive from sherds with a cross-section of (at least) 1 cm2 in vertical orientation relative to the vessel (Braekmans and Degryse 2016 p. 234; Quinn 2013 p. 23). As stated above, most vessels studied here stem from museum collections. In addition, the drive to study vessels for which complete specific *chaînes opératoires* can be reconstructed, resulted in a high number of relatively complete vessels in the macroscopic study. These vessels were not always available for destructive sampling of vertical sections. As a result, the samples for petrography and macroscopy differ in two respects.

The first difference is the sample volume. The sample volume for ceramic petrography is smaller than that for macroscopy, as not all studied vessels were available for destructive sampling. By implication, rare vessel types may not appear in the petrographic dataset (see Section 5.3). In addition, there is no distinction between megaliths, early flat graves, and late flat graves for the petrographic samples. This is necessary to create a petrographic dataset with sufficient volume to be representative of the Funnel Beaker West body of knowledge.

The second difference is the inclusion of vessels not studied through macromorphology. Some sites simply did not yield any vessels suitable for macroscopic and petrographic analysis. In these cases, petrographic samples from similar vessels which could be sampled were included in the dataset. This preserves the variation within the dataset but implies there is no perfect overlap between macroscopy and ceramic petrography.

As a result of both differences, the petrographic samples for Funnel Beaker West and Corded Ware act as a subsample of the bodies of knowledge. Therefore, a direct integration of both analyses, which connects each specific *chaîne opératoire* to raw materials, is not possible (see Section 4.1). Instead, Chapters 8 and 9 correlate the outcomes of the petrographic analysis to the macroscopic analyses. This correlation shows that various paste recipes occur in the bodies of knowledge (see Ch. 9).

5.3 Selected Vessels and Samples

This section provides an overview of the sampled vessels and sites. All Funnel Beaker West and Corded Ware vessels studied here stem from funerary contexts (see Appendix B). There are two reasons to sample this specific site type. Firstly, funerary sites are the defining elements of both Funnel Beaker West and Corded Ware (see Section 2.1), and settlements from these two archaeological cultures are rare in the study area (Bakker 1982; Drenth *et al.* 2008; Fokkens 2012 pp. 22–3). Secondly, funerary sites more often yield complete vessels than settlement sites due to the deposition of intact vessels as grave goods and the lack of younger disturbances. As such, there is a synergy between the focus on funerary sites and the preference for complete specific *chaînes opératoires* (see Section 5.1). In

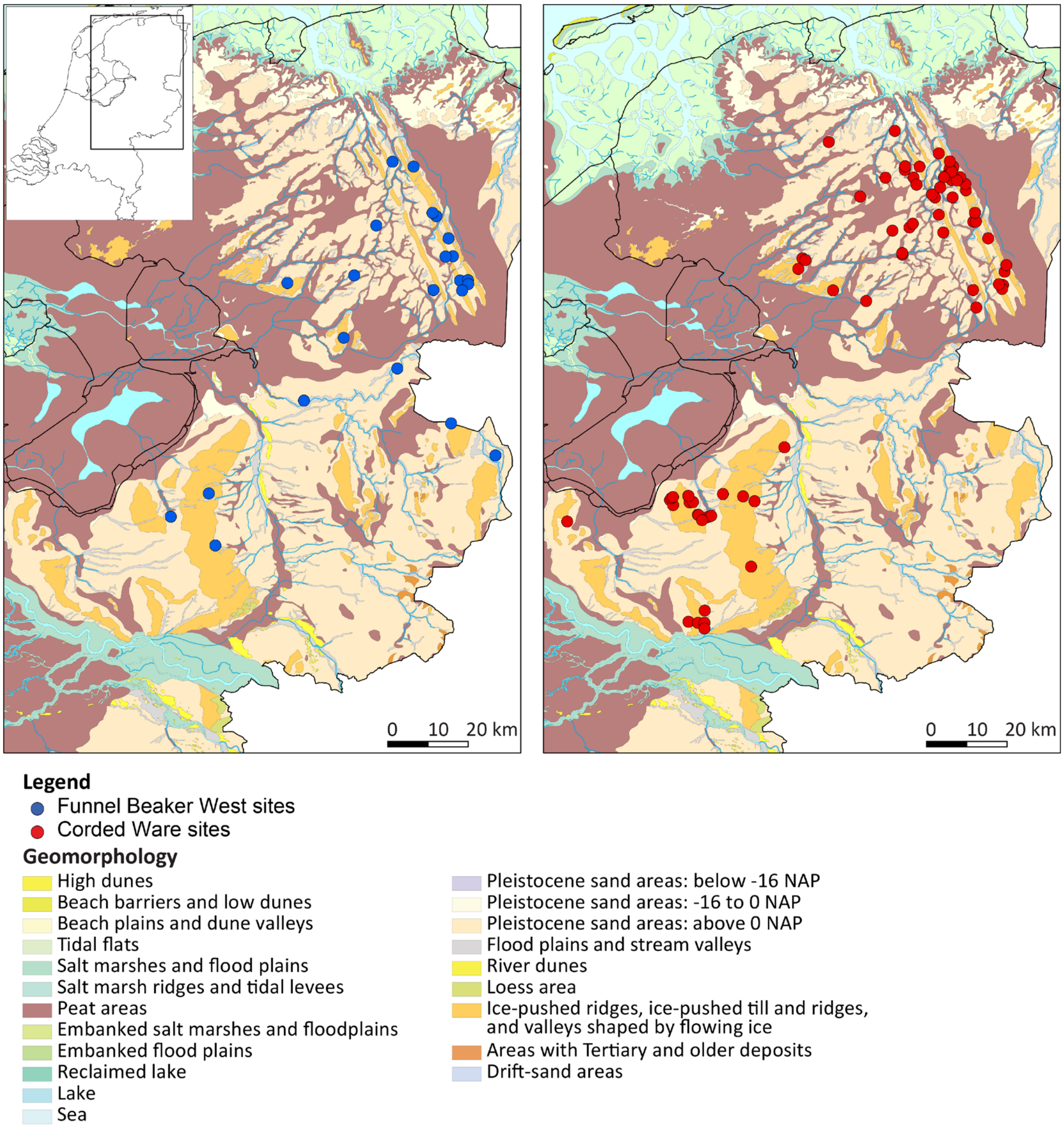


Figure 5.1: Geographic distribution of Funnel Beaker West and Corded Ware sites from which vessels were studied (see Appendix B). The background map is the paleogeographic map of the Netherlands around 2750 BCE (Vos and de Vries 2013 p. 49). The area covered by peat would have been less extensive towards the end of the 4th millennium BCE (cf. Vos *et al.* 2020).

addition, deriving both Funnel Beaker West and Corded Ware specific *chaînes opératoires* from funerary contexts ensures both bodies are comparable in terms of context.

Figure 5.1 presents the geographic distribution of the studied sites (see Appendix B). This distribution covers the two well-known clusters of Corded Ware and Funnel Beaker West sites in the research area: the Veluwe and the Drents Plateau (cf. Fokkens 2012 Fig. 5). The distribution is purposefully broad so as to incorporate potential regional variation in Funnel Beaker West and Corded Ware specific *chaînes opératoires*. Several studies argue that Funnel Beaker West funerary assemblages stem from local communities (cf.

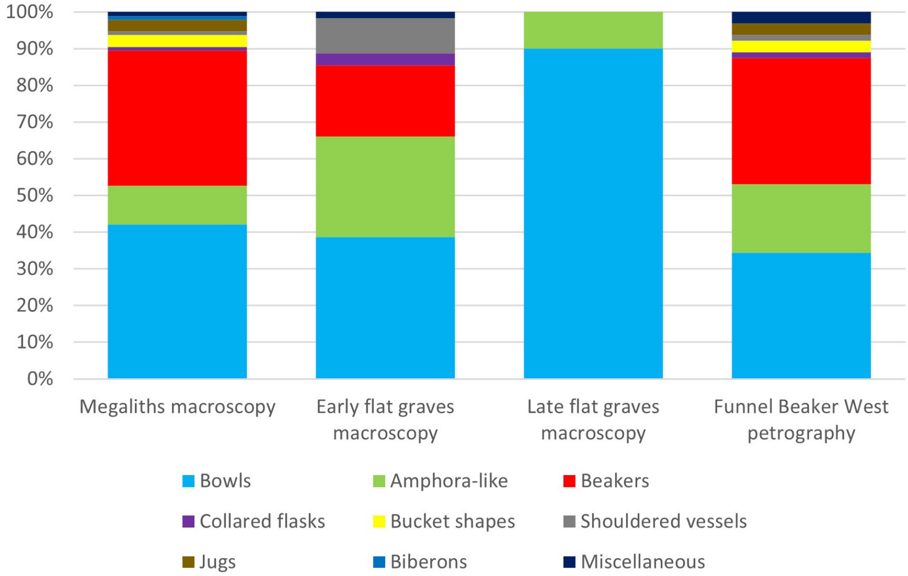


Figure 5.2: Relative distribution of Funnel Beaker West vessel types in the macroscopic and petrographic datasets (see Tab. 5.3 for raw data, Fig. 2.7 for type definitions). The composition of the macroscopic samples is comparable to the diversity in vessel types found in Funnel Beaker West assemblages (see Tab. 2.2). The composition of the petrographic is an average of the vessel types found in megalith inventories, early flat graves, and late flat graves.

Raemaekers and Van der Velde 2022 p. 186; Voss 1982 p. 91). Therefore, a more in-depth study of a single site or of a small number of sites could risk the overrepresentation of a local production process at the cost of the overall variation in ceramic production techniques. A broad geographic distribution prevents such a bias.

The geographic distributions of Funnel Beaker West and Corded Ware vessels differ with respect to the number of studied sites (see Fig. 5.1). Corded Ware sites form a diffuse spread with at most a handful of vessels per site. By contrast, Funnel Beaker West vessels stem from a small number of sites which yield large quantities of vessels. This difference is unavoidable because of the funerary practices associated with these groups. Corded Ware funerary practices often involve the deposition of one or at most two vessels in (semi-) isolated barrows and flat graves (cf. Wentink 2020 p. 48). Funnel Beaker West flat graves may feature similar vessel numbers, but these graves occur in more significant numbers at flat grave cemeteries (see Brindley 2022 Tab. 4.5 for a recent, well-excavated site). Funnel Beaker West megalithic tombs exacerbate this difference: a megalith typically yields large quantities of vessels (but see discussion below). Given these numerical differences in vessels per site, a broad, diffuse spread of Corded Ware sites is necessary to match a smaller number of Funnel Beaker West sites in terms of vessels.

Apart from a broad geographic distribution, the bodies of knowledge also cover the variation in vessel types for Funnel Beaker West and Corded Ware assemblages.

Figure 5.2 shows the composition of the macroscopic and petrographic datasets for the Funnel Beaker West body of knowledge. The vessels from megalith inventories, early flat graves, and late flat graves are highlighted as separate subsets (see Section 2.4). The relative proportion of vessel types (see Fig. 2.7) in the macroscopic dataset matches that in archaeological assemblages from these site types (see Tab. 2.2; Tab. 5.3). Bowls and beakers are most common in the subset for megalith inventories, with a broad range of other shapes, including amphora-like vessels in smaller percentages. Early flat graves feature a higher proportion of amphora-like vessels with less over-all variation in vessel types compared to megalith inventories. The subset for late flat graves consists almost exclusively of bowls. Both finds from flat graves and megaliths have been incorporated in this dataset because the typical complex bowls and cremations for this late phase can be found in both types of contexts (see Section 2.4).

The petrographic dataset for Funnel Beaker West is an average of the macroscopic subsets. Some of the rare vessel types in the macroscopic dataset (e.g. biberons) are absent in the petrographic dataset due to the smaller sample volume (see above). In addition, the number of miscellaneous vessels is higher in the petrographic data than in the macroscopic data. This is due to the incorporation of sherds from sites for which no vessels with complete specific *chaînes opératoires* could be sampled for petrography (see above).

In terms of vessel shapes (see Fig. 2.7), the Funnel Beaker West body of knowledge mostly consists of open vessel shapes (most bowls, and bucket shapes) and complex shapes (certain bowls, beakers, amphora-like vessels, collared flasks, shouldered vessels, jugs, biberons). Some bowls are closed shapes.

The macroscopic and petrographic datasets for the Corded Ware body of knowledge also reflect the vessel type distributions found in archaeological Corded Ware assemblages. Figure 5.3 shows the majority of the macroscopic and petrographic samples stem from beakers, with smaller amounts of amphora-like vessels and bowls (see Tab. 5.3). This type distribution is typical for Corded Ware funerary sites in the Netherlands (cf. Wentink 2020 Tab. 4.1). In terms of vessel shapes, the body of knowledge mostly consists of complex shapes (beakers, SWM's, and amphora-like vessels) and a small number of open and closed shapes (bowls; see Fig. 2.7).

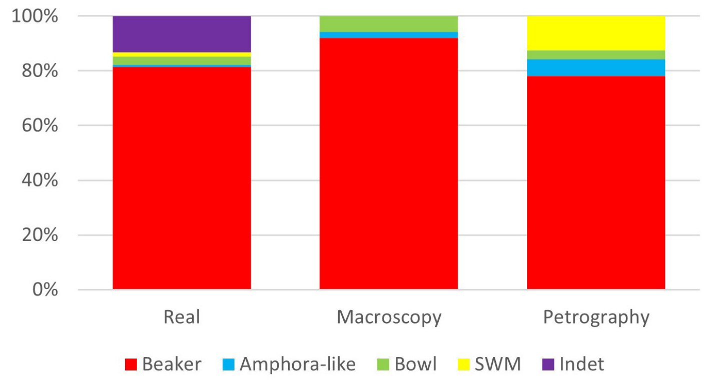


Figure 5.3: Relative vessel type distribution in the macroscopic and petrographic analyses for the Corded Ware body of knowledge (see Tab. 5.3 for raw data, Fig. 2.7 for type definitions). The graph also shows the percentages Corded Ware vessel types in archaeological assemblages (after: Wentink 2020 Tab. 4.1). The composition of these three groups is comparable: mainly beakers with smaller amounts of bowls and amphora-like vessels. Indeterminate vessels have been omitted from the studied material. The lack of complete specific *chaînes opératoires* for short-wave moulded wares relates to preservation and exclusion from funerary practices. This vessel type only appears in petrographic analyses.

The composition of the Corded Ware body of knowledge and archaeological Corded Ware assemblages differ in two respects. The first difference is minor: indeterminate vessels are excluded from the body of knowledge. The second difference is the percentage of short-wave moulded wares. This vessel type is rare in funerary contexts, and, if present, is generally incomplete (e.g. Lanting and Waals 1971 p. 100; cf. Wentink 2020, Tab. 4.1). As a result, none of these vessels from funerary contexts yield complete specific *chaînes opératoires*. Therefore, short-wave moulded wares do not appear in the macroscopic analyses, but have been included in the petrographic analyses to preserve variation there.

Lastly, the Corded Ware body of knowledge includes both classic Corded Ware vessels (n=85), and a small number of All-Over Ornamented vessels (n=4). Recent studies show these two types are not distinct: the radiocarbon dates of these vessels overlap (see Section 2.3; Beckerman 2012), as do funerary practices in burials with these ceramics (Wentink 2020 pp. 36–8). Therefore, there is no reason to separate these vessels.

In all, the composition of the bodies of knowledge does not differ substantially from type distributions observed in the archaeological record (see Tab. 5.3). As such, it is representative of the variation in Corded Ware vessel types.

This brings us to a final note on the size of megalith inventories. This observation has a bearing on the representativity of the Funnel Beaker West body of knowledge.

Funnel Beaker West megaliths yield exceptionally high vessel counts by Funnel Beaker standards. Whereas Funnel Beaker megaliths outside the Netherlands rarely yield more than 50 vessels (Midgley 2008 p. 139), various publications for Dutch megaliths report minima of several hundreds of vessels from a single megalith (see Tab. 5.4). I argue

Body of knowledge	**Funnel Beaker West**				**Corded Ware**		
Analysis	**Macroscopy**			**Ceramic Petrography**	**Observed**	**Macroscopy**	**Petrography**
Subset	Megalith inventories	Early flat graves	Late flat graves	Funnel Beaker West	Funerary contexts	Funerary contexts	Funerary contexts
Vessel type	*n*	*n*	*n*	*n*	*n*	*n*	*n*
Bowls	40	24	27	22	4	5	1
Amphora-like	10	17	3	12	1	2	2
Beakers	35	12	0	22	105	82	25
Collared flasks	1	2	0	1	0	0	0
Bucket shapes	3	0	0	2	0	0	0
Shouldered vessels	1	6	0	1	0	0	0
Jugs	3	0	0	2	0	0	0
SWM	-	-	-	-	2	0	4
Biberons	1	0	0	0	0	0	0
Miscellaneous	1	1	0	2	17	0	0
Total	**95**	**62**	**30**	**64**	**129**	**89**	**32**

Table 5.3: Overview of vessel type distributions for the Funnel Beaker West and Corded Ware body of knowledge. All numbers are absolute numbers, see Figure 2.7 for type definitions. The table includes an overview of vessel types in Corded Ware funerary contexts from Wentink (2020 Tab. 4.1) in the column 'observed'. For similar overviews of Funnel Beaker West, see Tab. 2.2. For convenience, the table reports vessel types with the same name on the same line.

Megalith	Vessels	Source	MNI
D6a	192	Brindley *et al.* (2002 p. 51)	-
D9	101	De Groot (1988 p. 83)	-
D19	400	Van Giffen (1927 p. 87; cf. Van Ginkel *et al.* 1999 p. 173)	-
D21	263	Van Giffen (1927 p. 158)	-
D22	41	Van Giffen (1927 p. 258)	-
D26	159	Van Rijn (1990) in Van Ginkel *et al.* (1999 p. 178)	-
D30	80	Brindley and Lanting (1992 p. 134)	-
D32a	165	Taayke (1985 p. 138, Tab. 1)	51
D32d	150	Kamlag (1988) in Van Ginkel *et al.* (1999 p. 196)	25
D40	60-80	Brindley and Lanting (1992 p. 117)	-
D43a	89	Molema (1987) in Van Ginkel *et al.* (1999 p. 197)	19
D53	660	Van Giffen (1951 pp. 102-4) in Van Ginkel *et al.* (1999 p. 191)	-
D54a	?	Meeüsen (1983) in Van Ginkel *et al.* (1999 p. 198)	43
D54b+c	?	Bouma (1985) in Van Ginkel *et al.* (1999 p. 199)	34
G1	150	Brindley and Lanting (1992 p. 139), cf. Bakker (1983)	-
G2	400	Brindley (1986a p. 37)	-
G3	33	Brindley (1983 p. 215)	-
O2	314	Ufkes (1993 p. 31)	-

Table 5.4: The number of vessels in megaliths (listed in alphabetic order) according to various publications. These totals can differ from those in Tab. 5.3, as publications report lower numbers of classified (including miscellaneous) vessels than the 'minimal' number of vessels in an assemblage, again underlining the lack of robust counting methods in these studies. The table also reports MNI's from this study for megaliths of which the entire inventory was available for study.

these exceptionally high minima are overestimates which result from a problematic counting method.

The publications mentioned in Tab. 5.4 do not count actual vessels, but unique groups of sherds. These groups are based on (refitted) profiles, surface appearance, and decorative patterns (cf. Brindley 1986a p. 37; Brindley and Lanting 1992 p. 117; Taayke 1985 p. 37). This counting method is likely to overestimate the number of ceramics in highly decorated, fragmented assemblages, because fragmentation reduces the odds of finding sherds which connect different decorative motives and vessel parts. Moreover, the resulting minima are not robust, because the counting method heavily relies on a researchers' overview of the assemblage, and time (and skill) available to refit sherds. This lack of robusticity results in discrepancies in the minimal number of vessels reported for sites. For example, different authors may report different minima for the same assemblage (compare the totals in Brindley and Lanting 1992 p. 139; Van Ginkel *et al.* 1999), or one author may report different minima within the same publication (see Tab. 5.4).

To overcome these issues, this study established a minimal number of individuals (MNI) for several megalith inventories of which all the finds could be studied. This method only counts the central fragments of the vessel base because any vessel can only produce one such sherd. The resulting vessel totals are underestimations but highly robust ones. Table 5.4 shows these MNI's for megalith inventories differ up to a factor of 6 from previously published minimal numbers of vessels (see D32d in Tab. 5.4). Discrepancies of this magnitude should force us to reconsider the size of megalith inventories. All the more so if further studies attest similar discrepancies for the other megaliths in Table 5.4. It is likely that the high minima reported for these sites are also gross overestimates and that the actual minimal number of individuals in Funnel Beaker West megaliths is more in line with the minima reported for other Funnel Beaker groups (cf. Midgley 2008 p. 139).

The smaller assemblage size for megalith inventories is beneficial for the representativity of the sample in this study. For example, the 12 vessels studied from the inventory of megalith D32d are more likely to encompass the variation at this site if the minimal number of individual vessels is 25 instead of 150 (see Tab. 5.4, Appendix C and D).

5.4 Overview

This chapter is an overview of the sampling strategy, research methods, and composition of the dataset.

The central aim of the sampling strategy is to construct bodies of knowledge which are representative of the variation within Funnel Beaker West, and Corded Ware ceramic production in the Netherlands. In addition, the dataset aims to select complete specific *chaînes opératoires* to facilitate the probabilistic comparison.

The reconstruction of specific *chaînes opératoires* is based on macroscopic analyses and ceramic petrography. Macroscopy is the primary source of information for all stages of the specific *chaîne opératoire* from roughing out to firing. The protocol for macroscopic analysis derives from Roux (2019a). In addition to macroscopy, this study uses ceramic petrography according to the protocols of Whitbread (1989, 1995) and Quinn (2013). Ceramic petrography provides key insights into the use and preparation of raw materials, as well as complementary evidence for various parts of the specific *chaîne opératoire*. However, the destructive nature of petrographic analysis implies not all vessels subject to macroscopy could be sampled. Therefore, subsequent chapters do not directly integrate the results from both analyses, but correlate the two.

The sample composition ensures coverage of the variation within Funnel Beaker West and Corded Ware assemblages in the Netherlands in two ways. Firstly, the bodies of knowledge draw vessels from sites throughout the geographic distribution of Funnel Beaker West and Corded Ware in the study area (see Fig. 5.1). Secondly, the composition of the bodies of knowledge is a direct representation of the variation in vessel types and shapes of both groups (see Tab. 5.3, Fig. 5.2-4). By drawing vessels from multiple sites and of multiple types and shapes, the comparisons of the specific *chaînes opératoires* capture the breadth of variation within Funnel Beaker West and Corded Ware in the Netherlands.

6

Funnel Beaker West Ceramic Technology

This chapter is about the outcomes of macroscopic analyses on the 187 vessels in the Funnel Beaker West body of knowledge. The base observations and supporting photographic documentation for each vessel are available in Appendices C and D, respectively. There is no discussion of raw materials and paste preparation in this chapter (see Ch. 8 instead) because these data stem from ceramic petrography rather than macroscopy and the samples differ (see Ch. 4 and 5). The presentation of macroscopic data has two aims. The first is to substantiate the diagnosis of particular techniques by presenting the associated technical traces. The second aim is to discuss these results with full attention to the nuances and complexities in the data ahead of the broader, comparative view taken in Chapters 9 and 10.

The chapter starts with a discussion of the available information about Funnel Beaker West ceramic technology in Section 6.1 to provide a broader context for this study. The results from this study itself are the subject of Section 6.2. Lastly, Section 6.3 is a summary of the outcomes.

The Funnel Beaker West body of knowledge is split into the subsets for megalith inventories, early flat graves, and late flat graves in the tables below (see Ch. 2; 5). The various vessel types and shapes (see Fig. 2.7) are mentioned where relevant, but not tabulated because of the low vessel count for certain rare types and shapes (see Ch. 5; Tab. 5.3). We take a closer look at the potential specialised production processes for certain vessel shapes and types during the abductive comparison (see Section 9.2).

6.1 Prior Studies

Despite the reputation of Funnel Beaker West ceramics as being among the finest wares to have been produced during prehistory, current knowledge about the production process is disjoint and reliant on old sources. Apart from oblique references in excavation reports, the most recent overviews of the Dutch material are from Van Giffen (1927) and Van der Leeuw (1976) with some additional information in Bakker (1979) and Brindley (1986b). The discussion of ceramic technology in the recent excavation report of a flat grave cemetery at Dalfsen (Brindley 2022) stands out but is limited to this site. Menne (2018) and Mennenga (2017) published some information on ceramic technology in Funnel Beaker

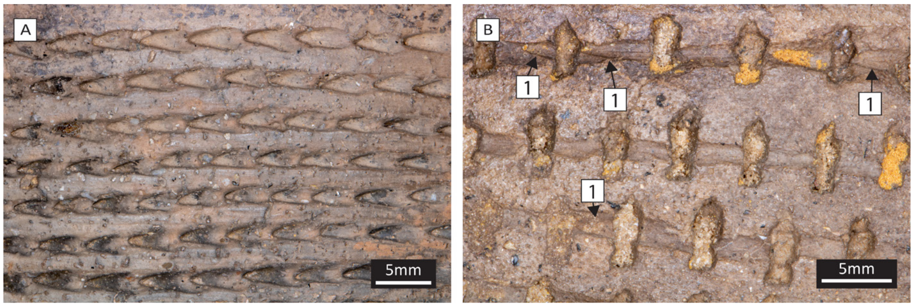


Figure 6.1: *Tiefstich* and *tvaerstik* decoration (cf. Brindley 1986b for the definition). A: Horizontal lines of *tiefstich* decoration on the upper body of vessel 27, made through simple oblique impressions with a conical tool (see section on decoration). B: A variant of *tvaerstik* decoration on the upper body of vessel 223. A horizontal line of simple oblique impressions with a conical tool, which has left some imprints at the base (1), and a second set of impressions (possibly with the same tool) set into this line at a perpendicular angle. These two examples highlight terminological inaccuracy: *tiefstich* and *tvaerstik* are not techniques, the same technique (i.e. a gesture with a specific tool) produces both of these decorations.

West ceramics from Germany. Lastly, Hulthén (1977) and Koch (1998) both present studies of ceramic technology in Funnel Beaker North vessels.

Three points of source criticism apply to the above-mentioned publications. Firstly, the definition of ceramic technology is often narrow. Decorative techniques and raw materials receive systematic attention, but information about other stages of the production process is scarce. Complete specific *chaînes opératoires* are absent. The second criticism is the lack of uniform vocabulary for ceramic production techniques. This caveat leads to inaccuracies and impedes comparisons across publications. For example, *tiefstich* and *tvaerstik* are not different decorative techniques but different motifs executed in the same decorative technique: simple oblique impressions (see Fig. 6.1). The last point of critique is about verifiability. These studies lack the textual and photographic documentation needed for independent assessment of the conclusions (cf. Brindley 2022; Koch 1998 for partial exceptions). This omission complicates the lack of uniform vocabulary because there is no base data to resolve uncertainties.

The following paragraphs are a discussion of the available information on Funnel Beaker ceramic technology with these three points of source criticism in mind. The information is translated into the terminology from Roux (2019a) to render it comparable to the outcomes of this study (see Section 6.2). By implication, household terms for the description of Funnel Beaker West ceramics, such as *tvaerstik* and *tiefstich*, do not feature in this chapter.

Roughing-out techniques appear homogenous in Funnel Beaker West and North vessels. Most authors claim to observe traces of coiling, modelling, or slab building (Brindley 2022 pp. 124–7; Hulthén 1977; Koch 1998; Van der Leeuw 1976 pp. 86; 108; Van Giffen 1927 pp. 348–9; 386). The break profiles include hollow breaks and breaks with internal or external bevels, which all result from different joining methods. Koch (1998) describes a roughing-out method which involves a clay disk as a base, coils joined with internal bevels in the lower body, and external bevels or straight joints in the upper body (cf. Brindley 2022 p. 126). The same method appears in the vessels studied here (see below).

Information on techniques in the preforming stage is sparse. Van der Leeuw (1976) and Koch (1998 pp. 125; 127) mention scraping and percussion but do not provide adequate evidence. According to Van Giffen (1927), Brindley (2022 p. 129), and Koch (1998 Pl. 30; 46; 90; 97) handles can be affixed directly to the vessel wall (as is the case with base rings), or through plugging a perforation in the wall, followed by modelling and perforation of the handle.

Little information is available for the finishing stage. Smoothing is regularly mentioned, but often without substantiation (Brindley 2022 p. 129; Koch 1998 p. 17; Menne 2018; Van der Leeuw 1976 p. 108).

Decorative techniques vary considerably. Studies mention simple incisions on wet and drier clay, simple impressions in stab-and-drag technique, excisions, paddled impressions, decorative applications, and incrustation (Bakker 1979; Brindley 2022 pp. 131–3, 1986b; Hulthén 1977; Koch 1998 pp. 127–8; 541; Van Giffen 1927). The same publications mention a range of tools for making these decorations: bone, cord, spatula, finger nails, cord, flint, and small sticks. Chemical analyses of the white mass in incrustations indicate this mass consists of heated, crushed bone. Brindley (1986b p. 50) and Menne (2018 p. 46) argue this mass is applied prior to firing and smoothed with a soft tool.

With regard to drying stages, Van der Leeuw (1976) and Koch (1998 p. 125) suggest the lower body of Funnel Beaker West vessels would be fashioned and dried prior to the construction of the upper body.

All authors describe burnishing as the most common surface treatment technique in Funnel Beaker ceramics (Brindley 2022 p. 131; Hulthén 1977; Koch 1998 p. 127; Menne 2018; Van der Leeuw 1976 p. 108). Koch (1998 p. 127) argues the direction of the gesture in burnishing operations switches from vertical on the lower body to horizontal on the upper body, which could indicate tilting of the vessel during this operation (cf. Brindley 2022 Figs. 4.72–3). Koch (1998 p. 129) also proposes smudging as an explanation for Funnel Beaker vessels with dark grey exterior surfaces which flake off to reveal oxidising margins.

The descriptions of firing cores in Funnel Beaker vessels all point towards oxidising surface colours such as yellow-brown and red-brown. These colours either continue throughout the core or appear only at the (exterior) margins (Hulthén 1977; Koch 1998 pp. 128–9; Menne 2018; Van der Leeuw 1976 p. 101; Van Giffen 1927). In terms of firing architecture, Koch (1998 pp. 127–8) argues no evidence exists for anything other than open firing for Funnel Beaker North (cf. Brindley 2022 pp. 125–6). Madsen and Fiedel (1987) do interpret a feature at Hevring as a pottery kiln, and Midgley (1992 pp. 345–6) mentions possible analogue features at other causewayed enclosures in Denmark. However, this study goes with the working assumption most of these vessels underwent open firing, given that these features in Denmark are the only potential kilns known to me.

The paragraphs above piece together information on Funnel Beaker ceramic technology from prior studies. The overview shows the use of similar techniques in ceramics from the Netherlands, Germany, Denmark, and Sweden. Such homogeneity suggests the potters in these regions shared technical knowledge, which is of interest for understanding the similarities between these archaeological cultures (see Ch. 11; 12). However, the interpretations in these studies are often impressionistic. Renewed studies of Funnel Beaker ceramic technology, in uniform vocabulary and with verifiable source data, are a prerequisite for further assessment of this homogeneity in ceramic technology. Therefore, these three points of source critique are taken up here. The next section is a presentation of information for all stages of the ceramic production process in a uniform vocabulary from Roux (2019a) and backed by photographic and textual documentation (see Appendix C and D). Hopefully, this discussion can be a starting point for renewed studies of Funnel Beaker ceramic technology.

6.2 Specific *Chaînes Opératoires* in the Funnel Beaker West Body of Knowledge

The previous section is a discussion of results from older studies. This section is about the results of this study. The order of the sections follows the stages of the ceramic *chaîne opératoire* proposed by Roux (2019a): roughing out, preforming, finishing, decoration, surface treatment, drying, and firing. Each section is a discussion and interpretation of the technical traces which relate to operations in that stage.

Roughing out

Roughing-out techniques transform the clay body into the approximate shape of the vessel (cf. Roux 2019a). This section starts with traces of these techniques on bases, and then discusses traces on vessel walls. This order follows from the technical traces on vessel bases (see below), which indicate that the base's fashioning preceded the wall's roughing-out.

Roughing out of Vessel Bases

Observed technical traces on the bases of Funnel Beaker West ceramics point to (combinations of) two roughing-out techniques: modelling and coiling.

The most common roughing-out method for bases is pinching, which is a modality of modelling (see Tab. 6.1). The diagnostic traces of this technique are the absence of indications for coiling and the regular occurrence of finger-sized hollows on the interior and/or exterior surfaces of the base (see Fig. 6.2A-B; cf. Roux 2019a p. 168). Two different procedures occur, labelled 'flattened disk' and 'lenticular mass' in Tab. 6.1 (see Fig. 6.2). Together, these procedures account for ca. 97% of the Funnel Beaker West vessels.

A 'lenticular mass' refers to a base which is concave, or flat on one side (usually the exterior), and convex on the other (usually the interior) with finger-sized hollows surrounding the centre of this mass (see Fig. 6.2A-B). The central mass also appears as a

	Subset	**Megalith inventories**		**Early flat graves**		**Late flat graves**		**Total (Funnel Beaker West)**	
Technique	Specification	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Modelling	Lenticular mass	66	69.5	53	85.5	26	86.7	145	77.5
	Flattened disk	26	27.4	7	11.3	3	10	36	19.3
	+ Adjacent coil	37	38.9	38	61.3	21	70	96	51.3
	+ Pressed against surface	4	4.2	4	6.5	0	0	8	4.3
	+ Double mass	3	3.2	1	1.6	0	0	4	2.1
Coiling	Spiral	3	3.2	2	3.2	1	3.3	6	3.2

Table 6.1: Roughing-out techniques detected in the bases of Funnel Beaker West vessels (n=187). All percentages relative to the total number of vessels in a subset: Megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30). Three basic procedures occur, and each base may feature a (combination of) further action(s), indicated by a '+' in the column specification.

distinct concentration in cross-sections of the base (see Fig. 6.2C), and fissures may appear at the attachment point of the lower wall on the interior surface of the base (see Fig. 6.2A and C). This base-forming procedure is the most common variant in vessels from megalith inventories (n=66), early fat graves (n=53), and late flat graves (n=26; see Tab. 6.1).

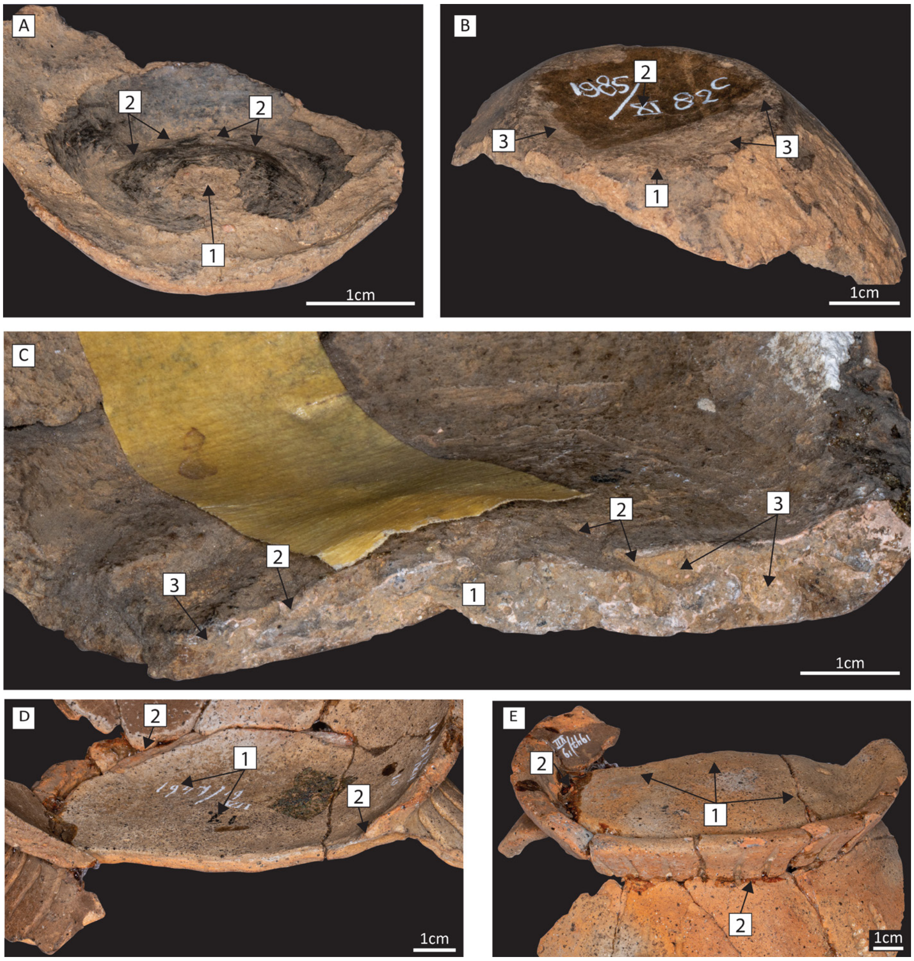


Figure 6.2: The two most common methods for roughing out the base through modelling: a lenticular mass (A-C) and a flattened disk (D-E). A: The base of vessel 303 is an example of a modelled lenticular mass. The base interior bulges at the centre (1) and exhibits finger-sized hollows (2). B: The base exterior of vessel 303 exhibits further signs of a modelled, lenticular mass, including a raised periphery (1), and a concave centre (2) lined with finger-sized hollows (3). C: A modelled lenticular mass is visible in the cross-section of the base of vessel 238. There is a lenticular mass at the centre (1) of which the edges are visible as fissures on the surface and voids in cross-section (2) at the attachment points of adjacent coils. The latter are also visible as relic coils (3) in cross-section. D: The base of vessel 295 is an example of the second modelling method: a flattened clay disk. The base interior is a single clay mass in cross-section with irregular thickness due to finger-sized hollows (1). The clay mass is delineated by a break (2) which shows the wall and base ring to be separate attachments. E: The base exterior of vessel 295 exhibits further traces typical of a flattened clay disk. The surface is convex and shows similar irregularities in thickness (1), as well as the same delineating break at the attachment point of the base ring (2).

The second base fashioning method is the ‘flattened disk’, and occurs in 26 vessels from megalith inventories, 7 early flat grave vessels, and 3 vessels from late flat graves (see Tab. 6.1). These bases consist of a single flat mass, which can be made out in cross-section. Indicators for coiling are absent, but finger-sized hollows occur regularly on the interior and exterior surface, and the base thickness is irregular (cf. Roux 2019a p. 168). Cross-sections show the wall and, if present, base rings are separate clay masses joined to this disk (see Fig. 6.2D-E).

Three additional operations occur on modelled bases (see Tab. 6.1). The first action is the placement of a coil adjacent to the modelled mass. These coils can be observed in cross-sections as relic coils around, for example, a lenticular mass, or as concentric fissures on the interior or exterior surface of the base (see Fig. 6.2C; 6.3B; cf. Roux 2019a Fig. 3.27). The periphery of the exterior may also appear raised due to this procedure. This operation occurs in over half the vessels from early flat graves (n=38), and late flat graves (n=21), but is less common in vessels from megalith inventories (n=37; see Tab. 6.1).

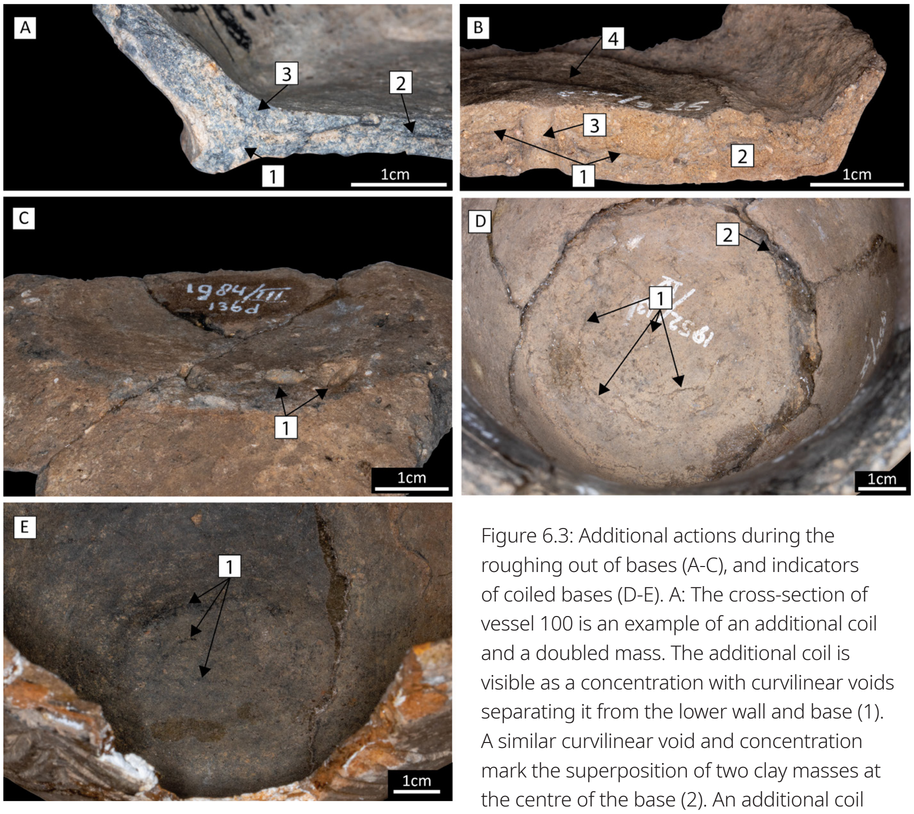


Figure 6.3: Additional actions during the roughing out of bases (A-C), and indicators of coiled bases (D-E). A: The cross-section of vessel 100 is an example of an additional coil and a doubled mass. The additional coil is visible as a concentration with curvilinear voids separating it from the lower wall and base (1). A similar curvilinear void and concentration mark the superposition of two clay masses at the centre of the base (2). An additional coil was smoothed against the joint of the base and lower wall as can be seen from the concentrations and curvilinear void (3). B: The base of vessel 26 further exemplifies the application of a double mass and additional coil. A void is visible in cross-section which separates the lower and upper mass of the base (1), and an additional coil is visible as a concentration in cross-section (2). A perforation sits at the centre of the base (3), and the centre of the base interior bulges on the interior with finger-sized hollows (4). C: The base exterior of vessel 300 was pressed into a surface, as evidenced by several deep impressions with irregular microrelief (1). D: Traces of coiling on the base interior of vessel 143. Specifically, a spiralling fissure (1) and a circular break around the joint with the lower wall (2). E: Traces of coiling also appear on the base interior of vessel 226 as a spiralling over-thickness (1).

The second additional procedure entails pressing the plastic clay mass of the base into a flat surface. This operation is difficult to detect due to erosion and frequent application of surface treatment to the base exterior in Funnel Beaker West vessels (see surface treatment). Key indicators are deep impressions made on wet clay (mostly from organic material) on the base exterior, and pull-outs on these surfaces (see Fig. 6.3C). These traces occur on 4 vessels from megalith inventories, and 4 vessels from early flat graves (see Tab. 6.1).

The last additional action occurs in only 3 vessels from megalith inventories, and 1 vessel from early flat graves (see Tab. 6.1). This operation consists of adding a second clay mass on top of the base interior, covering the entire surface. This action is only visible in cross-sections through the occurrence of elongated voids between both clay masses (see Fig. 6.3A-B). Consequently, the number reported in Table 6.1 is likely an underestimate.

Apart from modelling, coiling also occurs as roughing-out technique for bases in Funnel Beaker West vessels, albeit rarely (megalith inventories: n=3; early flat graves: n=2; late flat graves: n=1; see Tab. 6.1). In all cases, the roughing out of the bases followed the spiral coiling procedure. The indicators for this procedure are the occurrence of fissures and/or an over-thickness in a spiralling pattern (see Fig. 6.3D-E; cf. Roux 2019a Fig. 3.24). These traces usually appear on the base interior.

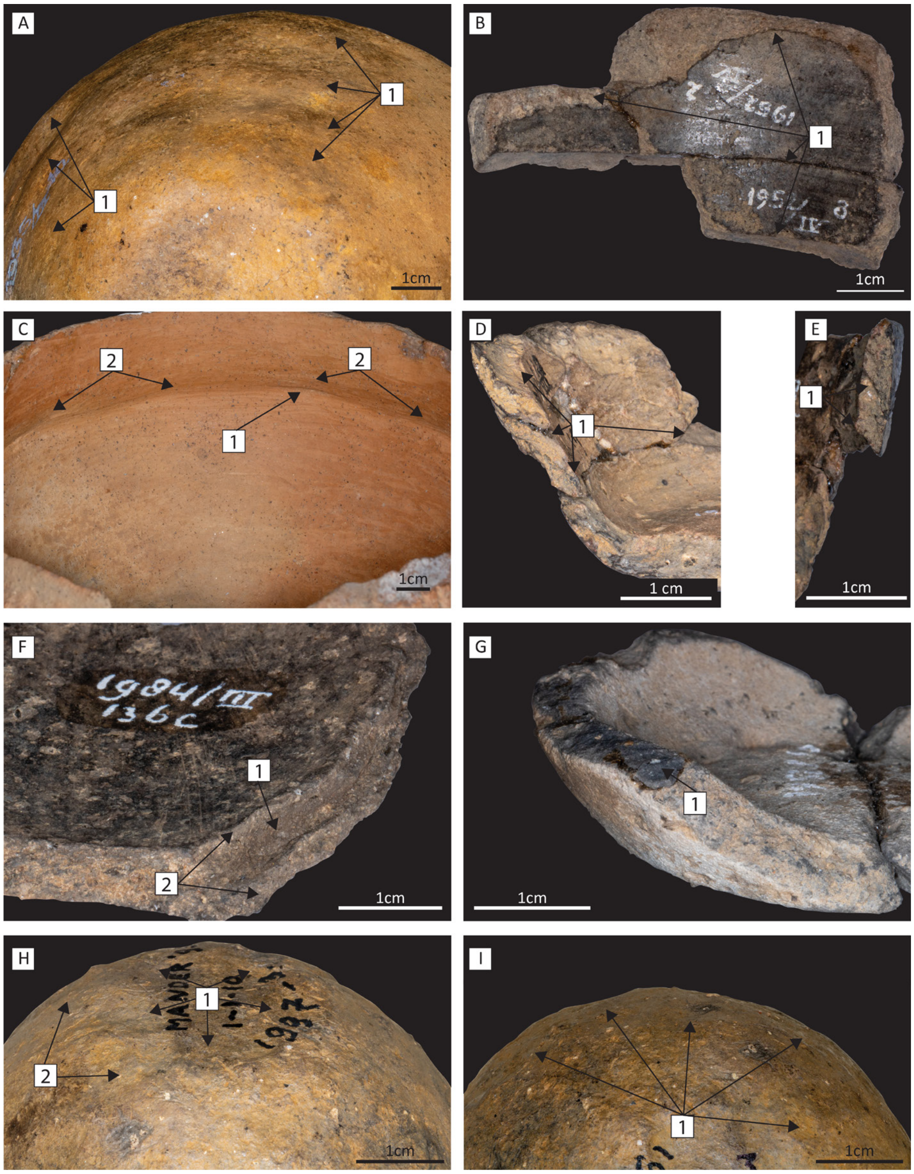
Roughing out of Vessel Walls

The next paragraphs summarise observations of roughing-out techniques in vessel walls. Two techniques occur: coiling and modelling, the former with five variants (see Tab. 6.2).

Coiling is the most frequent roughing-out technique for vessel walls in the Funnel Beaker West body of knowledge (see Tab. 6.2). Indicators for coiling include regular undulations in the vessel wall (see Fig. 6.4A), a horizontal breakage pattern (see Fig. 6.4B), as well as fissures in horizontal orientation (see Fig. 6.4C). Fissures are common on the interior surface near the transitions between the base, lower body, and upper body (e.g. Fig. 6.4C). These traces are generic indicators for the use of coiling techniques following the segment or ring procedure (cf. Roux 2019a pp. 160–1). Around half of the vessels only yield these generic indicators (see Tab. 6.2). The other vessels exhibit traces of the joining method through concentrations in cross-sections and/or break profiles (cf. Roux 2019a pp. 160–3).

	Subset	**Megalith inventories**		**Early flat graves**		**Late flat graves**		**Total (Funnel Beaker West)**	
Technique	Break profiles	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Coiling	Indeterminate	37	38.9	43	69.4	20	66.7	100	53.5
	Internal bevels	23	24.2	8	12.9	6	20	37	19.8
	Alternating internal and external bevels	8	8.4	3	4.8	1	3.3	12	6.4
	Flattened joints	5	5.3	2	3.2	0	0	7	3.7
	U-shaped joints	12	12.6	5	8.1	2	6.7	19	10.2
	External bevels	0	0	1	1.6	0	0	1	0.5
Modelling	None	13	13.7	3	4.8	1	3.3	17	9.1

Table 6.2 Roughing-out techniques for vessel walls. All percentages relative to the total number of vessels in megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30). Multiple techniques may occur in the same vessel. For coil joints, see Fig. 6.5.



The majority of the vessels with traces of coil joining methods has break profiles with internal bevels (see Fig. 6.4D; 6.5; Tab. 6.2). These breaks result coiling by pinching or spreading, whereby the potter applies pressure to the interior surface of the vessel to join the coils (cf. Roux 2019a p. 161). These traces appear in ca. 10-30% of vessels from megalith inventories, early flat graves, and late flat graves (see Tab. 6.2). Break profiles with external bevels (see Fig. 6.4E; 6.5A), which result from the same operation but with pressure applied to the exterior surface instead, are rare (see Tab. 6.2; Fig. 6.5A). However, around 10% of the vessels from megalith inventories, and ca. 5% of vessels from early and late flat graves exhibit traces of both joining methods (see Tab. 6.2; Fig. 6.4D-E; 6.5A). Most of these vessels are complex shapes (beakers and amphora-like vessels), and the breaks with internal bevels occur in the lower body, whereas breaks with external bevels occur in

Figure 6.4 (opposite page): Signs of roughing-out techniques in vessel walls: Coiling (A-G) and modelling (H-I). A: Rhythmic horizontal undulations (1), visible when viewed at an oblique angle from below, indicate the use of coils to shape the lower body of vessel 236. B: Horizontal breakage pattern (1) on the upper interior surface of vessel 114, which indicates the use of the coiling technique. C: Remnants of a horizontal fissure (1) on the interior shoulder of vessel 320 indicates the use of coiling. Furthermore, elongated finger-sized hollows in vertical direction (2) appear, which result from preforming by continuous pressure. D: The lower body of vessel 285 features a horizontal breakage pattern and breaks with internal bevels (1), indicative for the reworking of coil joints by pinching or spreading with internal pressure. E: The upper body of vessel 285 also features a horizontal breakage pattern, but the breaks have external bevels, which implies coiling by pinching or spreading with external pressure. F: A hollow break on vessel 302 with depressed centre (1) and raised edges (2), which indicates the joining of coils with little modification to the coil. G: A straight break on the lower body of vessel 113, implying the flattening of coils prior to joining. H: The base exterior of vessel 196 exhibits several finger-sized hollows in a circular pattern (1), and further hollows on the lower body (2). These traces indicate roughing out of the vessel wall through modelling. I: These hollows (1) also occur on the upper body of vessel 196 when viewed at an oblique angle, further indicating the use of modelling as roughing-out technique for the vessel wall.

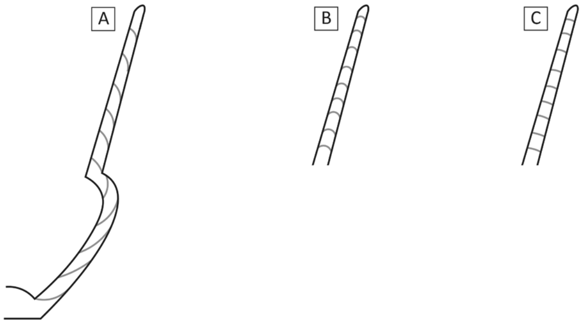


Figure 6.5: Schematic vessel profiles with different coil joints (in grey). A: Vessel profile with coils with internal bevels in the lower body, and external bevels in the upper body. Both coil joints result from joining by pinching or spreading but pressure is applied to the interior surface in the case of internal bevels and vice versa for external bevels B: coils with U-shaped joints, which result from coiling by pinching with minimal modification of the coils. C: Coils with flattened joints, which also result from coiling by pinching, but with some modification of the coil (cf. Roux 2019, p. 160-3).

the upper body. The transition between the two is often located on the shoulder, where a coil has been placed on the interior of the lower body, and subsequently reworked, leaving a distinct fissure (see Fig. 6.4C; Fig. 6.5A). This alternation of coil joining methods might be a construction method specific for complex shapes, as many of the vessels which only feature breaks with internal bevels are either open shapes or complex shapes with these breaks on the lower body (cf. Koch 1998).

Two further joining methods appear. Roughly 10% of the vessels from megalith inventories, early flat graves, and late flat graves exhibit U-shaped break profiles (see Tab. 6.2; Fig. 6.4F; 6.5B). This break profile result from minimal modification of the coils during coiling by pinching (cf. Roux 2019a p. 161, Fig. 3.26). A similar break profile, namely horizontal joints, occurs in ca. 5% of vessels from megalith inventories, and 3% of vessels from early flat graves (see Tab. 6.2; Fig. 6.4G; 6.5C). This break profile also results from coiling by pinching, but with flattening of the coil prior to stacking (cf. Roux 2019a p. 161,

Fig. 3.26). Straight break profiles also occur in the upper body of vessels with breaks which have break profiles with internal bevels in the lower body, as described above for breaks with internal and external bevels.

Whereas the majority of all Funnel Beaker West vessels yield indicators for the use of coiling, a small percentage of vessels lack these indicators (ca. 10% of vessels from megaliths, versus <5% of vessels from early and late flat graves, see Tab. 6.2). These vessels exhibit traces of modelling, in particular pinching. The indicators are finger-sized hollows which appear across the entire vessel surface, and stark fluctuations in wall thickness (see Fig. 6.4H-I; cf. Roux 2019a p. 168). This technique only appears in small bowls.

Preforming

Preforming techniques transform the rough-out of a vessel into its final shape (Roux 2019a p. 64). In addition to the traces of these techniques, the fashioning of separate elements such as base rings and handles is also discussed here. This combination is because both operations appear after roughing out, but before finishing in the specific *chaînes opératoires* (see below, cf. Roux 2019a p. 90).

Traces of two preforming techniques appear in the Funnel Beaker West body of knowledge: continuous pressure and scraping (see Tab. 6.3). These techniques may occur together on (different parts of) the same vessel.

Preforming by continuous pressure is most common in Funnel Beaker West specific *chaînes opératoires* (see Tab. 6.3). This technique involves exerting pressure on the vessel wall with hands while the vessel is wet. Key traces of this technique are elongated, finger-sized hollows which most frequently appear in vertical or diagonal orientation on the exterior shoulder, upper interior, and lower interior, as well as the rim area, and around the base ring (see Fig. 6.6A-D; 6.4C; cf. Roux 2019a pp. 66, 174–5). These traces can also occur on the lowermost exterior and create a protruding foot (see Fig. 6.6C).

The second preforming technique is scraping, which involves exerting pressure on wet clay with a hard tool with the aim of changing the profile of the vessel rough-out (cf. Roux 2019a pp. 63, 66, 174–5). Scraping can be hard to distinguish from other techniques which work wet clay surfaces with hard tools, especially if erosion and surface treatment come into play (see Fig. 6.6F). The following traces have been interpreted as evidence for

Subsets	**Megalith inventories**		**Early flat graves**		**Late flat graves**		**Total (Funnel Beaker West)**	
Technique	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Continuous pressure	95	98.9	62	100	30	100	187	100
Scraping	22	23.2	12	19.4	2	6.7	36	19.3
Perforation handle	14	14.7	16	25.8	6	20	36	19.3
Application base ring	9	9.5	10	16.1	11	36.7	30	16.0
Application handle	8	8.4	4	6.5	14	46.7	26	13.9

Table 6.3: Preforming techniques and attachment of separate elements in Funnel Beaker West ceramics (n=187). All percentages relative to the total number of vessels in a subset: Megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30). Various techniques may occur in the same vessel.

scraping. Firstly, there are bands of broad, deep striations with thickened edges (if the surface is unmodified after this operation). Secondly, the bases of these striations may also exhibit threaded or ribbed striations, and the microrelief must be irregular (see Fig. 6.6E-F; cf. Roux 2019a pp. 174–5). 22 vessels from megaliths, 12 vessels from early flat graves, and 2 vessels from late flat graves yield the above-mentioned traces (see Tab. 6.3).

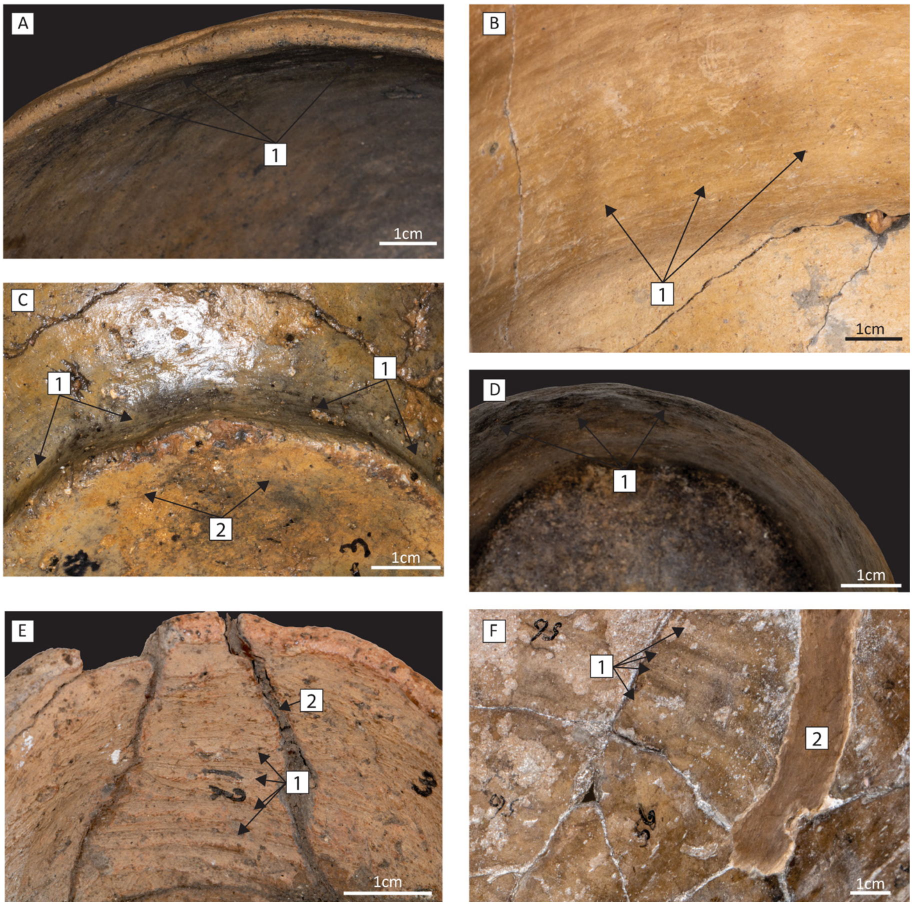


Figure 6.6: Traces of preforming techniques: Continuous pressure (A-D) and scraping (E-F). A: Traces of preforming by continuous pressures in the shape of elongated finger-sized hollows in vertical orientation (1) on either side of the rim of vessel 226. B: Elongated finger-sized hollows in vertical orientation (1), indicating preforming by continuous pressure. Photograph of the upper interior of vessel 192, just above the shoulder. C: Further traces of preforming by continuous pressure. Elongated finger-sized hollows on the lowermost exterior of vessel 197 (1), and on the periphery of the base exterior (2), creating a protruding foot. A consolidation agent causes, at least in part, the high gloss on the surface. D: The diagonal elongated finger-sized hollows (1) on the lower exterior of vessel 232 (viewed at an oblique angle from below) are traces of preforming by continuous pressure. E: Traces of scraping on the interior surface of vessel 245. The arrows indicate some of the deep, sub-horizontal striations with thickened edges and ribbed striations at the base (1). The grey mass in the breaks (2) results from modern conservation efforts. F: The upper interior of vessel 265 exhibits (possible) traces of scraping in the shape of deep striations (1) similar to those in 6.6E, but on a reworked and eroded surface. The darker areas might be remnants of thickened edges. The homogeneous brown mass (2) is coloured gypsum and part of a modern restauration.

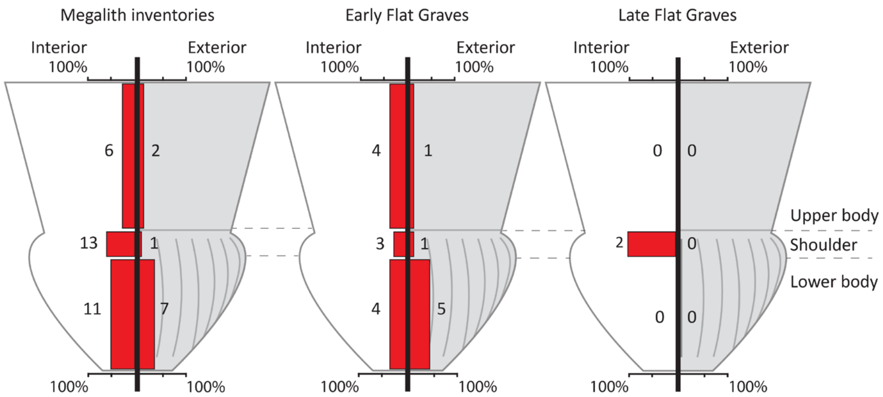


Figure 6.7: Schematic of the location of traces related to scraping in vessels from megalith inventories, early flat graves, and late flat graves. The width of the red bars indicates the percentage of vessels with traces of scraping in this location relative to the total number of vessels with traces of scraping in a subset (megalith inventories, n = 22; early flat graves, n=12; or late flat graves, n=2; see Tab. 6.3). The numbers at the end of the red bars indicate the absolute number of vessels with traces of scraping in this location.

Traces of scraping appear more often on certain vessel surfaces than others (see Fig. 6.7). Three patterns stand out. Firstly, interior and lower surfaces feature these traces more often than upper and exterior surfaces. A possible explanation for this pattern is the preferential application of finishing, decoration, and surface treatment to the better accessible (i.e. upper and exterior) parts of vessels (see hence). Each of these subsequent operations can obliterate traces of prior operations. As such, the exact figures in Fig. 6.7. should be interpreted with care.

The second pattern is the preferential application of scraping on the interior shoulder (see Fig. 6.7). This pattern might partially result from the poor accessibility of this zone during subsequent operations, but could equally well indicate a targeted technical procedure, which relates to the change in the orientation of coil joints in this area (see roughing out).

The last pattern is the frequent appearance of traces of scraping on the lower exterior of vessels from megalith inventories and early flat graves (see Fig. 6.7). The cause of this pattern is the preferential application of scraping to the lowermost exterior surfaces, just above the protruding foot, of these ceramics.

Fashioning of Handles and Base Rings

The fashioning of attachments such as handles and base rings is discussed together with traces of preforming techniques here because traces from subsequent stages of the *chaîne opératoire* (i.e. finishing and decorative techniques) often cross-cut fashioning traces on these attachments (see Fig. 6.8). Therefore, these operations are performed towards the end of the preforming stage.

The technical traces on these attached elements point towards the use of two production methods, labelled ‘perforation’ and ‘application’ in Table 6.3 (cf. Roux 2019a pp. 90–1).

The perforation method consists of perforating the vessel wall, plugging this perforation with a clay mass, and modelling and/or perforating this mass to create a handle. A second coil may be placed around the joint between the handle and the wall to reinforce it. This procedure leaves a number of traces. The plug and reinforcement mass appear as separate and are surrounded by voids if a break runs across the attachment point, or the handle comes loose (see Fig. 6.8A&C). The plugging may also leave a circular fissure or over-thickness on the interior surface of the vessel opposite of the attachment point (Fig. 6.8D-E). The application of an additional clay mass to reinforce the handle can form a local over-thickness surrounding the attachment point (see Fig. 6.8C). Finger-sized hollows on the handle indicate shaping through a pinching operation (cf. Fig. 6.8G-H). The perforations in handles always exhibit irregular microrelief at the bases, and sometimes striations with thickened edges (see Fig. 6.8F). Therefore, the perforations were likely performed on wet clay. A biberon (vessel 323) exhibits a special case of this procedure: a fissure around the perforation in the wall indicates the plug was a tubular clay mass which also formed the characteristic hollow handle (see Fig. 6.8E). Handles fashioned through the perforation method appear in megalith inventories (n=14), early flat graves (n=16), and late flat graves (n=20; see Tab. 6.3).

The second technique for the fashioning of handles is the application of a clay mass. This procedure appears in 8 vessels from megalith inventories, 4 vessels from early flat graves, and 14 vessels from late flat graves (see Tab. 6.3). These handles consist of clay masses applied against the surface of a vessel solely through pressure, and may be modelled and sometimes perforated afterward. The clay mass is a localised over-thickness, which can exhibit fissures at the attachment point (Fig. 6.8G-H). Traces of a plug (see above) are absent. If the handle itself has been perforated, the traces of the perforation are identical to those described above, and therefore also result from an operation on wet clay. Some handles combine both application methods: they have traces of a plug on one end, and traces of application on the other (e.g. Fig. 6.8A-B).

Apart from handles, base rings are also applied elements. Base rings consist of one (or more) coil(s) applied below the main mass of the base. Common traces of this action are 1) relic coils visible in cross-sections of the base; 2) a distinct, protruding ring; as well as 3) fissures between the exterior of the base and the base ring, and between the lower exterior body and base ring (see Fig. 6.2D-E). The base rings can also feature breaks with internal bevels, similar to those described under roughing out. 9 vessels from megalith inventories, 10 vessels from early flat graves, and 11 vessels from late flat graves exhibit a base ring (see Tab. 6.3).

Finishing

Finishing techniques modify the vessel surface after roughing out and preforming (cf. Roux 2019a p. 92). Traces from this stage are rare on Funnel Beaker West vessels due to extensive surface treatment (see hence). Traces of finishing often only survive in small areas which escaped surface treatment (see Fig. 6.9A). Consequently, patterns in the distribution of these traces likely result from preferential preservation rather than preferential application (see also scraping).

The vast majority of Funnel Beaker West vessels (n=171) exhibit traces of finishing with a soft tool on wet clay (see Tab. 6.4). These traces include surfaces with an irregular microtopography with protruding particles, matt aspect, and striations with threaded or ribbed edges (see Fig. 6.9B-C; cf. Roux 2019a pp. 196–7). These surfaces may exhibit more ribbed striation and partially covered, protruding particles if water was added during the

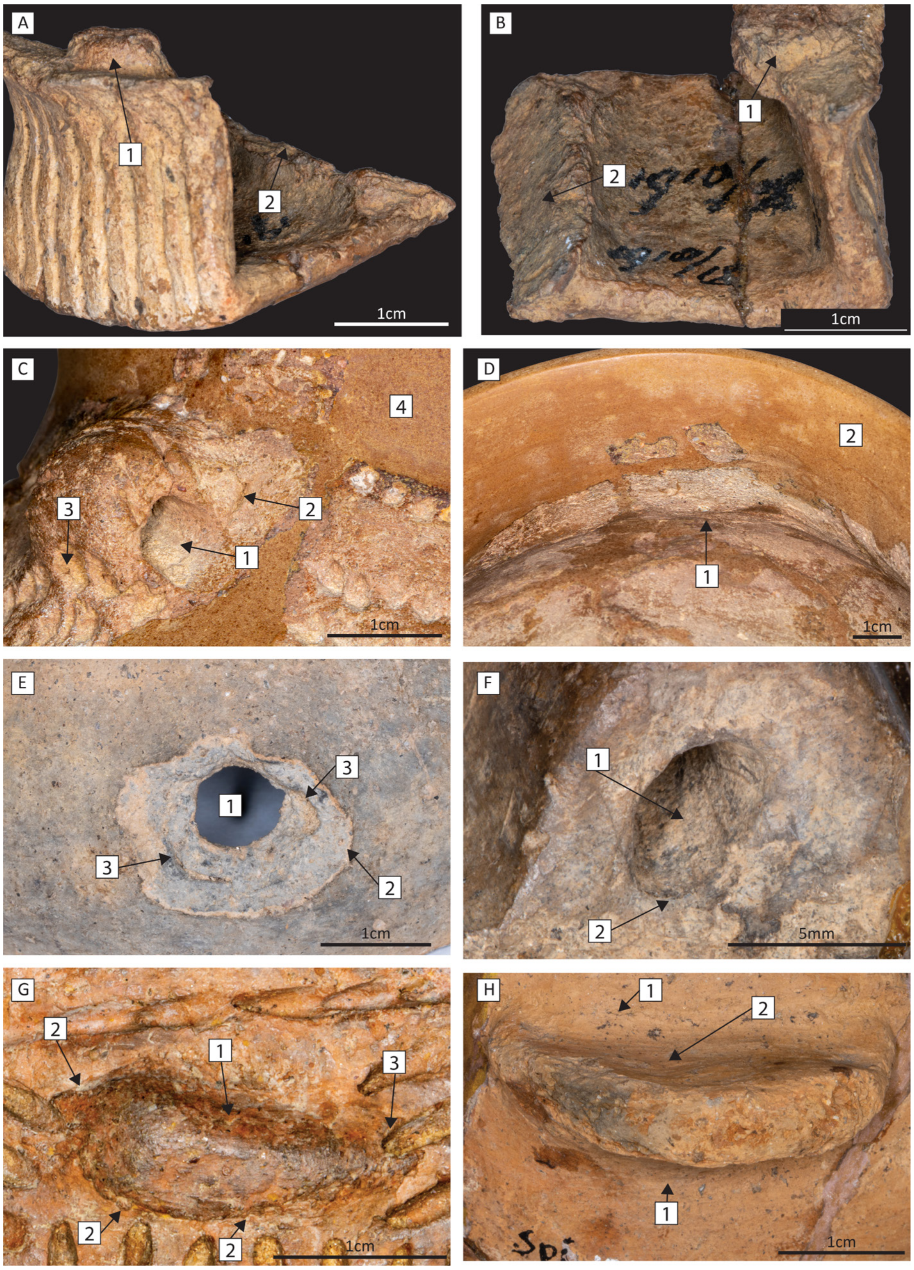

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Figure 6.8 (opposite page): The fashioning of handles: Traces of application by perforation of the vessel wall (A-E), application by pressure (A-B, G-H), and subsequent actions such as perforation of the handle (C, F). A: The handle of vessel 188 exhibits the remnants of a plug on the rim-facing part with signs of a clay mass smoothed against the wall surrounding it (1). This part was applied through a perforation in the vessel wall. The other part of the handle exhibits a flat surface on the lower attachment point (2), which is typical for handles applied through pressure alone. B: Alternate view of the same handle on vessel 188 shows the plug (1) and, in more detail, the flattened lower part (2). C: The handle of vessel 233 exhibits a perforation (1); an over-thickness in the area surrounding the attachment point of the handle indicates the presence of an additional clay mass to reinforce the joint with the wall (2); decorative impressions cut across the handle and over-thickness (3). The brown masses are modern, coloured gypsum used to complete the refit (4). D: The interior surface opposite of the handle on vessel 233 bulges sharply (1), likely due to the presence of a plug. Modern, coloured gypsum is also present on this side (2). E: A biberon (vessel 323), which lacks its characteristic hollow handle (see Fig. 2.7), features a round perforation in the vessel wall (1), surrounded by shallow break at the attachment point of the handle (2). The break exhibits a ring fissure (3), which indicates the applied mass was a tube-like structure. F: The perforation on the handle of vessel 268 shows striation with irregular microrelief and ribbed striation at the base (1), as well as thickened edges (2), which were reworked during surface treatment along with the remainder of the vessel surface (see surface treatment). These traces indicate the clay was plastic during the making of the perforation. G: An applied handle on vessel 4 shows finger-sized hollows from shaping, and an irregular fissure at the application point (2). Decorative impressions with a conical tool cut across the mass of the handle (3). H: The handle of vessel 258 exhibits a similar irregular fissure near the attachment point (1), as well as finger-sized hollows from a shaping operation (2).

Smoothing	**Subset**	**Megalith inventories**		**Early flat graves**		**Late flat graves**		**Total (Funnel Beaker West)**	
Hydric state	Tool	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Wet clay	Soft tool	84	88.4	59	95.2	28	93.3	171	91.4
	Hard tool	14	14.7	4	6.5	3	10	20	10.7
Leather-hard clay	Soft tool	1	1.1	0	0	0	0	1	0.5

Table 6.4 Finishing techniques in vessels from megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30) vessels (total = 187). A vessel from a megalith (vessel 245) has been excluded from this table as it yielded no traces of processes in between preforming and surface treatment. Actions with hard and soft tools may co-occur on the same vessel.

smoothing process (see Fig. 6.9C; cf. Roux 2019a pp. 196–7). Common locations for these traces are surfaces on and around the base interior and lower interior, but isolated zones may appear on all other vessel surfaces.

A small amount of Funnel Beaker West vessels (n=20) exhibits traces of a smoothing operation with a hard tool on wet clay (see Tab. 6.4). The surfaces are comparable in most respects to those smoothed by soft tools while wet, but in addition feature shallow striations with thickened edges which end on over-thicknesses from movement of the wet paste (see Fig. 6.9D-E; cf. Roux 2019a pp. 196–7). The percentage of vessels with these traces varies between megalith inventories (14.7%), early flat graves (6.5%), and late flat graves (10%; see Tab. 6.4).

Two vessels in the Funnel Beaker West body of knowledge stand out as exceptions in terms of finishing. Firstly, vessel 245 exhibits no traces of finishing techniques, but only of scraping (see Fig. 6.6E; 6.12F). Secondly, vessel 324 exhibits traces of smoothing with a soft

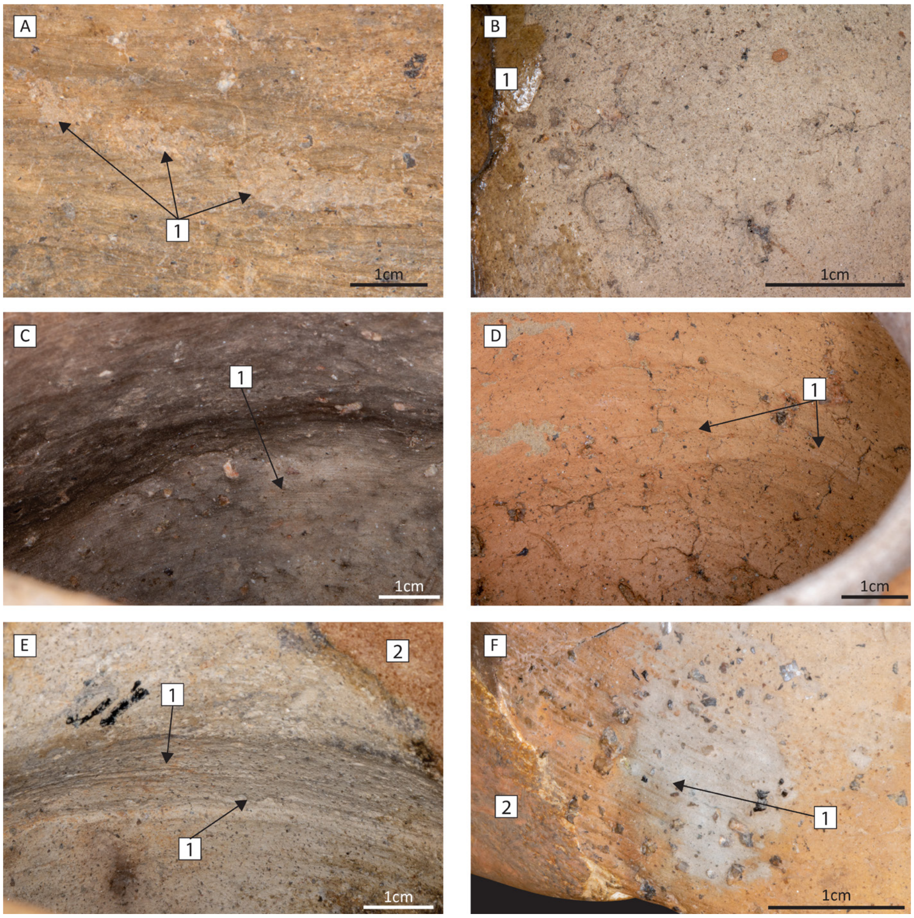

Figure 6.9: Traces of finishing techniques: Preservation of traces (A), smoothing wet clay with a soft tool (B-C), and a hard tool (D), as well as smoothing leather-hard clay (F). A: An unburnished zone on the upper interior surface of vessel 250 which exhibits an irregular microtopography, protruding particles, and matt aspect (1). This likely indicates wet smoothing. Evidence for finishing techniques often derives from such small zones in otherwise reworked areas. B: Signs of wet smoothing with a soft tool on the lower interior surface of vessel 344, primarily an irregular microtopography, protruding particles, and a matt aspect. Modern glue covers part of the vessel, causing high gloss and a seemingly compact surface (1). C: The surface on the shoulder interior of vessel 214 was smoothed while wet with additional water. This operation resulted in an irregular microtopography, ribbed striations in parallel horizontal orientation (1), and partially covered, protruding particles. D: The lower interior surface of vessel 283 was smoothed while wet with a hard tool, possibly with added water. The surface has a matt aspect, irregular microtopography, partially covered, protruding particles with star-shaped cracks, and striations with thickened edges (1). E: The shoulder interior of vessel 254 is similar to D, but with more pronounced striations with thickened edges (1), and protruding coarse fraction. Likely as a result of smoothing wet clay with a hard tool. The vessel was refitted with coloured gypsum (2). F: A zone on the upper exterior surface of vessel 324 may have been smoothed while leather-hard. The surface has a protruding, partially covered coarse fraction with ribbed striation on a regular, somewhat compact, microtopography (1). Vessel partially supplemented with coloured gypsum during restauration (2).

tool on a leather-hard surface. This interpretation is tentative because these traces only survive on a small section of the upper exterior. This surface is matt, but has relatively compact microtopography with ribbed striations trailing partially covered, protruding particles (see Fig. 6.9F). These traces indicate the smoothing of a leather-hard clay with a soft, wet tool (cf. Roux 2019a Fig. 3.54).

Decoration

Funnel Beaker West ceramics exhibit great variation in terms of decorative techniques (see Tab. 6.5). Three general conclusions about this stage of the production process precede the in-depth discussion of technical traces.

Firstly, the variation in decorative techniques (see Tab. 6.5), and tools used for these techniques (see Tab. 6.6) differs between megalith inventories, early flat graves, and late flat graves. Megalith inventories are most varied in terms of decorative techniques: simple impressions, simple incisions, excisions, and incrustations all feature (see Tab. 6.5). Megalith inventories also show most variation in tools used for decorative techniques (see Tab. 6.6), and the lowest percentage of undecorated vessels (ca. 25%, see Tab. 6.5). Crucially, this variation decreases in all respects in vessels from early and late flat graves. The percentage of undecorated vessels is higher in these subsets (ca. 40-50%, see Tab. 6.5) than in megalith inventories. Moreover, all decorative techniques and tools feature less frequently; only the most frequently found techniques (i.e. simple (oblique) impressions and simple incisions) and tools (i.e. conical tools) in megalith inventories occur in substantial percentages on vessels from early and late flat graves (see Tab. 6.5, Tab. 6.6). In

Subset		**Megalith inventories**		**Early flat graves**		**Late flat graves**		**Total (Funnel Beaker West)**	
Technique	Specification	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Simple incisions	Wet clay (see Fig. 6.10C)	25	26.3	8	12.9	4	13.3	37	19.8
	Leather-hard clay (see Fig. 6.10D)	2	2.1	0	0	0	0	2	1.1
Simple impressions	Various tools (see Tab. 6.6; Fig. 6.11)	8	8.4	0	0	4	13.3	12	6.4
Simple oblique impressions	Various tools (see Tab. 6.6; Fig. 6.11)	55	57.9	23	37.1	8	26.7	86	46
Tilted impressions	Spatula (see Fig. 6.10F)	0	0	2	3.2	0	0	2	1.1
Applique (see Fig.6.11G)		0	0	1	1.6	1	3.3	2	1.1
Excisions	Wet (see Fig. 6.10E; 6.11I-J)	13	13.7	3	4.8	1	3.3	17	9.1
	Leather-hard (see Fig. 6.10H)	3	3.2	0	0	0	0	3	1.6
Incrustation (see Fig. 6.10I)		8	8.4	2	3.2	0	0	10	5.3
None detected		24	25.3	30	48.4	16	53.3	70	37.4

Table 6.5: Decorative techniques in vessels from megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30; total = 187). Multiple techniques can occur on the same vessel. All percentages relative to the total number of vessels from the respective subset.

		Simple Oblique Impressions			Simple impressions		
Tool		**Megalithic inventories**	**Early flat graves**	**Late flat graves**	**Megalith inventories**	**Early flat graves**	**Late flat graves**
Description	Figure	*n*	*n*	*n*	*n*	*n*	*n*
Conical	6.11B	42	19	5	1	0	0
Stump	6.11D	8	4	1	4	0	1
Flat round	6.11C	9	3	1	1	0	0
Spatula	6.11F	2	0	1	0	2	3
Pronged	6.11G	2	1	0	1	0	0
Hollow	6.11E	1	0	0	1	0	1
Maggot	6.11H	0	1	0	0	0	0
Triangular	6.11A	1	0	0	0	0	0

Table 6.6: Overview of the tools used in simple impressions and simple oblique impressions in Funnel Beaker West ceramics. No percentages are reported because the absolute values are relatively low. Impressions from multiple tools can appear on one vessel.

Figure 6.10 (opposite page): Decorative techniques in Funnel Beaker West ceramics. Position of the vessel (A-B), simple incisions (C-D), excisions (E, H), tilted impressions (F), application (G), and incrustation (I). A: The location of decorative incisions (1) near the base, and angle of insertion for the simple impressions (2) on the vessel wall is such that the vessel was likely placed upside down, or held at an angle during decoration, as tools would not be able to reach these locations at these angles with the vessel in an upright position. This vessel (ID: 246) was also refit with coloured gypsum (3). B: The position of the camera is directly above the deepest point of the simple oblique impressions (1) of vessel 4, showing the angle of insertion was likely from the base towards the rim with the vessel either held upside down or at an oblique angle. C: The incisions on vessel 266 show well-developed thickened edges (1), irregular microrelief, and ribbed striation at the base (2). These indicate simple incisions on wet clay. The vessel was refit with coloured gypsum (3). D: The incisions on vessel 275 show no thickened edges, although the surface was likely reworked (1), and regular, compact microrelief at the bases (2) with some sand in the recesses which adheres to glue from the refitting procedure (3). These simple incisions likely occurred on leather-hard clay. E: Complex decorated field on vessel 268 created by layering various decorative techniques. Key are the simple impressions (1) which cut across excisions with thickened edges (2) and striated bases (3). Surface treatment reworked all edges (4), and some glue is present from the refit (5). F: Tilted impressions on vessel 226 with thickened edges (1) and impressions of the tool at the bases (2). The lines undulate due to movement of the tool. G: An applied cordon is visible as an over-thickness (1) with fissures at the attachment point (2) on the exterior shoulder of vessel 221. The cordon is interrupted by the handle (3). Excisions are visible further down (4), as well as modern, coloured gypsum from refitting (5). H: Excisions on vessel 241 which exhibit bases with a compact, regular microrelief (1) typical for an operation on leather-hard clay. Surface treatment resulted in reworked edges (2). I: Vessel 270 is another example of layered decorations, as well as incrustation. A line of (possibly) simple incisions (1) is cross-cut by simple oblique impressions (2), and white powdered mass from an incrustation fills these depressions (3).

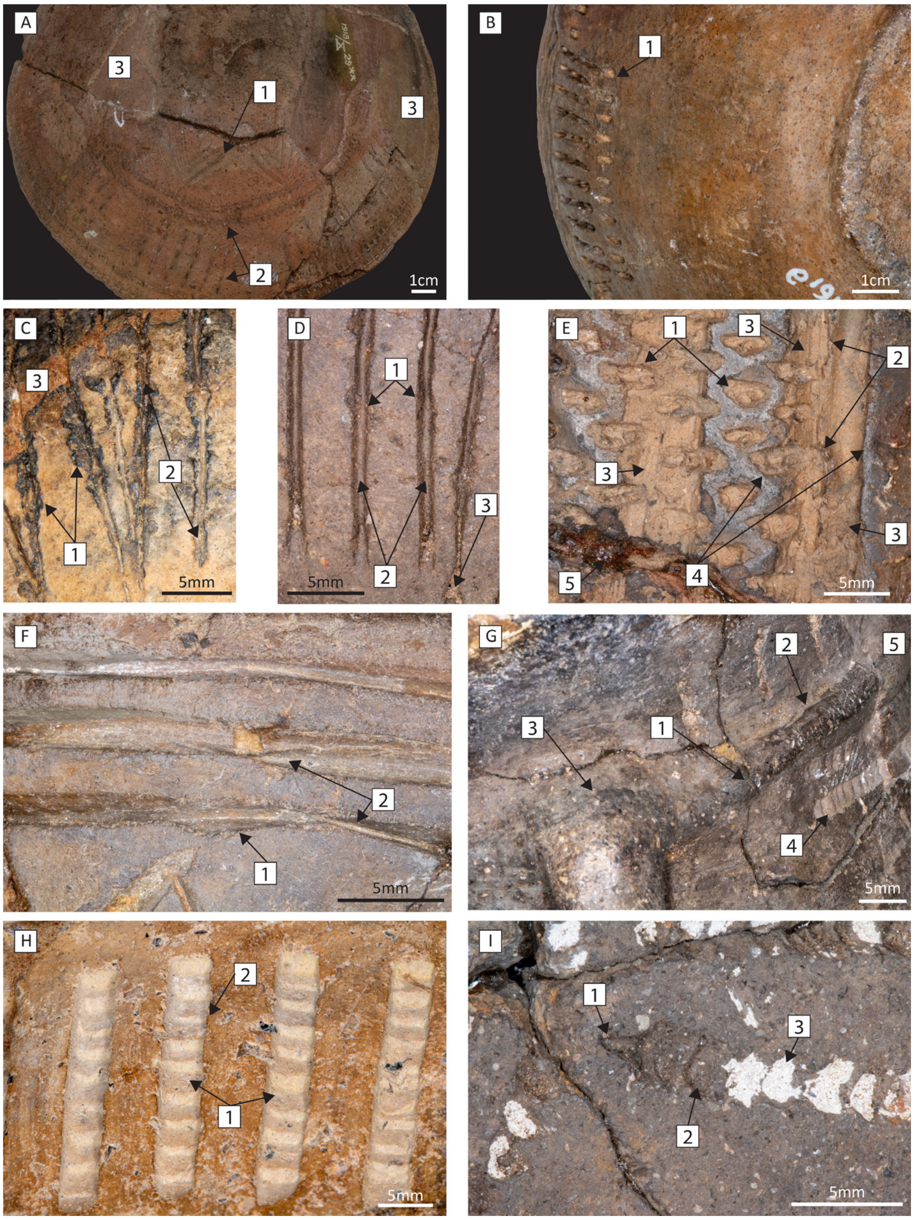
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Figure 6.11 (opposite page): Impressions and excisions with various tools, and with schematic representations of the tools below each image. A: Simple oblique impression with a triangular tool on vessel 260. B: Dense field of simple oblique impressions with a conical tool on vessel 1. C: Simple oblique impressions with a flat round tool on vessel 33 forming vertical lines with imprints of the tools at the base. Gloss on the surface due to modern consolidating agent. D: Simple oblique impressions with a stump tool set into (probable) simple incisions on vessel 192. E: Simple impressions with a hollow tool on vessel 340. The centre of the impression is raised relative to the periphery. F: Simple impressions with a spatula on the handle of vessel 251. G: Simple oblique impressions with a pronged tool on vessel 114. The tip of the tool had two raised surfaces and a depressed centre, leaving a horseshoe-shaped depression on the vessel. Light surface erosion in this area of the vessel. H: Impressions with a maggot-like tool on vessel 233. The depressed areas feature several ridges which divide the impression into multiple bulbous bands. The vessel surface is eroded in this area. Panels I and J show tools employed in excisions. I: A gouge-like tool with a crescentic, flat edge applied in a discontinuous motion on vessel 305. J: Vertical lines of excisions with a gouge-like tool with a straight, flat edge on vessel 224.

other words, the application of decorative techniques becomes more standardised from megalith inventories to early and late flat graves.

Secondly, the location of decoration on Funnel Beaker West vessels on the lower body, and the angle of insertion of the tools, suggest these vessels were held at an oblique angle, or placed upside down while decorating (see Fig. 6.10A-B). Further evidence for this upside-down positioning of vessels during parts of the production process derives from surface treatment (see below).

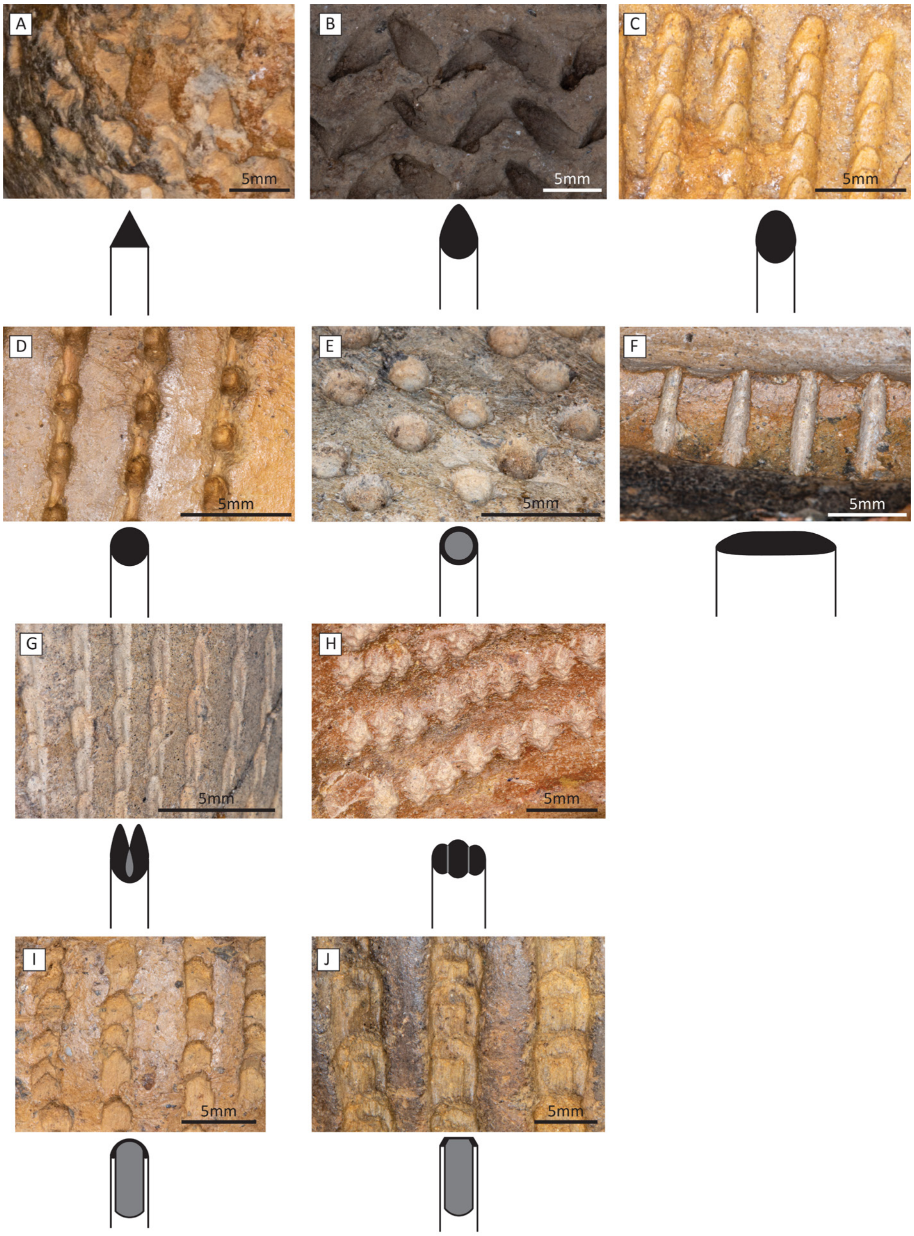
Thirdly, Funnel Beaker West ceramics often feature ‘layered’ decorations. Potters superimpose various decorative techniques, or multiple iterations of the same technique with different tools, in the same area. This creates decorations which can be complex to disentangle or record (e.g. Fig. 6.10E, see also Fig. 6.1B).

Following the general conclusions about decorative techniques in Funnel Beaker West vessels above, let us explore the tools and decorative techniques in the next paragraph.

The most common decorative techniques are simple impression and a variant of this technique: simple oblique impression. ‘Simple’ refers to the gesture, which only consists of the insertion and extraction of a tool (cf. Roux 2019a p. 106, contrast tilted impressions). The difference between simple impressions and simple oblique impressions is the angle of insertion. The angle of insertion is perpendicular to the vessel wall in simple impressions, and oblique in simple oblique impressions.

Simple oblique impressions are the most common decorative technique, appearing on 55 vessels from megalith inventories, 23 vessels from early flat graves, and 8 vessels from late flat graves (see Tab. 6.5). Simple impressions are less common, occurring in 8 vessels from megalith inventories, and 4 vessels from late flat graves (see Tab. 6.5; Fig. 6.11E). As a rule, the bases of the impressions have irregular microrelief and thickened edges may occur, hinting at an application on wet clay (see Fig. 6.10E; 6.11; cf. Roux 2019a pp. 204–5). In some cases, the microrelief of the bases may appear more compact, which might indicate a drier, but still plastic clay (e.g. Fig. 6.11C, cf. Roux 2019a pp. 204–5). If surface treatment occurs, the edges of the impressions are often reworked (see Fig. 6.10E; 6.10I), which means decoration occurred prior to surface treatment regardless of the state of the paste.

The tools employed in simple (oblique) impressions are varied (see Tab. 6.6). These tools are classified below by the shape of the impressions they left on the vessels.



The most used decorative tools sit on a continuous spectrum. Triangular tools form one end of this spectrum. As the name indicates, triangular tools have flat tips which taper sharply (see Fig. 6.11A). Simple oblique impressions with a triangular tool occur only once on a vessel from a megalith inventory (see Tab. 6.6). The spectrum then continues with conical tools, which are the most used tool group (see Tab. 6.6). These tools have sharply tapering tips like triangular tools, but a more rounded cross-section. Their use results in tear-shaped depressions (see Fig. 6.11B). Conical tools feature most often in simple oblique impressions. The impressions often form dense clusters in linear arrangements (e.g.

Fig. 6.1). The other end of the spectrum consists of flat round tools, which are the third most common group of tools (see Tab. 6.6). These tools often have a rounded diameter, but the tip has a flat, more rounded edge (see Fig. 6.11C). This tool group resembles the gouge-like tools used for some of the excisions (see below).

The second most common tool group are stump tools (see Tab. 6.6). Stump tools resemble conical tools in their rounded diameter (square diameters are rare), but have a flat or slightly bulging tip rather than a tapering tip (see Fig. 6.11D). This group features more often on vessels from megalith inventories than vessel from flat graves (see Tab. 6.6).

The next tool group are the spatulae. This name refers to a comparatively large tools with an elongate, blunt edge of which one side is usually rounded and the other flat (see Fig. 6.11F). Impressions of this tool type occur most often in ceramics from late flat graves (see Tab. 6.6).

By contrast, the pronged tools are most common in ceramics from megaliths (see Tab. 6.6). Pronged tools are a heterogeneous category of tools which share a characteristic edge with multiple protruding elements. For example, two conical tips (see Fig. 6.11G).

The penultimate tool group are hollow tools. These tools usually have rounded, tubular tips which leave negative impressions on the vessel wall (see Fig. 6.11E). These tools feature in ceramics from megaliths and late flat graves (see Tab. 6.6).

The last tool group occurs only once in a vessel from an early flat grave (see Tab. 6.6). The label of this group is 'maggot-like': the tool left three bulbous impressions with two smaller impressions flanking a larger one (see Fig. 6.11H). Parallels for this tool exist in Funnel Beaker North (cf. Koch 1998 no. 219 on 'treble stamps').

The second most common decorative technique is simple incision (cf. Roux 2019a p. 107 for a definition). The simple incisions on Funnel Beaker West ceramics show signs of application to wet and leather-hard clay. The distinction between these states depends on the microrelief of the incision. The occurrence of thickened edges, and bases with an irregular microrelief and threaded or ribbed striations indicate incisions on wet clay (see Fig. 6.10C); whereas striations with compacted microrelief and scalloped edges indicate incised leather-hard clay (see Fig. 6.10D; cf. Roux 2019a pp. 204–5). Simple incisions on Funnel Beaker West vessels can be hard to distinguish from continuous simple impressions. The distinction here depends on the presence of impressions from the tooltip at regular intervals (see Fig. 6.1B). Unfortunately, incisions often had simple (oblique) impressions set into them (e.g. Fig. 6.11D), meaning their detection partially depends on the density of these later impressions.

Simple incisions on wet clay occur in several vessels from megalith inventories (n=25), whereas incisions on leather-hard clay are rare in these contexts (n=2; Tab. 6.5). Simple incisions on wet clay occur on only eight vessels from early flat graves, and none of these vessels yield traces of simple incision on leather-hard clay (Tab. 6.5). Four vessels from late flat graves exhibits traces of simple incisions applied to wet clay (see Tab. 6.5).

The third most common decorative technique is excision. This technique involves removing material from the vessel wall to create decorative depressions (cf. Roux 2019a p. 108 for a definition). Excisions and simple oblique impressions can be difficult to distinguish in Funnel Beaker West ceramics because both appear as linear arrangements of deep depressions with tool marks at regular intervals. The distinction here depends on the detection of undercut sections of the vessel wall which remained in place as the gouge-like tool was extracted. Following this criterion, excisions occur almost exclusively on ceramics from megaliths (n=16), and in some vessels from early flat graves (n=3), and late flat graves (n=1). The gouge-like tools used to make these excisions either have rounded or square edges (see Fig. 6.11I-J). The excisions were applied to wet and leather-hard pastes (see Fig. 6.10E; H-I; 6.11I-J; contra Roux 2019a pp. 108, 204). The excisions on leather-hard paste exhibit bases with compact, regular microrelief, except for the irregular area where clay material was extracted (see Fig. 6.10H). The excisions on wet clay exhibit bases with an irregular microrelief, which may exhibit threaded ribbed striations, as well as thickened edges. Furthermore, simple (oblique) impressions can be set into these excisions (see Fig. 6.10E). This implies the excisions were made in wet clay, because impressions can only be made on wet clay (Roux 2019a pp. 106, 204).

The fourth most common decorative technique is incrustation (cf. Roux 2019a p. 108 for a definition; see Tab. 6.5). Incrustations take the form of a powdered white mass in depressions on the exterior surface. These depressions result from other decorative techniques (see Fig. 6.10I). The total number of vessels with incrustation is an absolute minimum for two reasons. Firstly, the preservation of the heated and crushed bone which makes up the incrustations is poor in the acidic, sandy environment of Funnel Beaker West contexts (see Section 2.1). Secondly, vessels which exhibit traces of a white powdered mass in depressions along with signs of a modern restauration with gypsum have been treated with extreme caution. The origins of the white mass in depressions are uncertain in these cases, and only those vessels for which the texture of modern gypsum clearly differed from that of the potential bone paste have been included. Following these criteria, incrustations appear in 8 vessels from megalith inventories, and 2 vessels from early flat graves (see Tab. 6.6).

Incrustations are difficult to situate within specific *chaînes opératoires*. This paragraph extrapolates several observations on well-preserved vessels to pin down the general position of incrustations in Funnel Beaker West ceramic production. The application of incrustations logically post-dates that of any impression or excision. Surface treatment on leather-hard surfaces follows the application of decorative techniques in most specific *chaînes opératoires*. In vessels which combine burnishing and incrustation, the decorative depressions exhibit reworked edges from surface treatment (e.g. Fig. 6.10H). Therefore, incrustations either did not hinder this effect of surface treatment or occurred afterward. More importantly, in all vessels with incrustations (including vessel 270 which was subjected to smudging after firing, see Fig. 6.10I) the colour of the bases of the decorative depressions is similar to the surface colour of the vessel as a whole, regardless of the incrustations. This implies the presence of the incrustation either did not hinder the chemical reactions which caused the surface colours or that the incrustations post-date the firing (and smudging) processes. Given these observations, it is more likely that incrustations were generally applied after firing and smudging, than that they preceded surface treatment and/or firing but did not affect the outcomes of either procedure. This assumption is applied to all specific *chaînes opératoires* in the probabilistic comparisons in Chapter 10. However, experiments should ideally be performed to verify this assumption.

The penultimate decorative technique is tilted impression. Tilted impressions are similar to simple impressions, but the tool is shifted between insertion and extraction (cf. Roux 2019a p. 106). Two vessels from early flat graves exhibit traces of tilted impressions (see Tab. 6.5). The tool appears to have been a spatula which was used to create a horizontal line. As a result of the tilting, the line consists of several tell-tale arcs with impressions of the spatula at the base (see Fig. 6.10F).

The last, least detected, decorative technique is application, which appears in one vessel from early flat graves, and one vessel from late flat graves (see Tab. 6.5). The applied masses are cordons which are visible as local over-thicknesses on the vessel surface with fissures near the point of attachment (see Fig. 6.10G; cf. Roux 2019a p. 109). These decorative applications are distinct from those for handles because there are no signs of modelling and perforations which are common in the fashioning of handles (see preforming). Decorative applications occur prior to other decorative techniques in specific *chaînes opératoires*, as other decorative techniques cut across the applied clay masses (see Fig. 6.10G).

Surface Treatment

Surface treatment techniques are operations which modify the appearance of the vessel surface. Roux (2019a pp. 98–101) distinguishes various techniques, three of which occur in Funnel Beaker West body of knowledge: burnishing, shining, and smudging. Surface treatment is common in Funnel Beaker West, occurring in ca. 90% of all vessels (see Tab. 6.7). Proper detection of surface treatment techniques ideally involves optical microscopy, but this could not be performed due to time constraints. Therefore, the interpretations below are kept at a generic level.

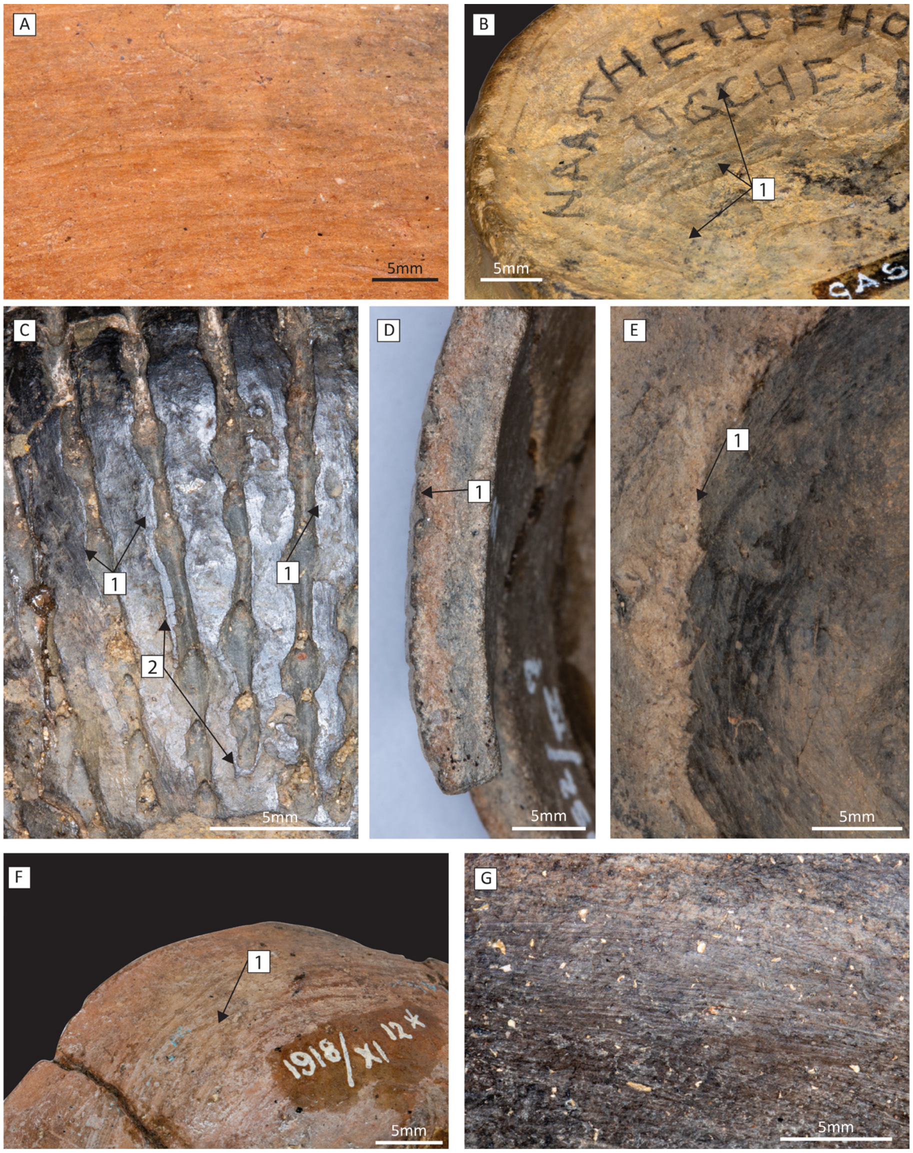
Burnishing is by far the most common form of surface treatment on Funnel Beaker West vessels (megaliths n = 81; early flat graves n = 55; late flat graves n=28; see Tab. 6.7). Burnishing involves rubbing a hard tool against leather-hard or dry clay (Roux 2019a pp. 201–2). The traces interpreted as signs of burnishing are: 1) a compact microtopography of the surface, 2) high gloss, 3) inserted particles, and 4) the presence of parallel bands of striations with compact microrelief, and scalloped or regular edges (see Fig. 6.12A-C). Funnel Beaker West vessels commonly exhibit striations with scalloped edges, which likely indicates burnishing took place while the clay was in a soft leather-hard state (cf. Lepère 2014). The exterior and upper interior surfaces most often feature traces of burnishing, but traces are still common on interior surfaces (see Fig. 6.13). The typical striations are most often in sub-horizontal orientations on

Figure 6.12: Surface treatment techniques: Burnishing (A-C), smudging (D-E), shining (F), and potentially softening (G). A: Traces or burnishing on the interior surface of vessel 237, namely a compact microtopography, inserted particles, gloss, and parallel horizontal striations with scalloped edges. B: Burnished base exterior of vessel 311 with striations with scalloped edges (1), compact microrelief, gloss, and inserted particles. The presence of these traces on the base exterior indicates the vessel was upside down for part of the production process. C: The lower exterior of vessel 211 shows signs of burnishing on stiff leather-hard clay. There is vertical striation with regular edges (1), gloss, and compact microtopography with inserted particles. The edges of simple oblique impressions with a conical tool have been reworked (2). D: Evidence for smudging in vessel 114. The breaks show a dark grey layer overlying the oxidised red-brown outer margin, likely as a result of smudging. E: Similar evidence for smudging on the lower interior of vessel 303. A break reveals the dark grey inner surface overlies a red-brown, oxidised margin of the core, which indicates smudging F: The exterior surface of vessel 245 was subjected to shining. This surface exhibits traces of scraping similar to the interior (1; see Fig. 6.6E), but these are notably smoothed down on the exterior surface. The depicted surface also has a more compact microtopography with inserted particles and a slight gloss. G: The exterior shoulder of vessel 219 falls into an anomalous category, and may have been subject to softening: The surface has a compact microtopography, glossy appearance, and inserted particles, but ribbed striation also appears.

all surfaces, except for the lower exterior and decorated fields. Striations in the latter areas may appear in a vertical direction (see Fig. 6.12C). This indicates potters worked with different motions depending on the vessel part.

A substantial portion of the vessels from megalith inventories (n=32), early flat graves (n=25), and late flat graves (n=24) exhibit signs of burnishing on the exterior of the base (see Fig. 6.12B). This is further evidence that Funnel Beaker West ceramic production probably involved working the vessel in an upside-down position during part(s) of the production process, as this part of the vessel is inaccessible with the vessel in an upright position (see also decorative techniques).

Within the category burnished, a small number of vessels exhibit anomalous surfaces which share most aspects of burnished surfaces, but appear fluidified with ribbed



Subset	Megalith inventories		Early flat graves		Late flat graves		Total (Funnel Beaker West)	
Technique	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Burnishing	81	85.3	55	88.7	28	93.3	164	87.7
Smudging	14	14.7	9	14.5	0	0	23	12.3
Shining	7	7.4	2	3.2	0	0	9	4.8
None detected	10	10.5	7	11.3	2	6.7	19	10.2

Table 6.7 Surface treatment in Funnel Beaker West vessels (n=187). Multiple forms of surface treatment may occur on the same vessel. All percentages relative to the total number of studied vessels from megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30).

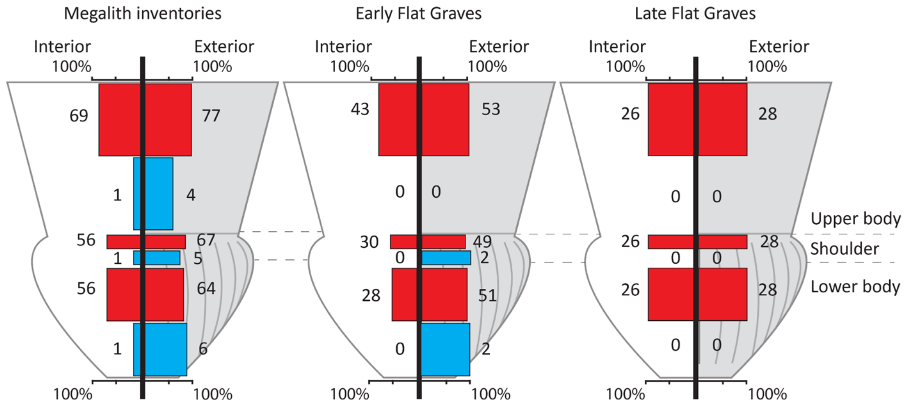


Figure 6.13: Schematic of the location of traces from burnishing and shining. The width of the horizontal bars indicates the percentage of vessels with traces or burnishing (red bars) or shining (blue bars) in a location relative to all vessels with traces of said operation in a subset (see Tab. 6.7). The numbers at the end of the bars indicate the absolute number of observations. More than one surface treatment technique can appear on a vessel. Observations for shining appear concentrated on (lower) exterior surfaces, but the low number of observations prohibits detailed interpretation. Traces of burnishing are prevalent on all ceramics, but occur most often on upper surfaces, and generally more on exterior surfaces than on interior surfaces.

striations in a compact microtopography (see Fig. 6.12G). These surfaces may have been subjected to softening, which involves rubbing a hard tool against a re-humidified leather-hard surface (cf. Lepère 2014; Roux 2019a pp. 96, 200–1). However, this interpretation remains tentative without microscopy.

The second most common surface treatment is smudging. Smudging involves subjecting a vessel to smoke after the firing process, and results in darkened surfaces (cf. Drieu *et al.* 2020; Roux 2019a p. 101). The following two indicators resulted in a positive detection for smudging: 1) the vessel exhibits a dark grey surface colour across an extensive area, and 2) this colour must, on flakes or firing cores, be a thin layer overlying a margin or core with a different, usually oxidising, colour (see Fig. 6.12D-E). Vessels with traces of smudging appear in megalith inventories (n=14) and early flat graves (n=9; see Tab. 6.7). Drieu *et al.* (2020) show these traces result from covering the vessel, while it is still hot from firing, with organic material such as moss.

The last detected surface treatment technique is shining. Shining involves rubbing a leather-hard or dry vessel surface with a soft tool. This tool can be made of various materials, such as wool or leather (cf. Roux 2019a p. 202). Traces interpreted as indications of shining are: 1) a compact surface with 2) a slight gloss, 3) inserted grains, and 4) smoothed-down protrusions from previous processes which nevertheless remain visible (see Fig. 6.12F). Shining is rare on Funnel Beaker West vessels. Only 7 vessels from megalith inventories and 2 vessels from early flat graves yield traces of this technique (see Tab. 6.7). These traces most often occur on the exterior surface, in particular the lower exterior, which includes the base. Traces of shining on the interior surface are rare in vessels from megalith inventories, and absent in vessels from flat graves (see Fig. 6.13).

Drying

The drying of vessels is a crucial part of the ceramic production process which can only be inferred for vessels in the archaeological record. The inferences below are based on the hydric states in which other operations are conducted.

The previous sections show the paste of Funnel Beaker West vessels usually remains in a wet state until at least the application of decorative techniques. If traces of surface treatment techniques occur, these traces always indicate the clay was leather-hard. As such, the drying to a leather-hard state usually occurs before surface treatment and after the application of decoration, with only a few exceptions.

Funnel Beaker West vessels show no traces of operations on dry clay. In general, there are no traces of techniques applied between surface treatment and firing. Therefore, the last drying phase, from a leather-hard paste to a dry paste, occurs between surface treatment and firing.

Firing

The firing of ceramic vessels encompasses a great number of factors which can only partially be reconstructed from archaeological remains. These factors include the architecture (if any) involved, the type of fuel, the arrangement of vessels and fuel, the soaking time, and the firing temperature (cf. Roux 2019a). Of these factors, the only one which can be reconstructed from macroscopy is the firing atmosphere.

The effects of the firing atmosphere on vessel surfaces can be observed with the naked eye, if erosion and/or refitting do not block sight of the core (see Tab. 6.8). Table 6.8 shows all but one of the Funnel Beaker West vessels exhibit oxidised exteriors.

In all cases where the core could be observed, the oxidation either continues (megalith inventories: n=10; early flat graves: n=9; late flat graves: n=1; see Fig. 6.14C), or transitions sharply into the darker brown or grey core. The latter vessels are split on the basis of the interior margin (see Tab. 6.8). The first group exhibit red-brown and yellow-brown interior surfaces, which indicate oxidation of the interior surface (see Fig. 6.14A). This group encompasses the majority of vessels from megalith inventories (n=53), early flat graves (n=32), and late flat graces (n=7). The second group of vessels exhibits interior surfaces in (dark) grey tones (see Fig. 6.14B). This group encompasses 28 vessels from megalith inventories, and 11 vessels from early flat graves (see Tab. 6.8). All of these firing cores indicate Funnel Beaker West vessels were fired in an atmosphere which was either reducing, or did not allow for the combustion of carbon. However, towards the end of the firing process the vessels were exposed to rapid cooling with an influx of oxygen-rich air.

Subset	Megalith inventories		Early flat graves		Late flat graves		Total (Funnel Beaker West)	
Core	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Ox-sRed-Ox	54	56.8	32	51.6	18	60	103	55.1
Ox-sRed-Red	27	28.5	11	17.7	6	20	45	24.1
Ox-Ox-Ox	10	10.5	9	14.5	3	10	22	11.8
Ox-Indet-Ox	2	2.1	9	14.5	2	6.7	13	7
Ox-Indet-Red	1	1.1	1	1.6	1	3.3	3	1.6
Red-Red-Red	1	1.1	0	0	0	0	1	0.5

Table 6.8: Observations on firing atmospheres in vessels from megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30; total = 187). The leftmost column encodes the sequence of colours and the transitions between them. The encoding has four elements: 1) 'Ox' which indicates a red or yellow shade of brown caused by oxidation processes; 2) 'Red' which indicates shades of grey likely caused by the presence of uncombusted carbon or a reducing firing atmosphere; 3) 's' or 'v' which indicates whether the boundary between the margins and the core is sharp (= 's') or gradual (= 'v'); and 4) 'Indet' which indicates the colour of a zone could not be observed, f.e. due to erosion. The sequence of these elements describes the sequence of colours: The first element on the left is the dominant colour of the exterior margin, followed by a dash and the description of the transition between colours, a description of the colour of the core, and lastly a dash and the dominant colour of the interior margin. The percentages are relative to the total number of studied vessels in a subset.

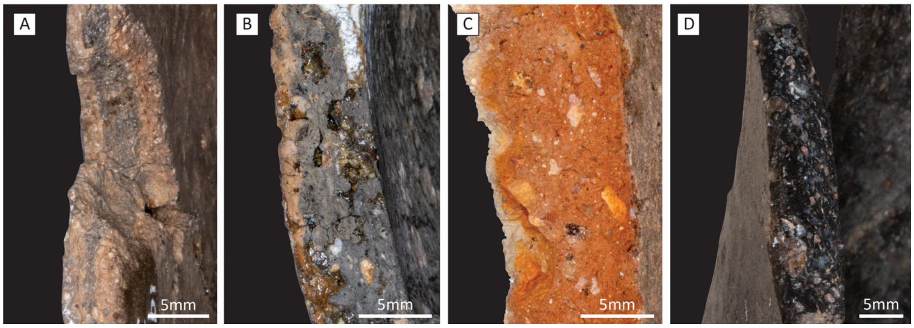


Figure 6.14: Examples of firing cores in Funnel Beaker West ceramics. A: Vessel 270 exhibits red-brown margins with a sharp transition to a dark grey core (code: Ox-sRed-Ox). The interior surface (right) has possibly been subjected to smudging, resulting in dark grey colours. B: The exterior margin of vessel 238 is red-brown with a sharp transition to a dark grey core and interior margin (code: Ox-sRed-Red). C: The core and margins of vessel 228 are completely red-brown (code: Ox-Ox-Ox). D: The core and margins of vessel 347 exhibits a homogeneous dark grey colour (code: Red-Red-Red).

This influx caused the oxidised margins with sharp transitions to reducing core. For some vessels, both the interior and exterior surfaces were exposed, for others only the exterior surfaces. This pattern might relate to vessels being placed upside down, filled/covered with fuel, or stacked during firing. In general, the above cores could indicate firing while covered with fuel, with stacked vessels, or in an enclosed space (cf. Roux 2019a; Rye 1981).

The sole exception to this pattern is a vessel from a megalith which exhibits grey tones across the interior, core, and exterior (see Tab. 6.8). This indicates reducing firing atmosphere without oxidation (see Fig. 6.14D).

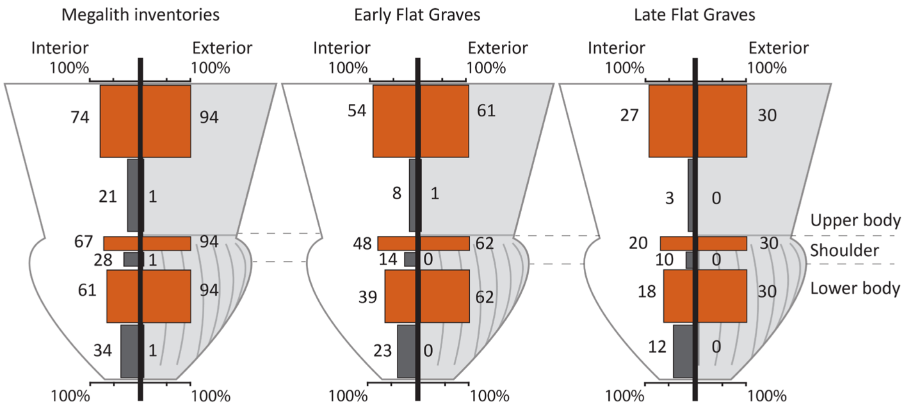


Figure 6.15: Schematic of the distribution of oxidising (terracotta) and reducing (grey) surface colours by vessel parts in Funnel Beaker West. The width of the bars indicates the percentage of vessels with these colours on the respective surface relative to the total of vessels in megalith inventories (n=95), early flat graves (n=62), and late flat graves (n=30), respectively. The numbers are the absolute number of vessels. These numbers may differ from those in Tab. 6.8 which only scores the dominant surface colours. The chart shows that oxidising colours are most common on all surfaces and that reducing colours are relatively more common or exclusive to the interior surfaces, and especially the lower interior.

The distribution of surface colours across different vessel parts (see Fig. 6.15) further illustrates these conclusions. Bright, oxidising colours are most common on all vessel surfaces with reducing, grey colours appearing comparatively more often or even exclusively on the interior surface (see Fig. 6.15). One vessel from the subset early flat graves exhibits reducing colours on the upper exterior, and one exceptional vessel from a megalith inventory has reducing colours across all exterior surfaces (see above). With regard to the interior surfaces, the data show that surfaces on the upper interior more often undergo oxidation than surfaces on the interior shoulder and especially the lower interior (see Fig. 6.15). This suggests the vessels were stacked, positioned, or filled with fuel such that the lower interior surfaces tended to escape oxidation towards the end of the firing process. In one case, the vessel may have been fired in a side-ways position, resulting in reducing surfaces on the upper exterior.

6.3 Summary

This chapter is a discussion of all technical traces on the studied Funnel Beaker West vessels, ordered according to the stages of the ceramic *chaîne opératoire*. This section is a brief overview of that discussion. Figures 6.16-8 are visual summaries which depict the specific *chaînes opératoires* of vessels from megalith inventories, early flat graves, and late flat graves as paths through the total *chaîne opératoire* (see Ch. 4). These graphs show the techniques, but not the modalities of techniques or tools discussed above (e.g. the node 'coiling' encompasses various joining procedures such as coiling by spreading or pinching and the node for simple impressions includes simple oblique impressions and all mentioned tools).

Technical traces from actions in the roughing-out stage indicate the use of two techniques: coiling and modelling. The majority of the bases are modelled, either by forming a lenticular clay mass, or a flattened disk. These modelled masses can be

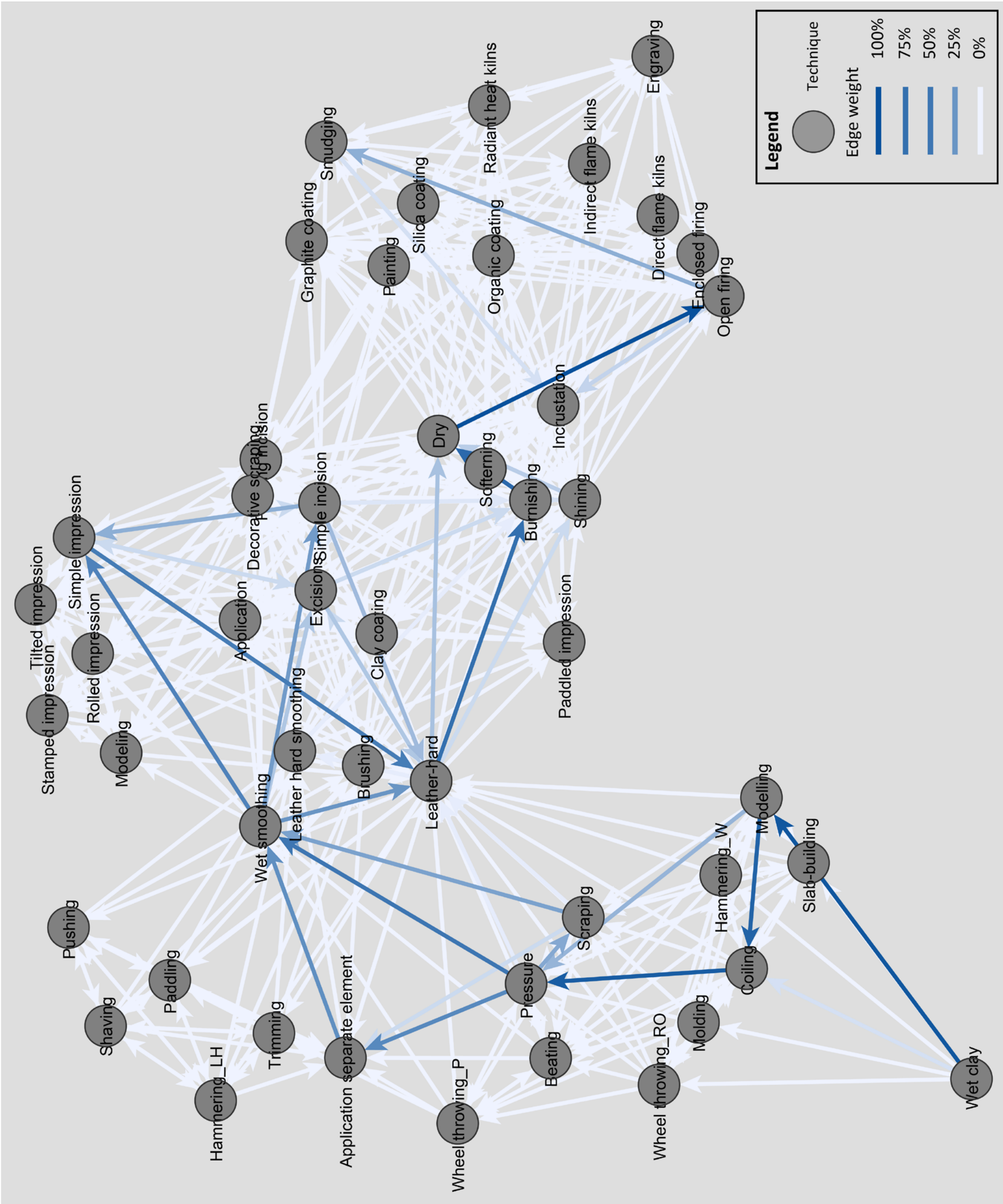


Figure 6.16: Network visualisation of the specific *chaînes opératoires* of 95 vessels from megalith inventories. The nodes are techniques, and the edges indicate two techniques can occur in sequence. The darker the blue colour of the edge, the higher the percentage of paths which runs along the edge. The visualisation shows the variation in production methods for this group of Funnel Beaker West vessels.

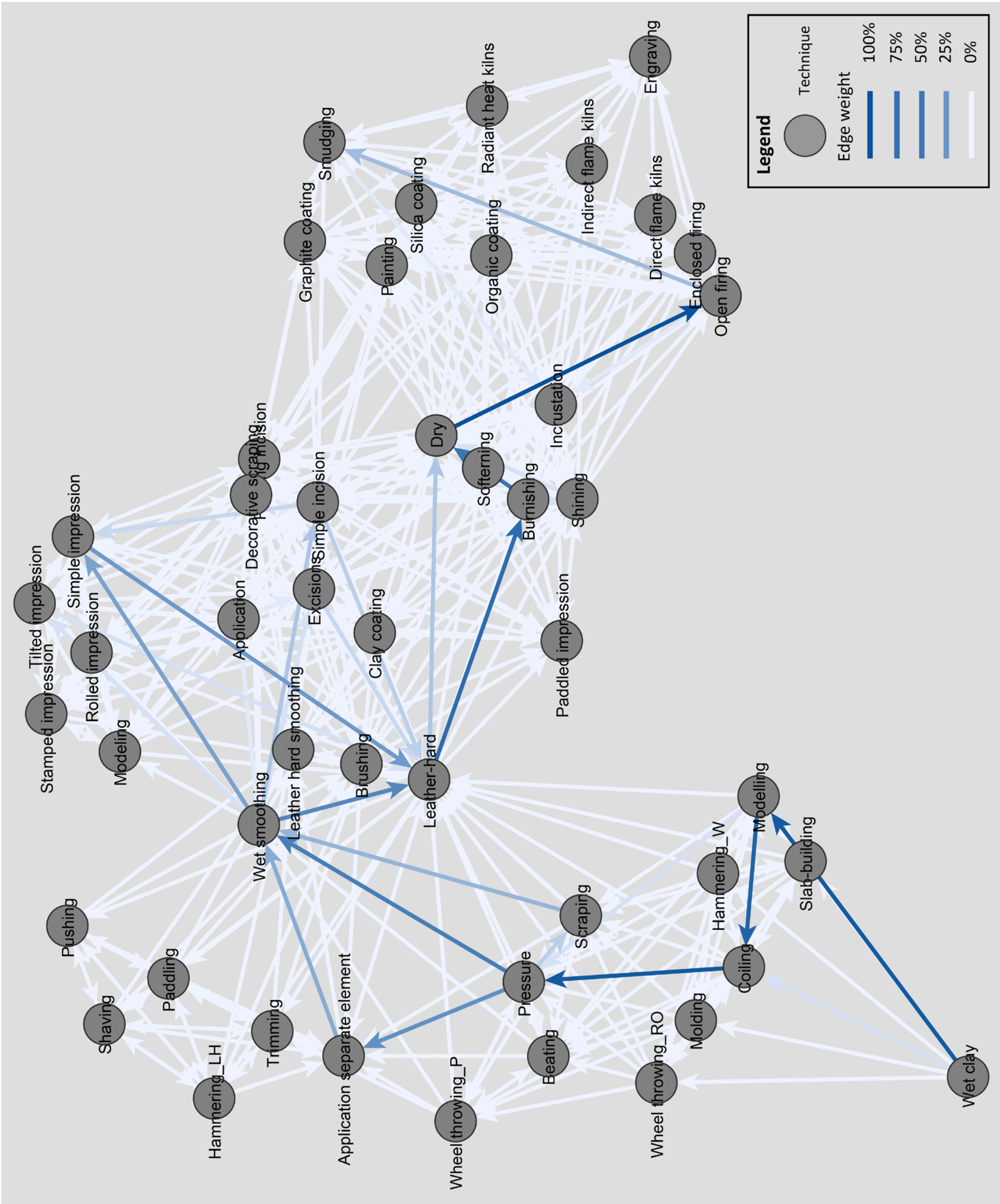


Figure 6.17: Network visualisation of the specific *chaînes opératoires* of 62 vessels from early flat graves. The nodes are techniques, and the edges indicate two techniques can occur in sequence. The darker the blue colour of the edge, the higher the percentage of paths which runs along the edge. The network visualisation shows the variation in production methods for these Funnel Beaker West vessels.

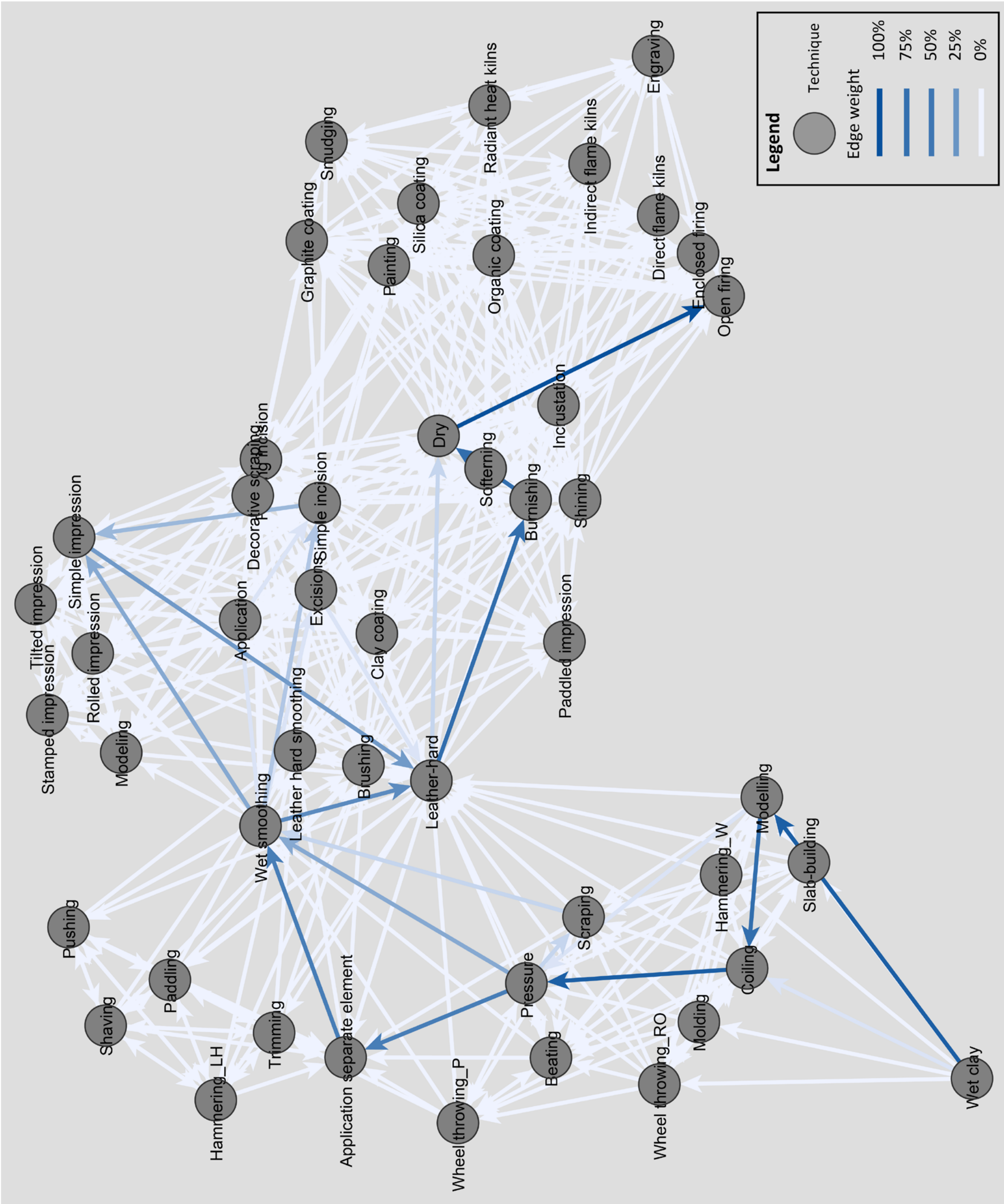


Figure 6.18: Network visualisation of the specific *chaînes opératoires* of 30 vessels from late flat graves. The nodes are techniques, and the edges indicate two techniques can occur in sequence. The darker the blue colour of the edge, the higher the percentage of paths which runs along the edge. The network visualisation shows the variation in production methods for these Funnel Beaker West vessels.

supplemented with coils in an adjacent position, and an additional clay mass on top of the initial mass. In some cases, the bases have been pressed into a flat surface. The fashioning of a small number of bases employs spiral coiling. The base construction method is similar across all subsets of the Funnel Beaker West body of knowledge. The fashioning of vessel walls employs the same two techniques. Coiling with the segment or ring procedure is the most common technique. The joining procedures involve pinching or spreading with more internal pressure, external pressure, a combination of internal and external pressure, flattening, or little modification. In addition, a small number of vessels is fully modelled. Similar to the roughing out of vessel bases, there is little difference between the subsets of the Funnel Beaker West bodies of knowledge in this procedure.

Two techniques were employed during the preforming stage: continuous pressure by hand, and scraping. The former technique occurs in nearly all vessels, whereas scraping occurs more rarely, and preferentially on the interior and lower surfaces of the vessels. Two different procedures for the fashioning of the handles occur during the preforming stage. The most common procedure is the plugging of a perforation in the vessel wall with a clay mass which is then modelled to form the handle. This handle is often perforated afterward. The alternative, less common, procedure is the application of a clay mass to the vessel wall, which may then be shaped through modelling and/or a perforation. The construction of base rings follows a similar procedure of applying one, or multiple coils, against the base exterior and shaping these through pressure with hand or hard tools. Base rings only occur on vessels from megalith inventories and early flat graves.

The actions during the finishing stage are relatively uniform across Funnel Beaker West ceramics and consist of smoothing wet clay. The majority of all vessels are smoothed with a soft tool, whereas a relatively small number were smoothed with a hard tool. Two vessels stand out as exceptions. The first may have been smoothed with a soft tool while leather-hard; the second exhibits no sign of finishing techniques.

The transition from the finishing stage to the decorative stage marks a point at which much variation starts to occur in specific *chaînes opératoires*. A substantial number of vessels exhibit no signs of decorative techniques. Moreover, some vessels exhibit signs of decorative techniques applied to leather-hard clay, meaning a drying stage occurred between the finishing and decorating stage, or alternately between different actions of the decorative stage. Further variation occurs within the decorative stage.

Vessels from megalith inventories, early flat graves, and late flat graves differ to some extent in decorative techniques and tools. Vessels from megalith inventories exhibit more variation in decorative techniques and tools for the application of these techniques than vessels from flat graves. Simple oblique impressions with conical tools are common among vessels from megalith inventories, but a substantial number of vessels exhibit additional decorative techniques such as incisions, simple impressions, excisions, tilted impressions, application, and incrustation. By contrast, vessels from flat graves show a narrower spectrum of decorative techniques of which simple oblique impressions with conical tools form a more substantial share.

Three further observations are of interest for the applicative of decorative techniques to Funnel Beaker West vessels. Firstly, the angle of insertion of some impressions, and the location of the decoration on inclined, lower vessel surfaces indicates the vessels may have rested in an upside-down position or at an oblique angle during decoration. Secondly, Funnel Beaker West vessels often have layered decorations in which multiple decorative techniques are superimposed. Lastly, the position of incrustation in specific *chaînes opératoires* is difficult to determine, as is the prevalence of said decorative technique due to preservation and conservation. A number of vessels yield indications that incrustation may occur after firing.

Surface treatment is prevalent in Funnel Beaker West ceramics. Burnishing in particular is common in all subsets, occurring on all vessel parts and in particular exterior surfaces. Shining is rare in Funnel Beaker West ceramics, but occurs in roughly equal measure on vessels from megalith inventories and early flat graves. Traces of burnishing and shining also occur on the base exterior, another indication Funnel Beaker West vessels may have been turned upside down during part of the production process. Both burnishing and shining were performed on leather-hard clay and followed the application of decorative techniques. By implication, a drying phase to achieve a leather-hard state intervened between the application of decoration and surface treatment. Smudging is an exception to this pattern: it takes place directly after firing and therefore much later in specific *chaînes opératoires* than other surface treatments. Traces of smudging only occur in vessels from megalith inventories and early flat graves.

Given that surface treatment occurs on leather-hard clay, and no traces occur of techniques between surface treatment and firing, a second drying phase to achieve dry consistency can be inferred at this step in the specific *chaînes opératoires*.

The last stage in many of the specific *chaînes opératoires* is firing, unless smudging or incrustation occurs (see above). The firing of Funnel Beaker West vessels frequently results in dark grey cores with sharp transitions to red-brown or yellow-brown exterior margins and in most cases interior margins. Such cores indicate the vessels were rapidly cooled with an influx of oxygen after the firing process. In general, such traces align with firing in an enclosed space, or with the vessels covered by fuel, and uncovered towards the end of the process. This firing process was in some cases followed by smudging and/or incrustation.

The above summary concludes this chapter about ceramic technology in the Funnel Beaker West body of knowledge. The next chapter conducts the same exercise for the Corded Ware vessels, followed by a chapter on petrographic analyses of Corded Ware and Funnel Beaker West ceramics.

7

Corded Ware Ceramic Technology

This chapter is a systematic description of the specific *chaînes opératoires* (n=89) in the Corded Ware body of knowledge (see Ch. 5). It is the counterpart of Chapter 6. The chapter is an in-depth presentation of the diagnostic technical traces behind the detected techniques and specific *chaînes opératoires*. The accompanying descriptions and photographic documentation can be found in Appendix C and D, respectively. This data feeds into the more abstract comparisons in Chapters 9 and 10. Similar to Chapter 6, there is no discussion of the petrographic evidence for raw materials or paste preparation in Corded Ware ceramics, as this evidence is discussed in Chapter 8. Similarly, vessel types and shapes are discussed where relevant but not tabulated due to the low number of vessels in certain rare categories (see Tab. 5.3; Ch. 5). A broader discussion about potential differences in production processes between different vessel types and shapes can be found in Section 9.2.

A discussion of previous work on Corded Ware ceramic technology precedes the descriptions of the specific *chaînes opératoires* in the Corded Ware body of knowledge. This discussion serves as a contextualisation for the data from this study.

7.1 Previous Studies

Corded Ware ceramic technology has received considerable scholarly attention, particularly from Dutch and Scandinavian authors following the seminal publications by Van der Leeuw (1976) and Hulthèn (1977). However, the resulting information is scattered under different cultural names.

Recent contributions to our knowledge about Dutch Corded Ware ceramic technology include Beckerman (2015), Kroon *et al.* (2019), and Wentink (2020). For Denmark, Hübner (2005) provides a succinct overview for a broad survey of Single Grave Culture burials, whereas Larsson (2009) and Holmqvist *et al.* (2018) discuss Battle Axe Culture vessels from Sweden and the Baltic. The following paragraphs combine information on vessels from all these studies under the label Corded Ware, regardless of region (see Section 2.1).

The same source criticism which applies to previous studies of Funnel Beaker West ceramic technology, also applies to studies of Corded Ware ceramic technology. The definition of ceramic technology in these studies is narrow, there is no uniform vocabulary, and verifying interpretations is difficult due to a lack of documentation (see Section 6.1).

Extant studies indicate Corded Ware ceramic technology varies between the Netherlands and Scandinavia. In the Netherlands, roughing-out techniques consist of modelling for the lower body and several variants of coiling for the vessel wall (Beckerman 2015; Kroon *et al.*

2019; Van der Leeuw 1976 pp. 86–7; Wentink 2020 pp. 50–1). By contrast, Larsson (2009 p. 242) and Hulthén (1977 p. 149) describe vessels made primarily through modelling, with only rarely a coil added to the upper body. Both authors state fully coiled vessels only occur in late stages. Hübner (2005 p. 174) reports both fully coiled and fully modelled vessels from Denmark.

Two different preforming processes figure according to Van der Leeuw (1976). The first process involves shaving the interior and/or exterior surface of vessels while the paste is leather-hard. The second process entails the exertion of pressure by hands on wet clay, possibly with the aid of a rotating support and wraps. However, these hypothesised processes cannot be established through comparisons with experimental ceramics (Wentink 2020 pp. 52–4), and this study found no traces of wraps or shaving, despite incorporating many of the vessels Van der Leeuw (1976) discusses.

Finishing and surface treatment operations are rarely distinguished and hard to discern from descriptions alone. Studies commonly report ‘smoothened’, ‘roughened’, ‘smitten’, ‘brushed’, or less frequently, ‘burnished’ surfaces (Beckerman 2015; Hübner 2005 p. 174; Kroon *et al.* 2019; Larsson 2009 p. 242).

The descriptions of decorative techniques are more uniform and encompass incisions and impressions. The impressions are said to employ a variety of tools, and combinations thereof, including (but not limited to) spatula, cord, stamps, and finger nails (Beckerman 2015; Grömer and Kern 2010; Hulthén 1977 p. 149; Kroon *et al.* 2019; Larsson 2009; Wentink 2020 p. 52). Larsson (2009 p. 245) states decoration occurs prior to the final working of the surface, as the decorations are reworked during surface treatment.

Inferences about drying stages are especially hard to derive from the available descriptions. Van der Leeuw (1976 p. 86) argues that Corded Ware vessels were constructed in two stages. The lower body is constructed first and left to dry, before the construction of the upper body. Larsson (2009 p. 245) mentions shallow impressions as an indication of decoration on a surface with a hydric state between wet and leather-hard.

With regard to firing, Hulthén (1977 p. 146) and Hübner (2005 p. 175) mention firing cores which exhibit full oxidation, oxidation of the margins due to influx of air after firing, or no oxidation at all. The latter two firing cores are sometimes interpreted as evidence of insufficient firing. In fact, such firing cores likely indicate covered firing paired with an influx of cool air towards the end of the process (cf. Beckerman 2015; Hübner 2005; Kroon *et al.* 2019; Larsson 2009 pp. 245–6).

The above summary of extant technological studies tentatively suggests regional variation within Corded Ware ceramic technology. The variation occurs in the roughing-out and preforming stages, with more uniformity in decoration, firing, finishing, and surface treatment. Such variation within Corded Ware ceramic technology is of interest, because it suggests not all these potters learned the same production process, but nevertheless produced similar vessels (cf. Gosselain 2018; Roux 2019a). However, an in-depth interpretation is tentative due to the lack of uniform terminology, verifiable data, and dedicated studies. As such, this study makes two contributions to our knowledge of Corded Ware ceramic technology. Firstly, it revisits a key dataset for our understanding of Corded Ware ceramic technology, namely the vessels from the Netherlands. Secondly, the study works towards more uniform terminology and better verifiability of interpretations by employing the *chaîne opératoire* approach of Roux (2019a).

7.2 Specific *Chaînes Opératoires* in the Corded Ware Body of Knowledge

This section is about the results of this study. The discussion of the technical traces is ordered into the stages of the ceramic *chaîne opératoire* as defined by Roux (2019a): roughing out, preforming, finishing, decoration, surface treatment, drying, and firing.

Roughing out

Roughing-out techniques rework the clay paste into an initial vessel shape (cf. Roux 2019a). The description of the roughing-out process starts with the shaping of the base and continues with the shaping of the vessel wall because traces on the vessel bases show their construction preceded that of the vessel wall.

Roughing out of Vessel Bases

Two techniques occur during the shaping of the base of Corded Ware vessels (see Tab. 7.1): modelling, with some additional operations (n =88), and coiling (n = 1).
The base of Corded Ware vessels is typically a separately modelled clay mass. Indications for modelling are a bulging interior surface of the base, finger-sized hollows surrounding the centre of the base interior, and an irregular thickness of the base (see Fig. 7.1A-B; cf. Roux 2019a p. 168). The base interior may also exhibit a circular fissure at the attachment to the lower interior wall, indicating the fusing of two separate masses (see Fig. 7.2A). If cross-sections can be observed, the orientation of voids and particles in the centre points to a single dense mass in a lenticular shape, hence the designation 'lenticular mass' (see Fig. 7.1C-D). Three additional actions can co-occur with the modelling of the base.

Firstly, the placement of a coil adjacent to the modelled mass (n=52; see Tab. 7.1). Indications for this operation include a fissure or break around the periphery of the base interior and/or exterior (see Fig. 7.2B), frequently combined with a raised periphery of the base exterior (see Fig. 7.1C-D). In addition, a relic coil (a more dense, semi-circular mass with preferential orientation of elongate particles and voids in the fabric) can appear in base cross-sections (see Fig. 7.1C-D). However, the absence of the above indicators does not imply the absence of coils in the base, as various subsequent operations might erase these traces.

Secondly, bases may have been pressed against a flat surface. Indications for this operation include an abrupt, highly flattened shape of the base exterior with pull-outs, and impressions with irregular microrelief into the main mass, which were made on wet clay. These indicators are present in 40 Corded Ware vessels (see Tab. 7.2, Fig. 7.3B). These 40 cases are more or less equally distributed across the bases without traces of an

		Corded Ware	
Technique	Specification	*n*	*%*
Modelling	Indeterminate	52	58.4
	Lenticular mass	36	40.5
	+ adjacent coil	52	58.4
	+ tipping over	4	4.5
	+ pressed into surface	40	44.9
Coiling	Spiral	1	1.1

Table 7.1: Overview of techniques employed in the fashioning of bases. The basic techniques are modelling into a lenticular mass and coiling. Three additional operations may feature, indicated by a '+' in the column specification. All percentages relative to the total number of Corded Ware vessels (n=89).

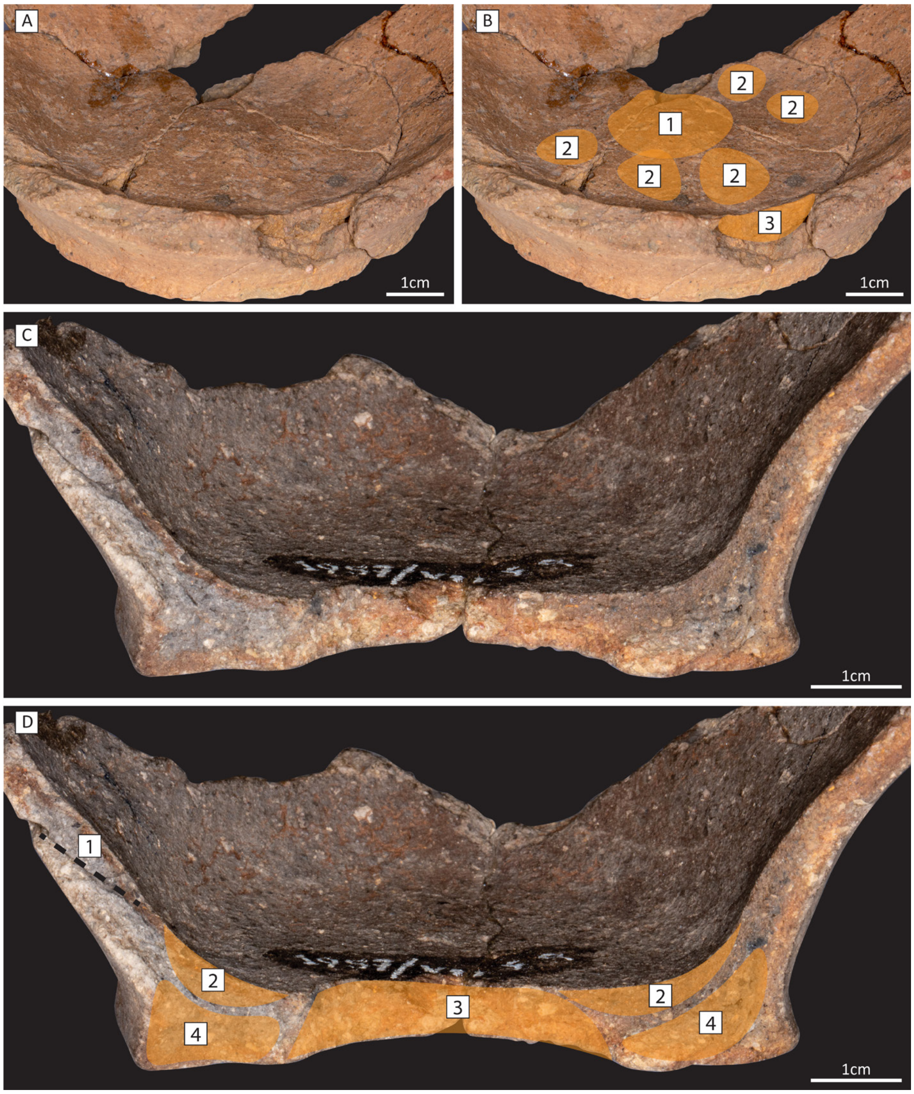


Figure 7.1 Shaping of the base, part 1: Examples of a lenticular mass. A: Lenticular mass in the base of vessel 169 (unannotated depiction of interior). B: Annotated depiction of the lenticular mass in the base of vessel 169. The bulging centre (1) is surrounded by finger-sized hollows (2) and a ring break around periphery revealing a separate mass (3). C: Lenticular mass visible in the cross-section of the base of vessel 175 (without annotations). D: A lenticular mass in the base of vessel 175 (with annotations). The base features a coil joint with an internal bevel in the lower wall (1); an added clay mass which was smeared out against the base and lower wall as indicated by curvilinear voids (2), as well as a central mass with a lenticular structure (3), flanked by a coil which is visible as a relic coil (4) which also causes the raised periphery of the exterior.

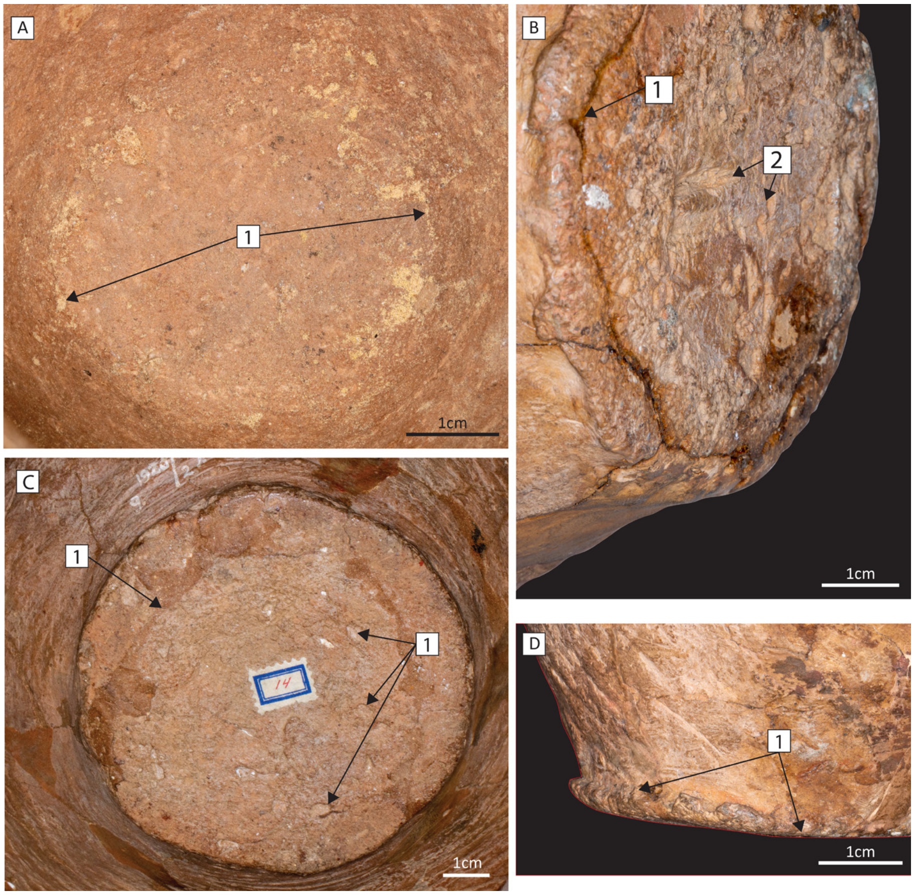


Figure 7.2 Shaping of the base, part 2: Circular fissure (A), pressing into surface (B), coiling (C), and tipping over (D). A: Example of a circular fissure. Base interior of vessel 132 features a ring fissure (1) along the joint with the lower wall, indicating the placement of coils onto a separately fashioned base. B: The base of vessel 16 exhibits a fissure from a peripheral coil (1), as well as depressions and pull-outs caused by the surface it was pressed into (2). C: The base exterior of vessel 337 shows signs of coiling. There is a prominent ring break (1), as well as a spiralling orientation among elongated impressions in the base (2), indicating the base may have been coiled. D: The base exterior of the of vessel 16 was deformed by being tipped over while wet, resulting in a skewed profile, and a thickened edge (1).

adjacent coil (n = 20) and those with such traces (n=19). Erosion and labelling of the base exterior can impede detection of the indicative features.

Thirdly, the tipping over of the vessel while the base was plastic. In 4 vessels, the periphery of the base exterior is deformed and slopes upward relative to the plane of the base (see Tab. 7.1). Such deformation can occur across the entire circumference of the base, or only on one side (see Fig. 7.2D). Either way, the deformation likely indicates the vessel was tipped over to one side or worked at an angle at some stage during the production process while the clay was still malleable.

Apart from modelling, a second roughing-out technique occurs in bases. A single vessel exhibits a coiled base (see Tab. 7.2). In this case, the base exterior exhibits spiralling fissures and impressions, which suggest spiralled coils make up the base (see Fig. 7.2C; cf. Roux 2019a pp. 160–2, Fig. 3.24).

Roughing out of Vessel Walls

The shaping of Corded Ware vessel walls proceeds through coiling (n = 88) or modelling (n=1; see Tab. 7.2).

Evidence for coiling consists of a number of indicators. Key traces are regular, horizontal undulations in the vessel wall, fissures in a similar orientation, as well as a horizontal breakage pattern (see Fig. 7.3A-B). These traces are apparent upon viewing the upper interior and lower exterior surfaces of vessels at an oblique angle (cf. Roux 2019a p. 160). They likely indicate the use of a segment or ring coiling procedure. Due to refitting, description of the joining method via observations on the break profiles (cf. Roux 2019a pp. 160–1) is impossible in all but exceptional cases. Therefore, specification of the joining method is limited to such cases. These cases (n=8) demonstrate the breadth of variation in the Corded Ware body of knowledge (see Tab. 7.2): all three joining methods mentioned by Roux (2019a pp. 57–8) occur in these 8 cases.

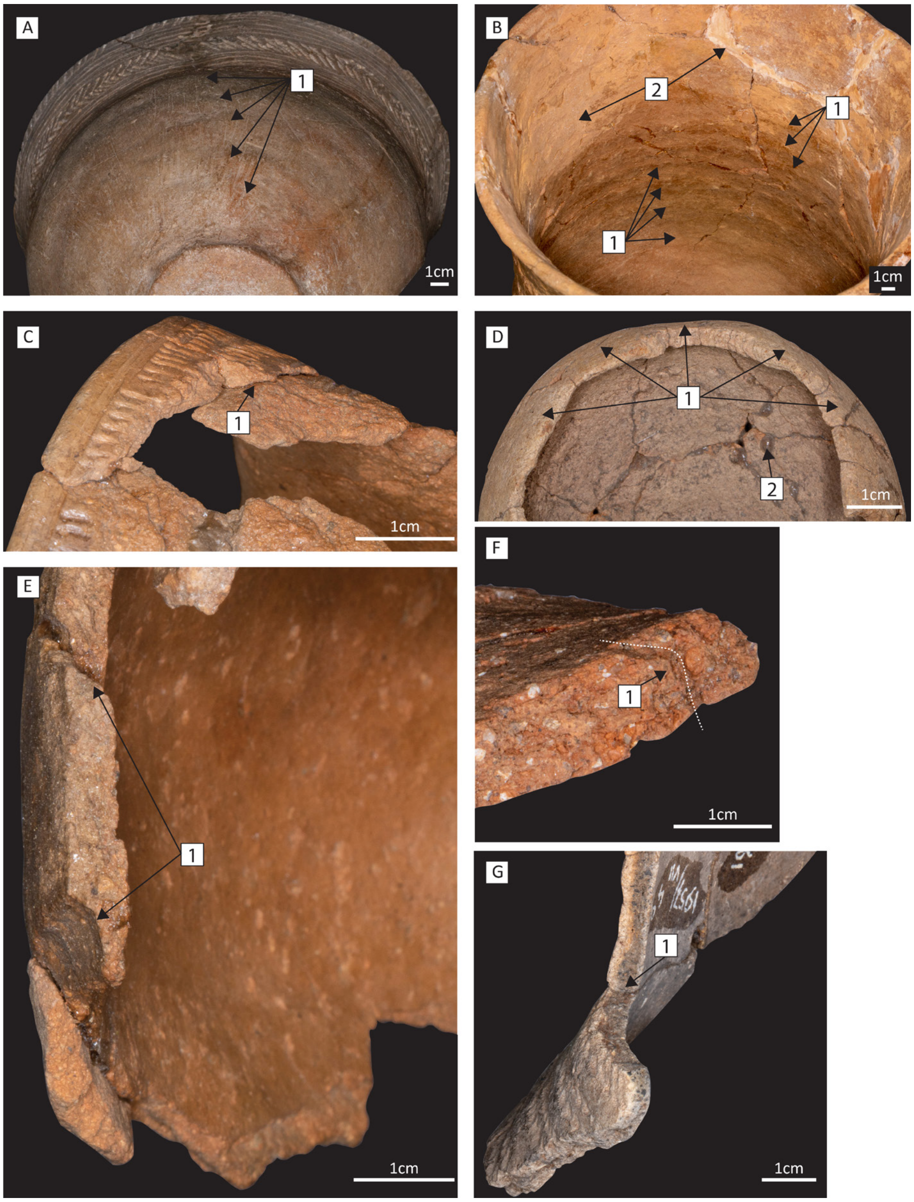
The most observed break profile is straight (see Fig. 7.3G, 6.5C), which is observed in 4 vessels, followed by U-shaped breaks which were detected twice (see Fig. 7.3F; 6.5B). Both break profiles indicate minimal deformation of the coils during coiling by pinching (cf. Roux 2019a p. 161). The third break profile occurs in one vessel. This vessel exhibits breaks with internal bevels, indicating the coils were subject to pinching or spreading with internal pressure upon joining (see Fig. 7.3E; 6.5A; cf. Roux 2019a p. 161, Fig. 3.24). Lastly, in a relatively complete, partially refit vessel, the break profiles alternate in the upper and lower body: coil joints with internal bevels appear in the lower body, and coil joints with external bevels in the upper body (see Fig. 7.3C & E; 6.5A; cf. Roux 2019a). This alternation indicates the joining process of coils proceeded through internal pressure in the lower body and changed to external pressure on the upper body.

Apart from the coiled vessels, a single vessel (Vessel ID 79) was fully modelled (see Tab. 7.2). Indicators of this process consist of finger-sized hollows which occur throughout the vessel wall, as well as an irregular wall thickness (see Fig. 7.3D; cf. Roux 2019a p. 168).

Figure 7.3 (opposite page): Shaping of the vessel wall: Indicators for coiling (A-B), bevelled breaks (C, E), indicators for modelling (D), hollow breaks (F), and horizontal breaks (G). A: Indicator for the use of coiling on vessel 314. Parallel horizontal, rhythmic undulations (1) visible on the lower exterior when viewed at an oblique angle. B: Indicators for coiling on the upper interior of vessel 312. Undulations similar to A (1). The orange mass is a modern refit with coloured gypsum (2). C: Breaks with external bevels (1) on the upper body of vessel 66 due to pressure on the exterior surface during coil joining while coiling by spreading or pinching (see also E for reversal in lower body). D: Indicators of modelling on vessel 79. Primarily, finger-sized hollows (1) on the exterior surface. The interior is severely eroded and refitted with glue (2). E: Breaks with internal bevels (1) on the lower body of vessel 66 (see also C for reversal in upper body), which result from pressure on the interior surface while joining coils during coiling by pinching or spreading. F: Relic coil indicated by a curvilinear fissure (1; just left of the dotted white line tracing it) in cross-section on the upper body of vessel 176. This break profile results from coiling by pinching with little modification of the coil while joining. G: Straight, horizontal break (1) on the upper body of vessel 175, which results from coiling by pinching with flattening of the coil joints.

		Corded Ware	
Technique	Specification	*n*	*%*
Coiling	Unspecified	80	89.9
	Flattened coil joints	4	4.5
	U-shaped coil joints	2	2.2
	Internal bevels	2	2.2
	Alternating internal and external bevels	1	1.1
Modelling	Unspecified	1	1.1

Table 7.2: Techniques employed in the fashioning of vessel walls. For a depiction of the various types of coil joints, see Fig. 6.5. All percentages relative to the total number of Corded Ware vessels (n=89).



Preforming

Roux (2019a p. 64) defines preforming as operations which give the rough-out of the vessel its final shape. Traces of three preforming actions occur on the studied Corded Ware vessels: preforming by continuous pressure, scraping, and application of separate elements for the handles (see Tab. 7.3; Fig. 7.4-5).

All 89 studied Corded Ware vessels exhibit signs of preforming by continuous pressure. During this operation, potters apply pressure to the rough-out of the vessel with their hands to finalise the shape of the rough-out (Roux 2019a p. 66). Key indicators for this operation are elongated, finger-sized hollows, often in diagonal and vertical orientation (cf. Roux 2019a pp. 174–5). Common locations for such traces on Corded Ware vessels are the protruding foot, the rim of the vessel, the interior and exterior of the shoulder, as well as the interior of the upper body (see Fig. 7.4).

The second most common preforming action is scraping with a hard tool. 34 vessels exhibit traces of this operation (see Tab. 7.3). Scraping entails exerting pressure with a hard tool on wet clay so as to give the vessel its final shape (cf. Roux 2019a pp. 64–6). The detections of scraping are presented between the following brackets: it is difficult to distinguish the use of hard tools on wet clay during preforming from similar operations during finishing, especially if subsequent surface treatment modified the surface, and if

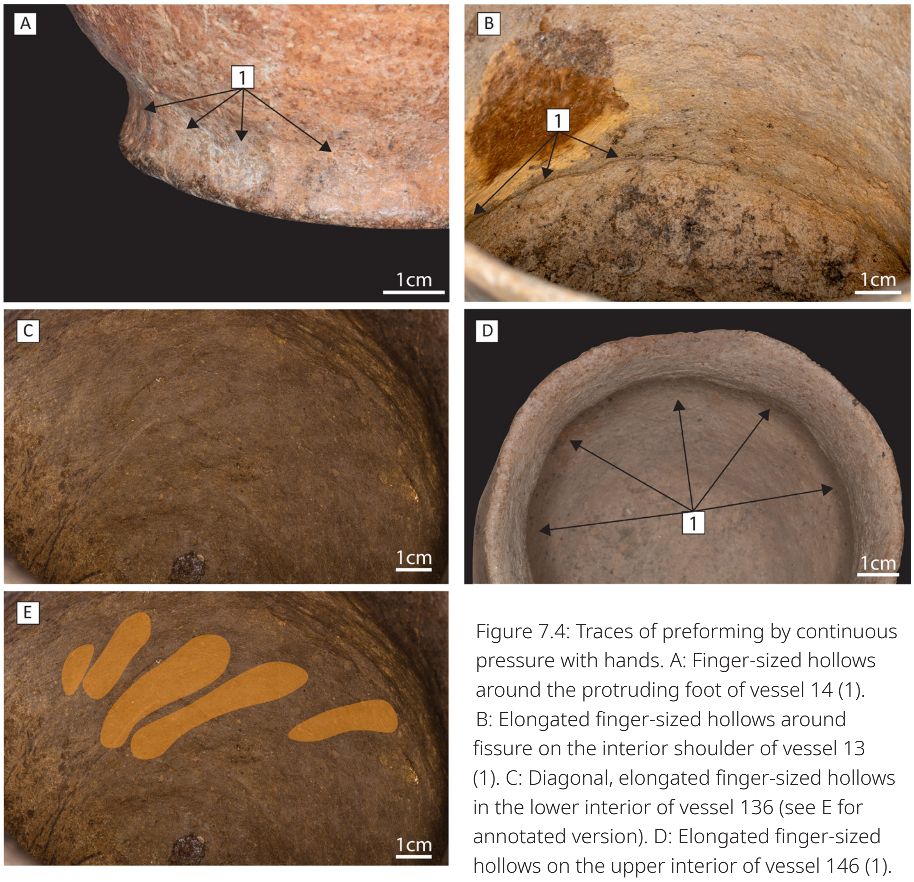


Figure 7.4: Traces of preforming by continuous pressure with hands. A: Finger-sized hollows around the protruding foot of vessel 14 (1). B: Elongated finger-sized hollows around fissure on the interior shoulder of vessel 13 (1). C: Diagonal, elongated finger-sized hollows in the lower interior of vessel 136 (see E for annotated version). D: Elongated finger-sized hollows on the upper interior of vessel 146 (1). E: Annotated version of panel C: the orange zones are elongated finger-sized hollows in the lower body of vessel 136 (see C for original).

		Corded Ware	
Technique	Specification	*n*	%
Continuous pressure	By hands	89	100
Scraping	Hard tool	34	38.2
Application of separate elements	Application	2	2.2

Table 7.3: Preforming in Corded Ware vessels. All percentages are relative to the total number of studied vessels (n=89). Multiple operations can occur on the same vessel.

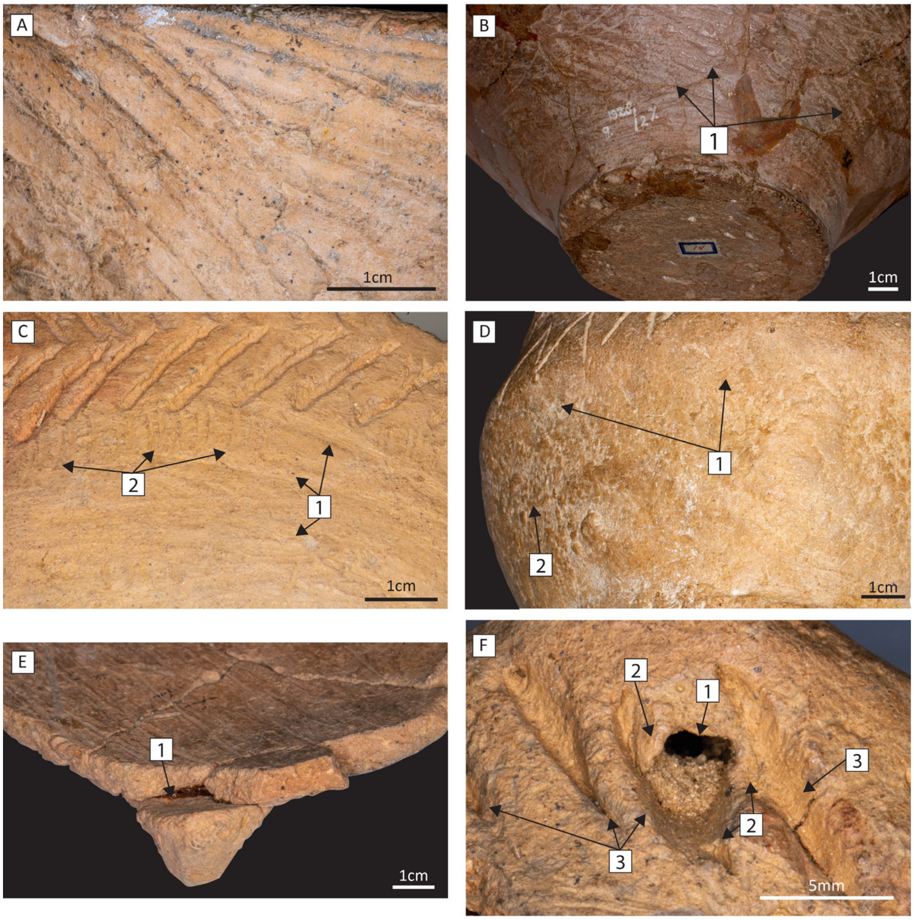


Figure 7.5: Traces of scraping (A-D), and the fashioning of handles (E-F). A: Vessel 16 exhibits typical traces of scraping, namely diagonal bands of deep striation with thickened edges, and bases with irregular microrelief and ribbed striation. Traces made with a hard tool in downward motions on the upper exterior. B: Reworked traces of scraping on the lower exterior of vessel 337. Bands of deep sub-horizontal and diagonal striation with thickened edges and ribbed striation at the base (1). C: Reworked traces of scraping on the shoulder of vessel 140. Bands of deep striation (1) similar to A and B, but smoothened down due to a subsequent operation; accompanied by possible impressions of the tool (2). D: Traces of scraping on the lower exterior of vessel 13. Two square, diagonal depressions with diffuse edges (arrows at the centre), caused by scraping downward with a hard tool; the resulting surface has an irregular microtopography with plastic over-thicknesses (2). E: The handle of vessel 169 was applied by pressure. The handle takes the shape of a separate clay mass affixed to (and coming away from) the surface as such (1). F: The perforation on the handle on vessel 169 was made with a rounded tool and is at present partially clogged with sand and glue residue (1), but exhibits thickened edges (2) where it cuts across several decorative impressions (3).

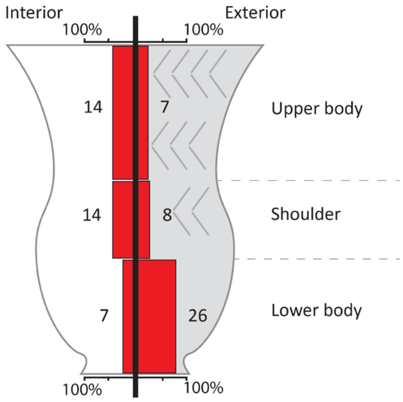


Figure 7.6: Vertical bar chart of the location of traces of scraping on vessel surfaces by vessel part for the interior and exterior. The width of the red bars indicates the percentage of vessels with traces of scraping on a specific location relative to the total number of vessels with traces of scraping (n=34). Note that traces of scraping can occur on multiple surfaces of the same vessel. The numbers indicate the absolute number of positive detections. Signs of scraping most often occur on the lower exterior, and less often on the interior shoulder and upper interior.

traces are sparse (e.g. Fig. 7.5D). The following traces are interpreted as scraping: broad, deep striations which cover a substantial surface area. The striations must exhibit signs of having been made on plastic clay: thickened edges, and bases with irregular microrelief and ribbed or threaded striation (cf. Roux 2019a pp. 174–5; see Fig. 7.5A-D). Traces of the edge of the hard tool are also present in some cases (cf. Roux 2019a Fig. 3.35). The striations on Corded Ware vessels most often occur in diagonal orientation on the lower exterior and seem to result from upward motions (see Fig. 7.6). Other prevalent locations are the interior shoulder and upper interior where the direction of the motion is sub-horizontal. A smaller number of vessels exhibit traces on the upper exterior and shoulder made with diagonal or vertical downward motions (see Fig. 7.5A-B; 7.6). Van der Leeuw (1976 specifically Pl. 15, 19) interprets such traces as 'scraping on leather-hard clay', but the distinct particle plucking which would result from such an operation is absent (cf. Roux 2019a Figs. 3.37-8).

The last operation discussed here is the fashioning of the handles (cf. Roux 2019a p. 90). Two of the studied vessels, both amphorae, exhibit handles. In both cases, the handles are constructed by applying a clay mass against the vessel surface: the handles break off as such, without revealing a plug (see Fig. 7.5E). Hollows can sometimes be detected on the interior surface opposite of the handle, which likely result from exertion of further pressure to affix the clay mass. In both vessels, the handle is perforated with a rounded tool while the clay was still wet, as indicated by the thickened edges on the perforation (see Fig. 7.5F). Traces of finishing and decorative techniques cut across the handles, indicating the position of this operation in the specific *chaînes opératoires* is just after preforming. However, the perforation on one of the handles cuts across decorative impressions, and was therefore made at a later stage (see Fig. 7.5F).

Finishing

Finishing techniques modify the vessel surface (cf. Roux 2019a p. 92). Finishing in Corded Ware vessels consists of smoothing on wet clay with soft tools such as hands (n=82), or hard tools such as bits of wood or pebbles (n=17; see Tab. 7.4; Fig. 7.7). These traces are not mutually exclusive: traces of hard and soft tools may occur on different zones of the same vessel. Moreover, traces of finishing techniques are not always present on every vessel part. These nuances are highlighted after the description of the diagnostic traces of these techniques.

	Corded Ware		
Technique	Specification	*n*	%
Wet smoothing	Soft tool	82	92.1
	Hard tool	17	19.1

Table 7.4: Corded Ware vessels with traces of wet smoothing by hard and soft tools. Traces of hard and soft tools can co-occur on the same vessel. The percentages are relative to the total number of vessels (n=89).

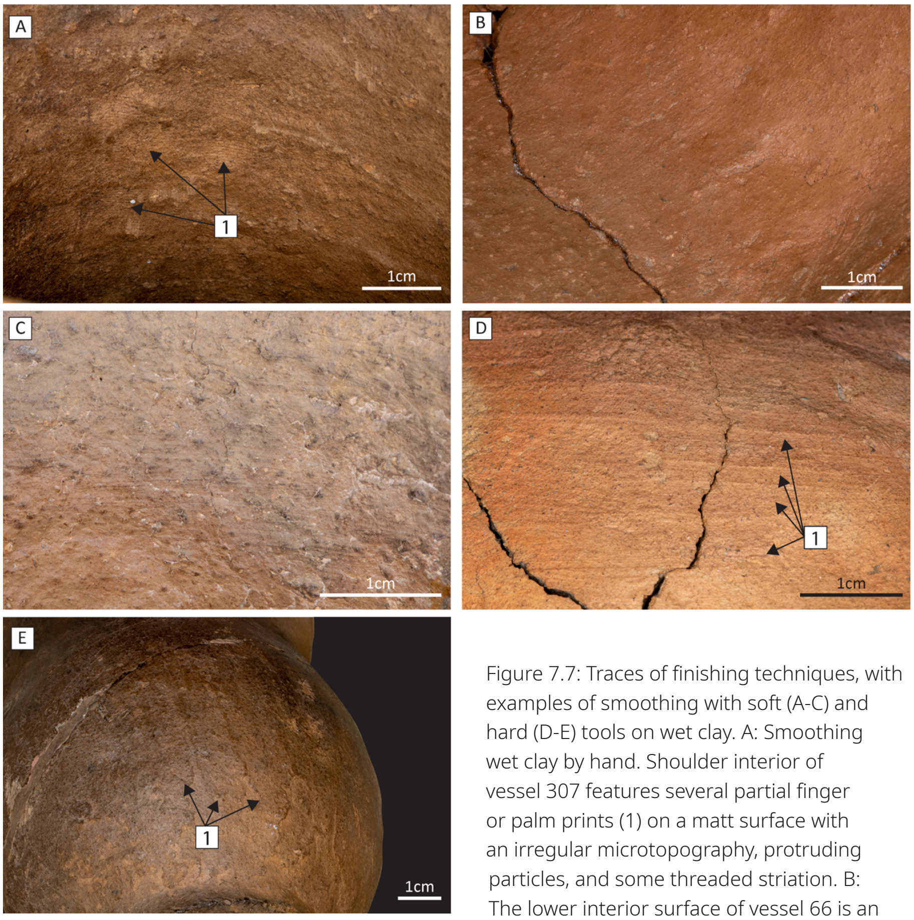


Figure 7.7: Traces of finishing techniques, with examples of smoothing with soft (A-C) and hard (D-E) tools on wet clay. A: Smoothing wet clay by hand. Shoulder interior of vessel 307 features several partial finger or palm prints (1) on a matt surface with an irregular microtopography, protruding particles, and some threaded striation. B: The lower interior surface of vessel 66 is an example of smoothing wet clay, likely with a soft tool. The surface exhibits protruding particles, occasional threaded and ribbed striation, and an irregular microtopography. C: The upper interior surface of vessel 333 is an example of smoothing wet clay with added water. The surface has partially and fully covered, protruding particles, an irregular microtopography, and parallel ribbed striation. D: Example of smoothing wet clay with a hard tool on the exterior surface of vessel 87. Typical parallel, banded striations in horizontal direction with thickened edges and threaded striation at the base (1) on a matt surface with irregular microtopography and protruding particles. E: The lower exterior surface of vessel 150 is another example of smoothing wet clay with a hard tool. The surface exhibits vertical, parallel bands with thickened edges, ending in over-thicknesses (1) as well as an irregular microtopography and protruding particles.

The surfaces worked with soft tools while wet exhibit protruding particles, an irregular microtopography, threaded or ribbed striation, and a matt aspect (see Fig. 7.7A-C). If more water was added, more ribbed striations and partially covered particles appear (see Fig. 7.7C; cf. Roux 2019 pp. 196–7).

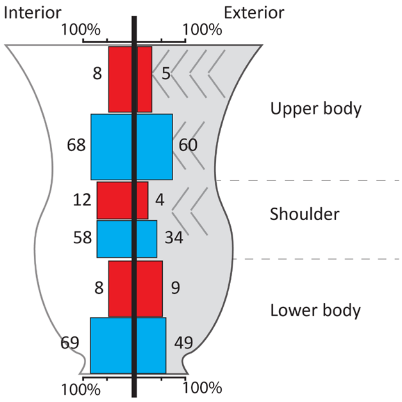


Figure 7.8: Schematic of a Corded Ware beaker with vertical bar chart of the usage of soft (blue) and hard (red) tools for finishing by location on the vessel body. The percentages are relative to the total number of vessels with traces of this operation (see Tab. 7.4), and the labels indicate the absolute number of vessels with traces in that particular location. In general, positive detections are higher on interior surfaces than on exterior surfaces due to the prevalence of surface treatment on the exterior. Moreover, a clear preference for the use of soft tools stands out, whereas traces of the application of hard tools preferentially occur on the interior shoulder and lower exterior.

The surfaces smoothed with hard tools while wet are similar in most respects, but frequently also feature banded striations with thickened edges which end in overthicknesses (see Fig. 7.7D-E; cf. Roux 2019a pp. 196–7). These striations often occur in diagonal or sub-horizontal orientation on Corded Ware vessels, indicating the potters made horizontal or sub-horizontal motions with the tool (see Fig. 7.7D-E). Traces of decorative techniques cut across these striations. It can be difficult to distinguish between such striations and traces of preforming by scraping because both operations involve the application of a hard tool to wet clay (see preforming). The traces listed here as finishing are generally shallower than those listed under preforming (compare Figs. 7.7D-E to 7.5A-B).

Operations with hard and soft tools may occur on the same vessel, and not all vessel surfaces yield traces of finishing operations. Several patterns stand out from the dataset as a whole (see Tab. 7.4, Fig. 7.8). Most vessels exhibit traces of finishing on the interior surface, because operations such as surface treatment are preferentially applied to the exterior surface, and in particularly the lower exterior and exterior shoulder (see Fig. 7.12). A clear preference for the use of soft tools during the finishing stage stands out for all surfaces (see Fig. 7.8; Tab. 7.4). However, traces of hard tools occur marginally more often on the interior shoulder and lower exterior of vessels (see Fig. 7.8), indicating preferential application of hard tools to finish these surfaces.

Decoration

Decorative techniques on Corded Ware ceramics chiefly fall into two groups: simple incisions and simple impressions, which both occur in ca. 50% of the studied vessels (see Tab. 7.5). Three further techniques play minor roles: tilted impressions, excisions, and appliques. These techniques appear in less than 10% of the vessels (see Tab. 7.5). 11 vessels in this dataset exhibit no decoration. The decoration involves various tool types, which can be inferred from the shape of the impression (see Tab. 7.5). Before describing these techniques, tools, and their traces, two general patterns in the application of decorative techniques are highlighted.

Firstly, Corded Ware specific *chaînes opératoires* exhibit some variation in this stage due to the use of different techniques, but also the different positions of these techniques relative to each other and to the complete sequence of operations. In general, decorative operations occur between finishing and surface treatment (if the latter is present), and usually while the clay was in a wet state. However, one vessel might feature simple impressions followed by

Decoration		State of paste		Total	
Technique	Tool	Wet	Leather-hard	*n*	*%*
Simple incisions	Unspecified	49	5	49	55.1
Simple impressions	All	47	0	47	52.8
	Cord	17	0	0	19.1
	Spatula	7	0	0	7.9
Simple oblique impressions	Spatula	22	0	0	24.7
	Almond	5	0	0	5.6
	Stump	3	0	0	3.4
	Pronged	2	0	0	2.2
	Hollow	1	0	0	1.1
Tilted impressions	All	6	0	6	6.7
	Spatula	6	0	0	6.7
Excisions	Hollow	2	0	2	2.2
Applique	Hands	1	1	1	1.1
No decoration	-	-	-	11	12.4

Table 7.5: Decorative techniques, split by tool and hydric state of the paste at the time of application. Simple oblique impressions count towards the total of simple impressions because this technique is a member of said family of decorative techniques, which is distinct because of a difference in the angle of insertion. Multiple decorative techniques may co-occur on the same vessel. The percentages are relative to the total number of vessels (n=89).

simple incisions, whereas another features simple incisions followed by simple impressions. In addition, some incisions do feature traces which indicate an operation on leather-hard clay, indicating drying occurred prior to the application of decorative techniques. As such, there is a general pattern in decorative techniques, but also variation.

Secondly, if evident, the application of decorative techniques appears to start at the rim and work downward. Indications for this procedure are impressions or incisions higher up the vessel body which are cross-cut by those below them. Moreover, impressions near the shoulder may exhibit more compact bases than those near the rim, indicating a relative difference in moisture between the times of application.

Following these two general observations, let us move on to discuss the specific decorative techniques and tools, starting with the most frequently found technique.

Simple incisions are the most common decorative technique (n=49, see Tab. 7.5). The term 'simple' implies the potter only made a linear cutting motion (cf. Roux 2019a p. 107 for the definition). Simple incisions most often show traces of an action on wet clay (n=44), and more rarely on leather-hard clay (n=5; see Tab. 7.5). The former category is evident from the thickened edges of the incisions, as well as the irregular microrelief, and sometimes ribbed striation, at the base of the incisions (see Fig. 7.9B). The thickened edges can disappear or be reworked due to surface treatment. By contrast, incisions made on leather-hard clay feature more compact microrelief at the bases and lack thickened edges (see Fig. 7.9C; cf. Roux 2019a pp. 204–5). Incisions which run along the circumference of the vessel tend to consist of multiple, smaller arcs, likely due to the discontinuous motion of the instrument as the vessel had to be rotated manually (see Fig. 7.9A). The starting and ending point of these incisions may also not join up.

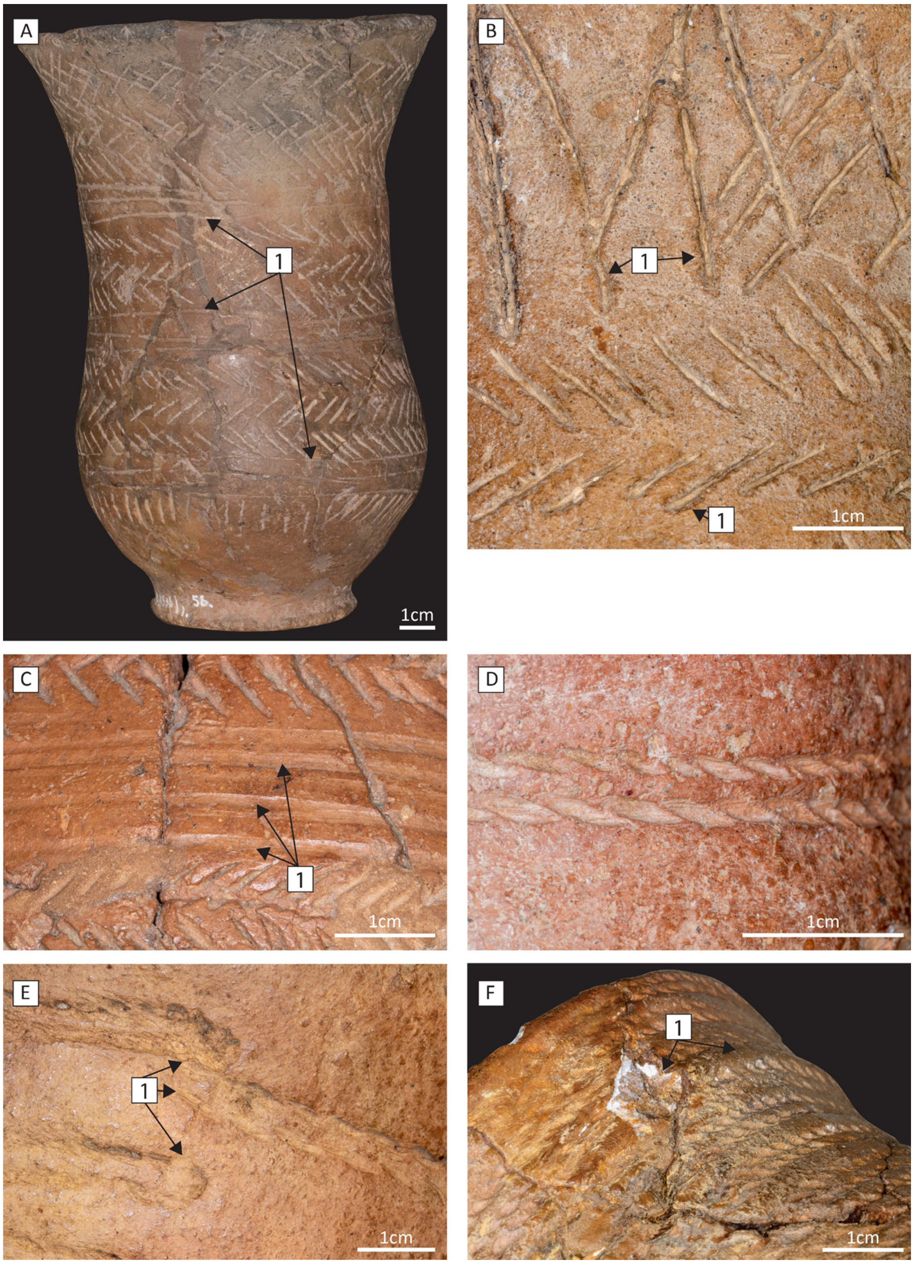


Figure 7.9: Decoration by simple incisions (A-C), simple impressions with cord (D-E), and appliques (F). A: Example of simple incisions on vessel 334. The horizontal incisions exhibit distinct arcs (1), likely because of the discontinuous motion of the incising action. B: Vessel 13 exemplifies traces of simple incisions on wet clay. The diagonal incisions exhibit clear thickened edges and irregular microrelief at the bases (1) which are indicative of an operation on wet clay. C: By contrast, vessel 313 exhibits signs of simple incisions on leather-hard clay. The horizontal incisions have compact microrelief at the bases and do not exhibit thickened edges (1). D: Simple impressions with an S-twisted cord on vessel 14; the bases of the impressions preserve imprints of the fibre, implying application to wet clay. E: Vessel 307 also exhibits simple impressions with an S-twisted cord, but the impressions preserve the folding point on the double cord lines and have thickened edges indicating an action on wet clay. F: Application of a cordon on the surface of vessel 76, resulting in a local over-thickness around the circumference of the upper body (1). Cord impressions cut across the cordon.

Simple impressions are the second most common technique and feature on 47 vessels and exhibiting considerable variation in tools used (see Tab. 7.5). The term simple impression means the potter only inserts and extracts the tool (cf. Roux 2019a p. 106 for the definition). In general, the bases of these impressions exhibit a (highly) irregular microrelief. Moreover, the base of cord impressions often retains imprints of the fibre. The simple impressions may also feature thickened edges or plastic deformation of the surrounding area. In sum, these impressions were made on wet clay (cf. Roux 2019a pp. 204–5).

For analytical purposes, a distinction is made between simple, and simple oblique impressions. The difference between the two is the angle of the tool relative to the surface of the vessel upon insertion. In simple impressions, the angle of insertion is roughly perpendicular to the vessel wall, whereas the angle is oblique in simple oblique impressions (cf. Roux 2019a p. 106).

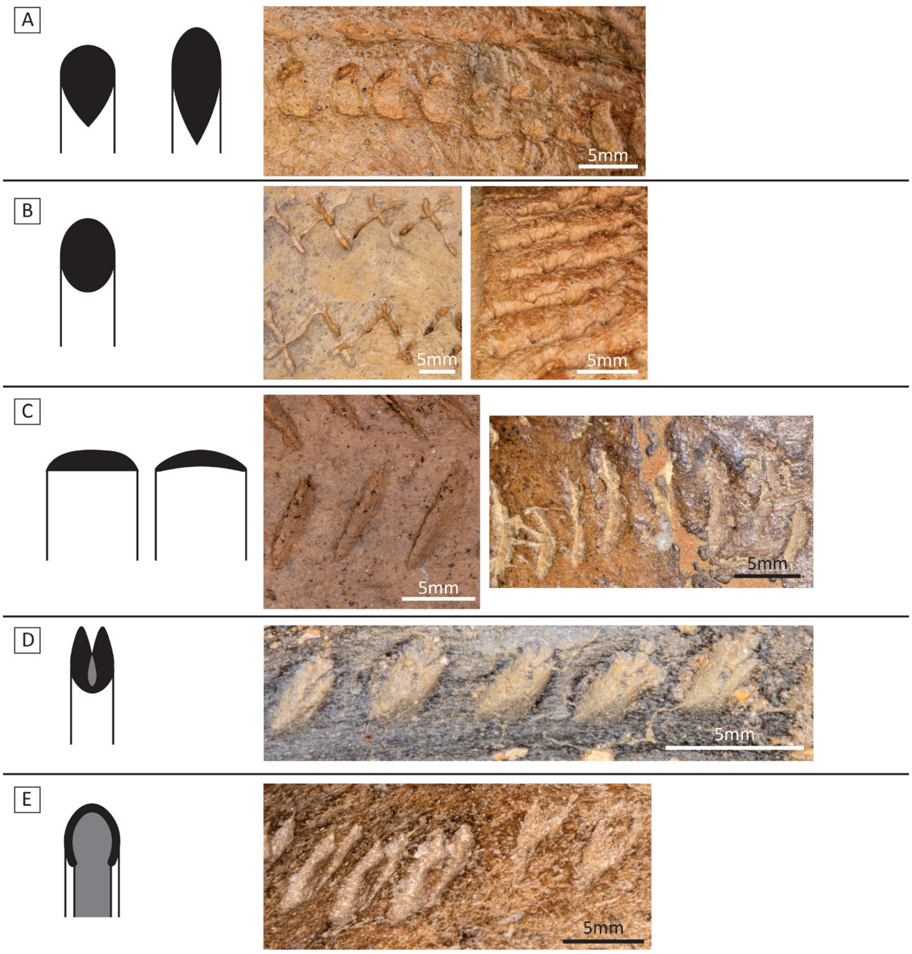


Figure 7.10: Decorative impressions with various tools. A: Double row of simple oblique impressions from an almond-shaped tool on vessel 55. B: Simple oblique impressions with a stump tool on vessels 18 (left) and 147 (right), the latter with jagged outline. C: Use of spatula for impressions. Simple impressions on vessel 169 (left) and simple oblique impressions on vessel 54 (right). D: Simple oblique impressions with a pronged tool on vessel 142. E: Simple oblique impressions with a hollow tool on vessel 117.

The most common tool for making simple impressions is the spatula (n=35; see Tab. 7.5). The term spatula refers to a tool category with considerable internal variation, unified by an elongated form in which (at least) one side is rounded. The other side may be rounded or straight. The joints between the two sides are either sharp or rounded (see Fig. 7.10C). In some cases, spatulae seem to have been used for multiple decorative techniques on the same vessel, such as simple incisions and simple impressions.

The second most common tool for impressions is cord (n=17; see Tab. 7.5; Fig. 7.9D & E). Several authors stress the distinction between S- and Z-twisted cord for the overall interpretation of Corded Ware (Grömer and Kern 2010 see further references; e.g. Larsson 2009 p. 244). All observed impressions feature S-twisted cord, as is common in Corded Ware vessels throughout Europe. The bases of these simple impressions do preserve the texture of the fibre, but the nature of the fibre could not be retraced.

Four additional tools for the making of impressions occur in the dataset (see Tab. 7.5), but are less common. The first group are almond-shaped tools (n=5) which have a cone-like tip with one rounded and one pointy end (see Fig. 7.10A). The tip may be more elongated (hence the name almond), or more rounded (in which case the form is more tear-shaped), but either way the diameter of the tool appears to have been rounded, rather than the elongated shape of spatulae. Stump tools (n=2) have a similar rounded diameter, but end in a flat tip cut more or less oblique to the length of the tool. As a result, impressions with this tool are elongate, and rounded impressions (see Fig. 7.10B). The third group of tools are the pronged tools, of which impressions occur only once in the studied vessels. This tool has multiple tips which leaves a depression with a differentiated base (see Fig. 7.10D). Lastly, hollow tools are rounded with raised edges, but leave the surface in the middle of the impression intact, resulting in a horseshoe shape (see Fig. 7.10E). Impressions from hollow tools occur on only one studied Corded Ware vessel (see Tab. 7.5).

This brings us to the final three decorative techniques in Corded Ware specific *chaînes opératoires*: tilted impressions, excisions, and appliques.

Tilted impressions are distinct from simple impressions by the motion of the tool. In simple impressions, the potter inserts and extracts the tool, whereas in tilted impressions, the potter twists or tilts the tool between insertion and extraction (cf. Roux 2019a p. 106). In Corded Ware vessels, the resulting impressions often exhibit the characteristics of a simple impression on one side (insertion), with a more elongated shape which ends in a shallow, sloping depression on the other end (see Fig. 7.11A&B). In all cases (n=6, see Tab. 7.5), the tool employed appears to have been a spatula of the type described under simple impressions (see Fig. 7.10C). The bases of these impressions have an irregular microrelief and may feature thickened edges. Therefore, this operation was applied to wet clay. Tilted impressions can be hard to distinguish from short, simple incisions. Tilted impressions are diagnosed if the base of the depression lacks the striations which would result from a cutting motion.

Excisions occur on 2 vessels (see Tab. 7.5). The tools for making excisions are hollow tools (as described under impressions, see Fig. 7.10D). These tools are inserted at an oblique angle. As such, the distinction between excisions and simple oblique impressions is complex (see also Ch. 6). Decorative depressions have been marked as excisions if 1) the depth is considerable, and 2) one end of the impressions undercuts the vessel wall (see Fig. 7.11C-D). These characteristics result from the insertion and extraction of a tool. In general, the excisions feature bases with an irregular microrelief and ribbed striation.

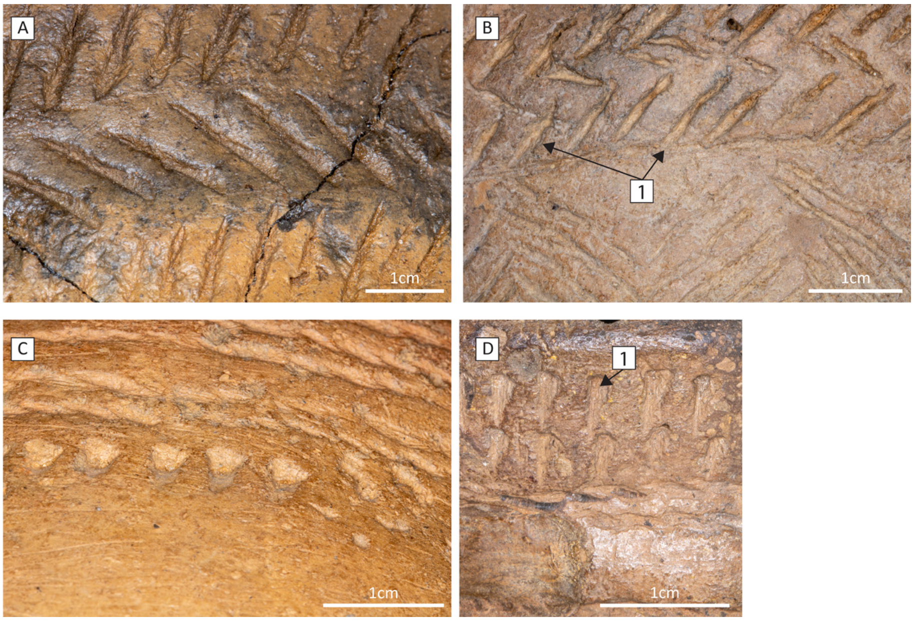


Figure 7.11: Tilted impressions (A-B) and excisions (C-D). A: Tilted impressions with a spatula on vessel 50. The spatula was inserted, tilted downward, and extracted resulting in a-symmetric depressions. B: Tilted impressions on vessel 327, the irregular width of the impressions results from movement of the tool after insertion. The depressions have thickened edges and cross-cut adjacent simple incisions (1), indicating an action on wet clay. C: Excisions on vessel 161 (viewed from below) with a tool with a rounded diameter which is inserted at an oblique angle, leaving irregular microrelief on the remaining vessel wall. D: Excisions in vessel 53, presumably on wet clay given the irregular microrelief and striation (1) at the base of the depressions.

This indicates they have been made on clay which was not entirely leather-hard (see Ch. 6; Fig. 7.11C-D; cf. Roux 2019a pp. 108, 204).

Only 1 vessel in the Corded Ware body of knowledge has a decorative applique (see Tab. 7.5; cf. Roux 2019a p. 109). In this case, a cordon was applied to the upper exterior of the vessel, resulting in a localised over-thickness. The application of simple impressions followed the application of this cordon (see Fig. 7.9F), indicating the clay was likely still wet when the cordon was applied to the vessel wall. Contrary to the applied masses employed for handles (see preforming), the applied cordon was not modelled or perforated, and thus does not seem to have been intended as a handle. Hence its inclusion under decorative techniques.

Surface Treatment

Surface treatments modify the surface appearance of a vessel (Roux 2019a p. 96). The detection and identification of surface treatment techniques is subject to a caveat. All identifications outlined below follow from observations with the naked eye or a hand lens (10x magnification). Optical microscopy is preferable for detection of surface treatment (cf. Lepère 2014; Roux 2019a), but could not be performed due to time constraints. As such, the interpretations below are kept at a generic level. In all, 70 Corded Ware vessels yield traces of surface treatment (see Tab. 7.6).

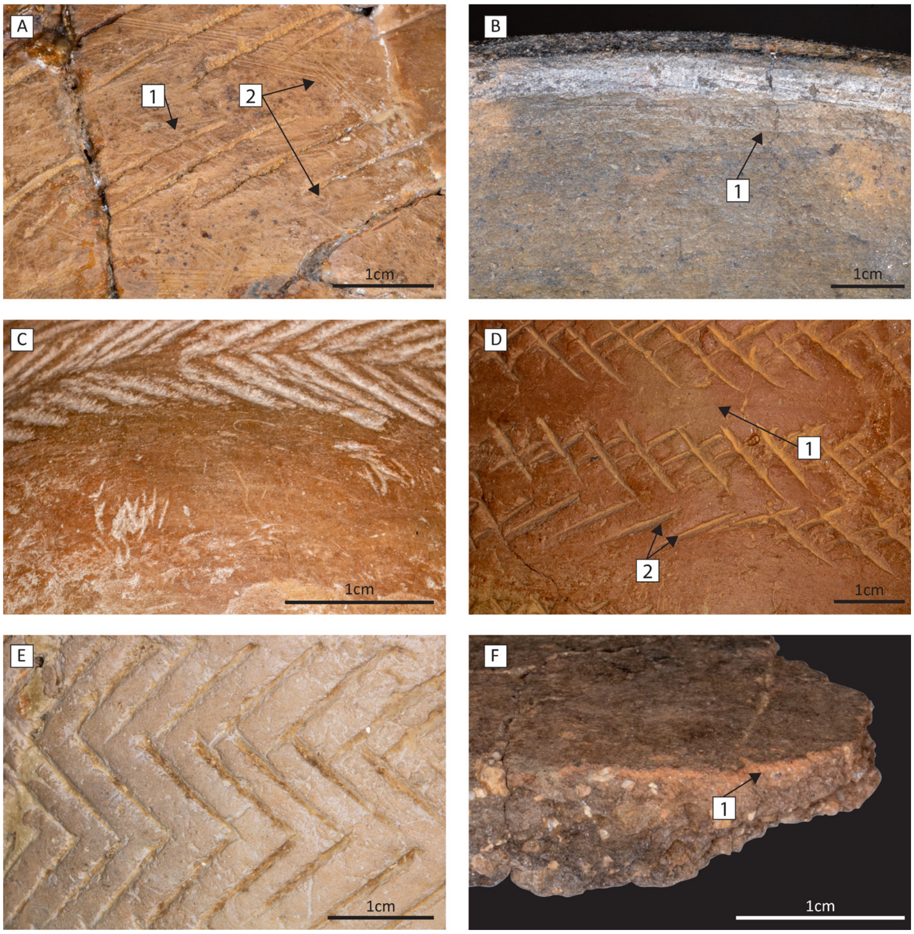


Figure 7.12: Surface treatments: Burnishing (A-B), burnishing and shining (C), shining (D-E), and smudging (F). A: Traces of burnishing on the upper exterior of vessel 78. Banded striations with regular or scalloped edges (1) in diagonal orientation cut across the decoration (2) on a surface with a compact microtopography, glossy aspect, and inserted particles. B: Traces of burnishing on the upper interior of vessel 57 in the shape of a surface with a compact microtopography, high gloss, inserted particles, and bands of parallel horizontal striations with compact bases and scalloped edges (1). C: Shining on a burnished surface on the exterior shoulder of vessel 136. The surface has a compact microtopography, glossy aspect, inserted grains, and subdued striations from burnishing. The reworking was likely a shining operation, given the smoothened down edges of the striations and decorative depressions. D: The upper exterior of vessel 312 exhibits a surface with traces of shining. The surface exhibits a slight gloss, a compact microtopography with inserted particles, as well as subdued traces of an action with a hard tool (1), and reworked edges of the decoration (2). E: The upper exterior of vessel 310 also exhibits traces of shining (see panel D), but with additional signs of erosion. F: The core and surface of vessel 176 shows signs of smudging. The exterior surface is darkened and glossy but overlies a red-brown margin of the core (1).

Table 7.6: Surface treatment on Corded Ware vessels. The percentages are relative to the total number of vessels studied (n=89). A vessel may exhibit traces of multiple surface treatments.

	Corded Ware	
Technique	*n*	*%*
Burnishing	38	42.7
Shining	37	41.6
Smudging	5	5.6
None Detected	19	21.3

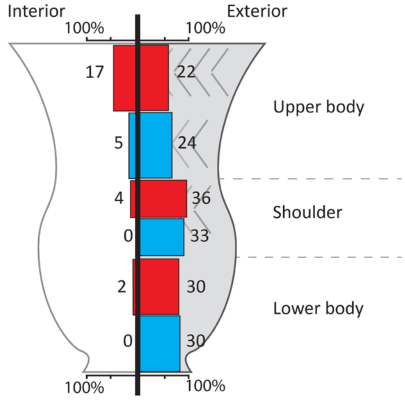


Figure 7.13: Schematic Corded Ware vessel with vertical bar chart of surface treatment operations burnishing (red) and shining (blue). The labels indicate the absolute number of vessels for which traces were found in that particular location. The percentages are relative to the total number of vessels with traces of either burnishing, or shining (see Tab. 7.6). Both operations are preferentially performed on the exterior surface, in particular the lower and shoulder, and slightly less often on the upper exterior surfaces. Burnishing also occurs on the upper interior surface, but traces of both techniques are otherwise relatively rare on interior surfaces.

The most common surface treatment technique is burnishing (n=35; see Tab. 7.6). Burnishing involves rubbing a hard object against leather-hard or dry clay and results in glossy surfaces with a compact microtopography, inserted particles, and striations with scalloped edges if the paste was leather-hard at the time, or more regular edges if the paste was drier (cf. Roux 2019a p. 201; Fig. 7.12A-B). Signs of burnishing most commonly occur around the exterior shoulder, lower exterior, upper exterior, and lastly, the upper interior of the vessel. Only in a handful of cases do such traces occur further down the interior surface (see Fig. 7.13; Tab. 7.6). Traces of burnishing on the exterior body regularly cut across decorations. By far, most observed traces are consistent with burnishing on soft leather-hard paste (n=36; see Tab. 7.6), but in two cases burnishing on stiff leather-hard or dry paste seems more likely.

The second most commonly observed surface treatment is shining (n=37, see Tab. 7.6). Shining involves rubbing the surface of a leather-hard or dry vessel with a soft object such as leather. These surfaces show some characteristics of finishing operations, but the protrusions appear subdued (especially the decorations, or striation from finishing operations with a hard tool) and surfaces may exhibit a slight sheen and a compact topography. Little to no macroscopic striation occurs (Lepère 2014; Roux 2019a p. 202; see Fig. 7.12C-E). Traces of shining occur most often on the exterior surface, especially on the shoulder and lower body, and sometimes on the upper interior, but never further down the interior surface (see Tab. 7.6, Fig. 7.13). In two cases, traces of shining appear to cut across traces of burnishing (see Fig. 7.11E). In all cases, the observed surfaces match those which Lepère (2014) classifies as occurring on soft or stiff leather-hard pastes.

The final form of surface treatment is smudging. This surface treatment is relatively rare (n=5; see Tab. 7.6, Fig. 7.12F). Smudging occurs after or towards the end of the firing process and consists of exposing ceramics to smoke, which permeates the exposed surfaces with carbon (cf. Drieu *et al.* 2020; Roux 2019a p. 101). The vessels designated as smudged exhibit the following characteristics. The surfaces are dark grey and often exhibit moderate gloss. The dark grey surfaces flake off to reveal, or in cross-section can be seen to overly, an oxidised (red-brown or yellow-brown) margin (see Fig. 7.12F). These characteristics must be consistent across a larger part of the vessel surface (i.e. incidental 'staining' during firing is excluded). Drieu *et al.* (2020) show that these traces are typical for covering a vessel with organic material while it is still hot from firing.

Drying

Drying cannot be observed directly on archaeological vessels. However, it is possible to infer the position of drying phases in the specific *chaîne opératoire* from traces left by other operations.

A general pattern emerges with regard to drying for the Corded Ware vessels studied here. The entire specific *chaîne opératoire* from roughing out, preforming, finishing, and ultimately decoration (with some exceptions, see Tab. 7.5; Fig. 7.10C) tends to be performed on wet clay. Surface treatment operations are the first actions detected on leather-hard clay. Traces of surface treatment on dry clay are rarely detected, and only one operation (smudging) occurs after firing. Therefore, the drying of the paste to leather-hard consistency can generally be placed between the application of decorative techniques and surface treatment, whereas drying to dry consistency can be placed between surface treatment and firing.

Firing

Archaeological vessels do not allow for a full reconstruction of firing processes. Such a full understanding of firing processes encompasses information on firing atmosphere, firing temperature, soaking time, firing architecture, fuel usage, and arrangement and treatment of the vessels (cf. Roux 2019a). Effectively, macroscopy only provides information on firing atmospheres.

A clear pattern emerges from observations of firing cores (see Tab. 7.7). In all vessels, the exterior surface generally exhibits lighter yellow or red shades of brown from oxidation. In addition, the interior surface generally exhibits similar colours in 79 out of 89 vessels, whereas the remaining 10 exhibit grey tones typical for uncombusted carbon or reducing firing atmospheres. Due to refitting, firing cores could only be observed on 71 vessels. 14 of these vessels exhibit a fully oxidised core. The remainder

	Corded Ware	
Core	*n*	%
Ox-sRed-Ox	47	52.8
Ox-Ox-Ox	14	15.7
Ox-Indet-Ox	18	20.2
Ox-sRed-Red	9	10.1
Ox-Indet-Red	1	1.1

Table 7.7: Firing atmospheres. All percentages relative to the total number of vessels (n=89). The codes indicate the succession of colours observed from the outer margin towards the inner margin. 'Ox' is a short-hand for reddish and yellowish colours from oxidising firing atmospheres, whereas 'Red' indicates shades of grey from uncombusted carbon or reducing atmospheres. 'Indet' implies no colour could be observed, f.e. due to refitting. The different zones of the core (outer margin, core, inner margin) are separated by dashes. The letters 's' and 'v', which precede the description of the core, indicate whether the boundaries between two zones are sharp or vague respectively. Vessels may exhibit some variation in firing cores throughout the vessel; the dominant colour is noted here.

all exhibit grey tones with sharp transitions to the red and yellow colours of the exterior and/or interior margins (see Fig. 7.14). Such cores result from a rapid influx of cold, oxygen-rich air after firing in a reducing atmosphere and/or firing at temperatures below the combustion point of carbon. They typically result from a firing process whereby the vessels are fired in an enclosed space such as an oven, stacked, or covered by fuel during firing, followed by rapid cooling as the oven is broken open or the vessels are recovered from underneath the fuel (Roux 2019a; Rye 1981).

Further evidence for these factors can be obtained by looking at the surface colours per vessel part. Figure 7.15 is a vertical bar chart of the occurrence of bright, oxidising colours and grey, reducing colours across vessel surfaces. The bar chart shows oxidising colours are most common on all vessel surfaces and reducing colours relatively more common on interior surfaces (cf. Tab. 7.7). Two further patterns stand out. Firstly, a small number of vessels exhibits reducing surface colours on the upper exterior, especially around the rim (e.g. Fig. 7.9A). Secondly, reducing surface colours appear most often on the lower interior

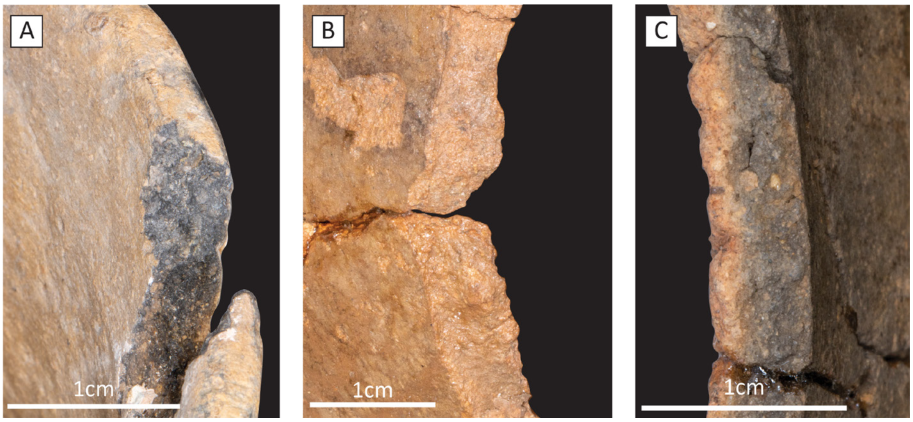
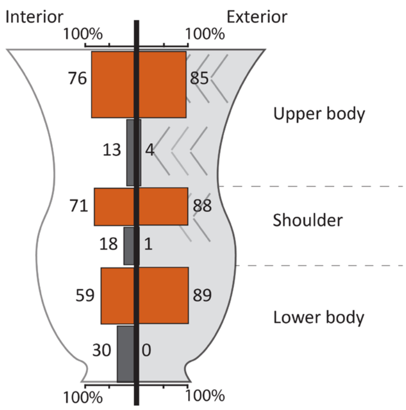


Figure 7.14: Firing atmospheres. A: The firing core of vessel 161 features red to yellow margins and a sharp transition to a grey core (code: Ox-sRed-Ox). B: The firing core of vessel 66 shows no distinction between the core and margins, all exhibit red-brown colours (code: Ox-Ox-Ox). C: Sharp transition between the red-brown colours of the exterior margin and the grey colour of the core and interior margin on vessel 168 (code: Ox-sRed-Red).

Figure 7.15: Vertical bar chart showing the distribution of oxidising (terracotta) and reducing (grey) surface colours by vessel part in Corded Ware vessels. The width of the bars indicates the percentage of vessels with a surface colour relative to all vessels (n=89); the numbers are the absolute number of vessels. These numbers may differ from those in Tab. 7.7, which only scores the dominant surface colours. Oxidising surface colours are most common on all vessel parts, reducing surface colours appear relatively more often on the interior, especially the lower interior. A small number of vessels exhibits reducing surface colours on the upper exterior and shoulder exterior.



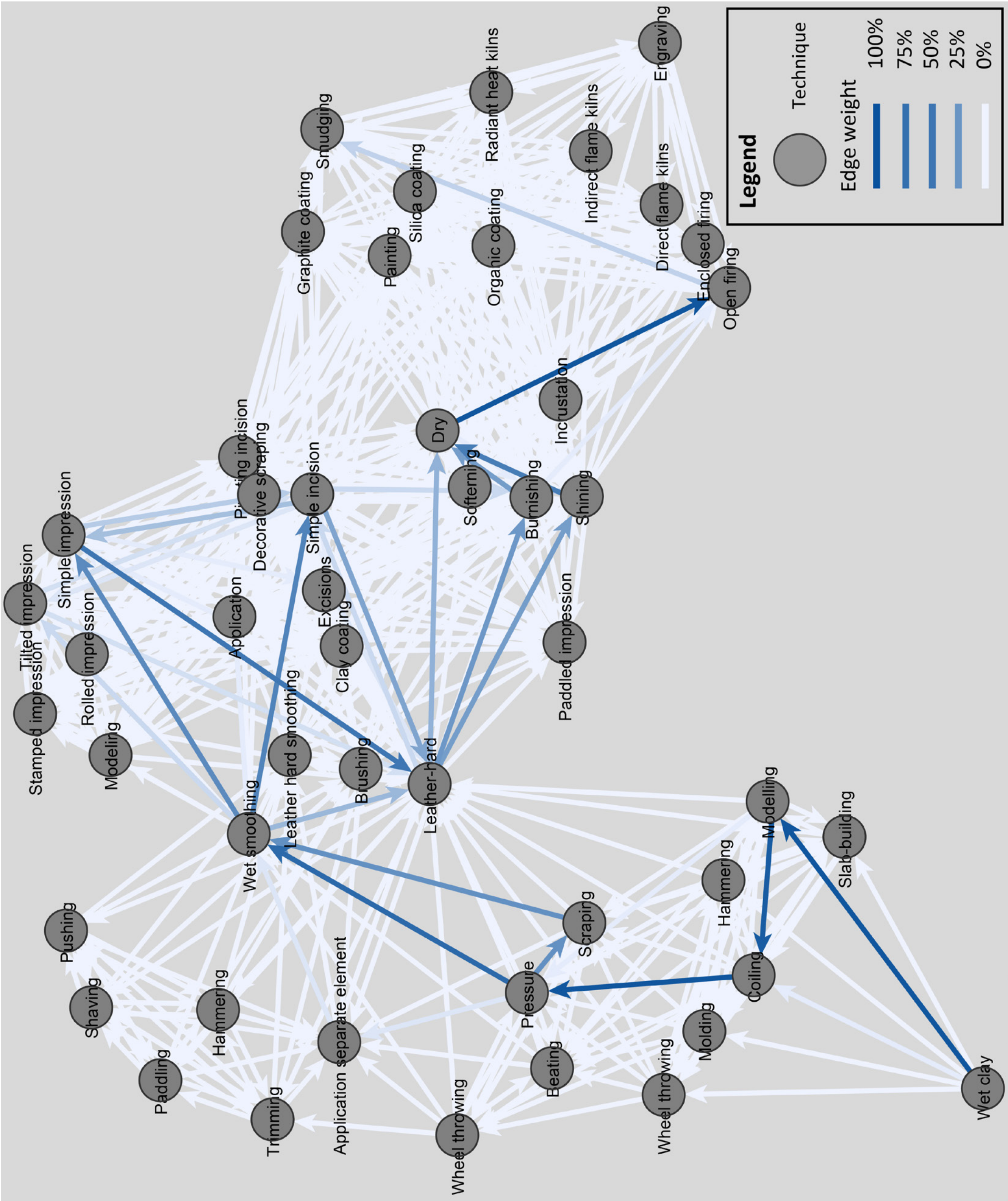


Figure 7.16: Visual summary of the Corded Ware specific *chaînes opératoires* through a network representation. The nodes are techniques, and the edges indicate two techniques can occur in sequence. The darker the blue of the edges, the more specific *chaînes opératoires* traverse the edge.

but far less often on the shoulder and upper interior (see Fig. 7.15). This suggests vessels were stacked or filled with fuel during firing such that the lower interior surfaces did not always undergo oxidation. The reducing surface colours on the upper and shoulder exterior may result from some vessels being positioned side-ways while firing.

7.3 Summary

This chapter is an overview of the 89 specific *chaînes opératoires* in the Corded Ware body of knowledge. Figure 7.16 is a visual summary of these specific *chaînes opératoires* as paths through the total *chaîne opératoire* (see Ch. 4). The visual summary only captures sequences of techniques (e.g. coiling, burnishing), and not modalities of techniques (e.g. coiling by pinching or spreading).

Corded Ware specific *chaînes opératoires* most often start with modelled bases, which can be pressed into flat surfaces or be supplemented with additional coils. The vessel wall is most often made through coiling with the segment or ring procedure. Several different joining procedures are detected. Preforming most often consists of the application of continuous pressure with hands, and less often scraping. The amphorae also exhibit applied clay masses which are fashioned into handles during this stage. Finishing involved the use of hard and soft tools on wet clay, sometimes side-by-side in different zones of the same vessel. Decorative techniques, if applied, most often fall between finishing and surface treatment, and predominantly occur on wet clay. The foremost decorative techniques are simple incisions and simple (oblique) impressions with various tools. Excisions, appliques, and tilted impressions feature decidedly less often. Vessels may exhibit signs of multiple decorative techniques. The next step in most specific *chaînes opératoires* is drying the paste to at least a leather-hard state. The subsequent surface treatments all occur on clay with at least soft leather-hard consistency. Surface treatment itself, if detected, consists of burnishing or shining, and is often limited to specific zones on the vessels. These operations are the last observed actions prior to further drying and firing. Firing itself most often seems to have ended with the rapid influx of cool air in reducing atmospheres. In a handful of vessels, firing may have been followed by the surface treatment smudging.

8

Petrography of Funnel Beaker West and Corded Ware Vessels

The subject of this chapter is the petrographic analysis of 64 Funnel Beaker West and 32 Corded Ware vessels. Ceramic petrography sheds light on two steps in the ceramic production process which cannot be studied with the naked eye alone: raw material selection and paste preparation. In addition, ceramic petrography provides complementary evidence for various other techniques, such as coiling and burnishing, as well as the provenance of the raw materials.

This chapter starts with a description of the petrographic groups (see Section 8.1). These groups are a summary of the reports for individual thin sections (see Appendix E) and capture patterns in the petrographic data which inform the discussions on ceramic technology and provenance below. We then move on to evidence for specific production techniques, particularly raw material selection and paste preparation (Section 8.2). In Section 8.3, the petrographic analysis is used to narrow down the potential raw material sources for the vessels, but a dedicated provenance study would be necessary for definite conclusions. The chapter ends with an overview of the above-mentioned outcomes in Section 8.4.

Specialised terms appear throughout this chapter, chiefly for grain sizes (e.g. 'fine gravel' and 'coarse sand') and the description of thin sections (e.g. 'bimodal grain size distribution' and 'calcareous matrix'). Table 8.1 is an overview of the terminology for grain sizes. All terminology relating to the description of thin sections can be found in Table 5.2 (and the references therein).

Table 8.1: Terminology for grain sizes of sediments used in the text. These size ranges are based on a national standard (NEN5104) which is broadly used for the description of sediments in the Netherlands (cf. Van der Meulen *et al.* 2003).

Name	Subdivision	Size range
Clay		<2 μm
Silt		≥2-63 μm
Sand	Fine sand	≥63-210 μm
	Coarse sand	≥210-2000 μm
Gravel	Fine gravel	≥2-5.6 mm
	Coarse gravel	≥5.6-63 mm

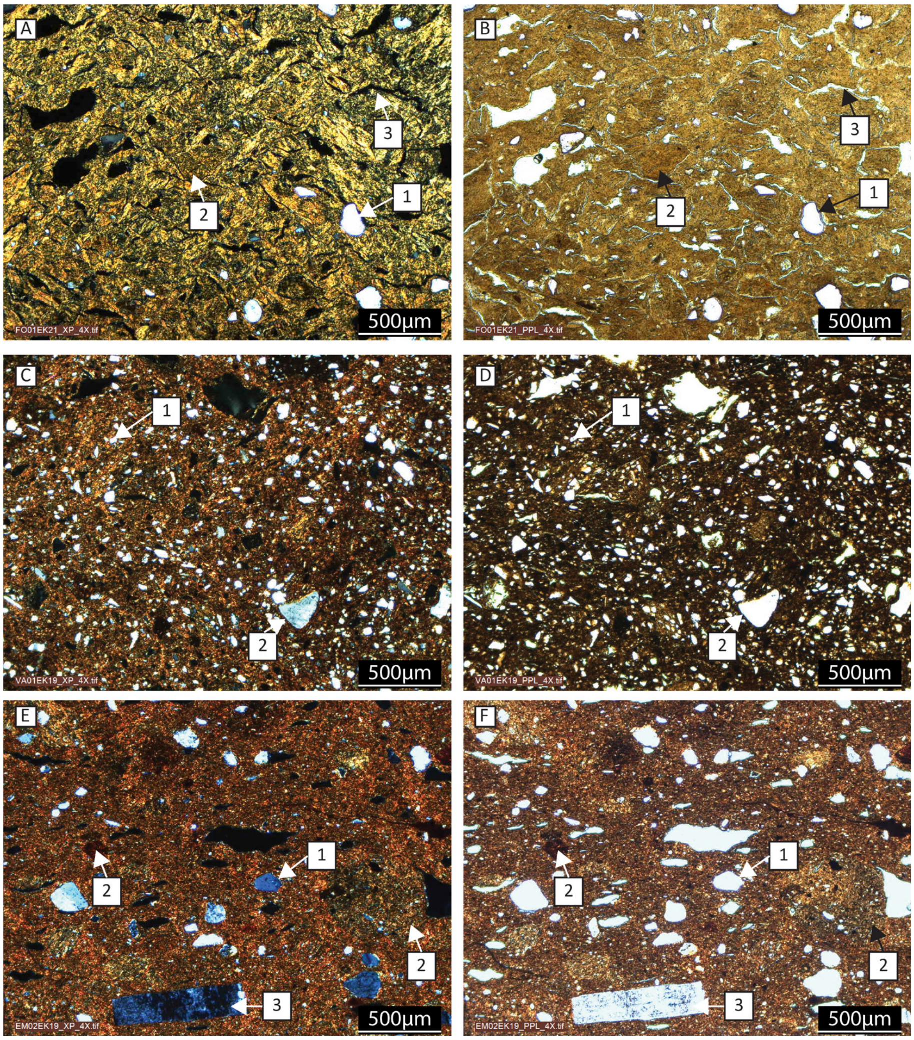


Figure 8.1: Micrographs of representative thin sections from groups 1, 2, and 3. A: FO01EK21 under crossed polars. This fabric belongs to group 1 and contains fine to coarse sand (1) but no grog in this case. The interference colour of the matrix is yellow-brown and clay lumps with diffuse boundaries occur (2). The porosity is relatively high with many elongated sinusoid voids (3). B: FO01EK21 in plane polarised light, see A for description. C: VA01EK19 under cross polarised light. This fabric is part of group 2. The interference colour of the matrix is brown and the matrix itself is compact with abundant silt (1) and occasional fine to coarse sand (2). D: VA01EK19 under plane polarised light, see C for a description. E: EM02EK19 in cross polarised light. The clay matrix exhibits red-brown interference colours, and the coarse fraction of the inclusions consists of coarse sand (1), clay lumps (2), and rarely angular igneous rock, in this case feldspar (3). F: VA01EK19 under plane polarised light, see E for a description.

8.1 Fabric Groups

The studied thin sections fall into four petrographic groups based on the properties of the matrix, inclusions, and pores. These factors inform the interpretations of techniques and provenance below. Table 8.2 shows the characteristics of each fabric group, Table 8.3 shows the distribution of the fabric groups across the bodies of knowledge. The following sections provide accompanying descriptions and illustrations (see Fig. 8.1; 8.2).

Group 1: Porous Fabric with Calcareous Clay, Sand, and Grog

The samples in the first fabric group exhibit the following characteristics (see Fig. 8.1A-B). Firstly, the coarse fraction of the inclusions features two components. The first component is a low amount (commonly around 15-5% surface area) of fine to coarse, rounded sand. The sand particles tend to be silicate: quartz is common, quartzite, chert, and feldspar occur less often (see Tab. 8.2). The second component is a low amount (<15% surface area, but often <5%) of larger, angular grog particles (see Tab. 8.2). In addition, the matrix is calcareous and exhibits yellow-brown interference colours in oxidised sections. The core either exhibits similar yellow-brown interference colours, or dark brown interference colours (see Tab. 8.2). The last characteristic of this fabric group is relatively high porosity (20-5%, typically 10-20% surface area; see Tab. 8.2). These pores primarily consist of elongated, sinusoid voids.

Apart from these defining characteristics, thin sections in this fabric group tend to exhibit high heterogeneity, particularly streaks and clay lumps with red-brown interference colours. Charred plant matter is usually absent with only two exceptions (see Tab. 8.2).

Fabric group 1 consists exclusively of Corded Ware beakers (see Tab. 8.3). The fabric group is highly similar to group IV: sand-tempered porous fabric in Kroon *et al.* (2019), which also consists of Corded Ware beakers from various sites in the coastal areas of the Netherlands.

Group 2: Compact Fabric with Silt and Coarse Grog

The second group has two defining characteristics (see Fig. 8.1C-D; Tab. 8.2). The first characteristic is a relatively high amount of silt in the fine fraction of the inclusions. As a result, the surface area taken up by inclusions lies around 30% (see Tab. 8.2). The inclusions in the fine fraction make up between 20 and 25% of the surface area. The silt is rich in rounded quartz. The second characteristic is the relatively low porosity (typically below 10% surface area) with vughs as the dominant void shape (see Tab. 8.2). However, there are a couple of samples with more elongated, sinusoid voids. The primary constituents of the inclusions in the coarse fraction are angular grog particles in combination with a fluctuating amount of coarse sand. This sand consists mainly of quartz, and other particles include feldspar, quartzite, and chert (see Tab. 8.2). The matrix tends to exhibit pale brown interference colours with occasional lighter yellow-brown colours at the margin and darker shades of brown at the core (see Tab. 8.2). Charred plant matter is absent in this group except for an isolate (see Tab. 8.2).

Fabric group 2 exclusively consists of Corded Ware vessels from various sites (similar to group 1). Both beakers and short-wave moulded vessels are present (see Tab. 8.3).

Group	1	2	3	4
Name	**Porous fabric with calcareous clay, sand, and grog**	**Compact fabric with silt and coarse grog**	**Compact fabric with grog, coarse sand, and grit**	**Poorly homogenised, bimodal fabric with grit and organics**
Samples	RU01EK19, BA01EK19, DR01EK19, EM03EK19, AN01EK19, NN02EK19, FO21EK1, XX21EK1, NN21EK4, EE21EK1	SL01EK19, VA01EK19, EP02EK19, BE01EK19, EM21EK4, AN02EK19	EM01EK19, HI21EK1, EE21EK2, HA21EK1, ZE01EK19, EM02EK19, NN01EK19, RO01EK19, EX01EK19*, BO21EK1, AN03EK19*, OD21EK1	Subgroup 1: EK21EM6, WE01EK19, HU03EK19, HU05EK19, MA21EK10, MA21EK8, EK21HO4, EK21HO5, EK21OD5, EK21OD6, EK21SP1, EK21SP2, EK21SP3, EK21SP4, EK21TY5, EK21TY6, EK21TY7, EK21TY8, EK21AA3, EK21AA4, EK21BE1, EK21BR1, EK21EK2, EK21EM9, EK21EM10, EK21EX2, EK21EX3, EK21HO2. Subgroup 2: EK21HO1, HU04EK19, HU02EK19, EP01EK19, HU01EK19, MA21EK5, NN21EK3, MA21EK1, MA21EK6, MA21EK9, MA21EK7, GI21EK1, NN21EK5, EK21HO6, EK21OD2, EK21OD4, EK21OD7, EK21OD8, EK21TY1, EK21TY2, EK21TY3, EK21TY4, EK21TY9, EK21AA1, EK21AA2, EK21AA5, EK21BR2, EK21EK1, EK21EM3, EK21EM7, EK21EM8, EK21EM11, EK21EX4, EK21EX5, EK21HO3, EK21BE2, MA21EK2, MA21EK3, MA21EK4, EK21OD3
Surface treatment	7 out of 10; Indicators of surface treatment by friction often only on one margin.	4 out of 6; Indicators of surface treatment by friction often only on one margin.	8 out of 12; Indicators of surface treatment by friction on one, or both margins.	57 out of 68; Indicators of surface treatment by friction most often on both margins. 8 out of 68 samples have indicators of smudging.
Matrix				
Colour (XP), optical activity, composition	Pale yellow-brown to dark brown in XP. Optical activity. Heterogeneous: clay lumps, laminations, and streaks. Calcareous.	Pale yellow-brown to dark brown in XP. Optical activity. Heterogeneous: primarily clay lumps, sometimes streaks. Calcareous.	Generally pale red-brown, varies from pale yellow- brown to dark brown. Optical activity. Heterogeneous: primarily clay lumps, some streaks and laminations. In between calcareous and ferruginous, or calcareous.	Pale yellow-brown to dark brown in XP. Optical activity. Heterogeneous: primarily streaks and lamination, less often clay lumps. Most often calcareous, rarely ferruginous (GI21EK1, EK21EK1, EK21HO6), or in between.
Porosity (approx.)	20-5%, mostly elongated sinusoid voids with moderate to poor orientation parallel to margins. More rarely vughs, planar voids, and vesicles.	10-5%, mostly vughs and elongated voids, more rarely channels, planar voids, and vesicles. Poor to moderate orientation parallel to margin.	5-20%, elongated voids, vughs, and vesicles. Strong to poor orientation to margin.	5-20%, planar voids, elongated voids, channels, vesicles, and vughs. Poor to strong orientation to the margin, often diagonal.
Paste (approx.)	80-55%	65-55%	85-55%	85-50%
Inclusions				
Description	10-30%. Bimodal, very poorly to moderately sorted, <3.6mm.	30%. Bimodal. Poorly to very poorly sorted. <3.45mm.	10-30%. Bimodal. Very poorly to moderately sorted. <3.35mm.	10-40%. Bimodal. Very poorly to poorly sorted. <4.25mm.
Igneous rock				
Granitic	Absent	Rare, <0.25mm, s.a.-a.	Rare to Very Rare, <2.1mm, v.a.-w.r.	Few-Rare, <4.25mm, v.a.-r.
Microgranite	Absent	Absent	Absent	Very Rare, <0.75mm, s.r.
Granodiorite	Absent	Absent	Absent	Very Few to Few, <3.4mm, a.-s.r.
Diorite	Absent	Absent	Absent	Few to Very Rare, <2.95mm, a.-s.r.
Gabbroic	Absent	Absent	Absent	Few, <2.2mm, a.-s.r.
Mafic	Absent	Absent	Very Rare, <0.2mm, w.r.	Rare, <1.05mm, a.
Ultramafic	Absent	Absent	Absent	Very Rare, <0.6mm, r.-s.r.

Group	1	2	3	4
Name	**Porous fabric with calcareous clay, sand, and grog**	**Compact fabric with silt and coarse grog**	**Compact fabric with grog, coarse sand, and grit**	**Poorly homogenised, bimodal fabric with grit and organics**
Indeterminate	Very Rare, <0.2mm, w.r.	Absent	Very Rare, <3.3mm, s.a.-s.r.	Absent
Metamorphic rock				
Quartzite	Rare to Very Rare, <0.6mm, w.r.-r.	Very Rare to Rare, <0.6mm, w.r.-s.r.	Rare to Very Rare, <0.72mm, w.r.-r.	Very Rare to Few, <1.85mm, w.r-a.
Felsic metamorphic	Absent	Absent	Absent	Very Rare-Few, <3.05mm, a.-s.r.
Sedimentary rock				
Chert	Very Rare, <0.3mm, w.r.	Very Rare to Rare, <0.25mm, r.-s.r.	Very Rare to Rare, <0.55mm, w.r.-a.	Very Rare to Rare, <0.6mm, r.-v.a.
Sandstone	Absent	Absent	Absent	Very Rare to Very Few, <2.05mm, w.r.-a.
Limestone	Absent	Absent	Absent	Very Rare, <0.3mm, a.
Mudstone	Absent	Absent	Absent	Rare, <0.4mm, w.r.
Minerals				
Quartz	Few to Rare, <0.85mm, w.r.-s.a.	Very Rare to Very Few, <1.1mm, w.r.-s.a.	Few-Very Rare, <0.95mm, w.r.-a.	Very Rare to Few, <1.55mm, w.r.-s.a.
Feldspar	Rare, <0.3mm, w.r.	Very Rare to Very Few, <0.8mm, w.r.-a.	Very Rare to Rare, <0.55mm, r.-s.a.	Very Rare, <1.35mm, s.r.
Opaque particle	Absent	Very Rare, <0.35, r.-s.a.	Absent	Very Rare to Rare, <0.35mm, w.r.-s.r.
Other inclusions				
Grog	Few to Rare, <3.6mm, a.-s.a.	Few to Very Few, <3.45mm, a.-s.a.	Very Few to Very Rare, <3.35mm, a.-s.a.	Absent
Clay lumps	Few to Rare, <1.75mm, w.r.-a.	Few to Rare, <0.95mm, w.r.-s.a.	Few to Rare, <2.95mm, w.r.-a.	Very Rare tot Few, <3.35mm, w.r.-s.a.
Charred plant matter	Seldom, 2 (out of 10) exceptions (NN02EK19, systematic; XX21EK1)	Seldom, for 1 (out of 5) exception (BE01EK19)	Seldom, 2 (out of 12) exceptions (HI21EK1; EM02EK19)	Common, 46 (out of 68): HU04EK19, HU02EK19, EP01EK19, HU03EK19, MA21EK1, MA21EK8, MA21EK10, MA21EK6, MA21EK9, MA21EK3, MA21EK4, EK21HO4, EK21HO5, EK21OD2, EK21OD3, EK21OD4, EK21OD6, EK21OD7, EK21OD8, EK21SP1, EK21SP2, EK21SP3, EK21SP4, EK21TY1, EK21TY2, EK21TY3, EK21TY4, EK21TY5, EK21TY6, EK21TY7, EK21TY9, EK21AA1, EK21AA2, EK21AA3, EK21AA4, EK21AA5, EK21BE2, EK21BR1, EK21BR2, EK21EK2, EK21EM3, EK21EM8, EK21EM10, EK21EM11, EK21EX5, EK21HO1
Bone	Absent	Absent	Absent	Very Rare to Rare, <2.9mm, a.-s.a.
Fine fraction of the inclusions				
Minerals and rocks	Quartz, muscovite, clay lumps, feldspar, plagioclase, opaque particle, chert, biotite, quartzite, sandstone, and chlorite.	Quartz, muscovite, feldspar, opaque particles, chert, quartzite, clay lumps, and chlorite.	Quartz, muscovite, clay lumps, chert, feldspar, plagioclase, opaque particle, quartzite, biotite, microcline, amphibole, sandstone, and chlorite.	Quartz, muscovite, clay lumps, opaque particles, feldspar, chert, biotite, plagioclase, amphibole, quartzite, microcline, orthoclase, sandstone, staurolite, epidote, and tourmaline.

Table 8.2: Overview of fabric groups. This table summarises each fabric group in terms of the properties of the matrix, inclusions, and pores. Sample names are composites of the author's initials 'EK', the year of sample submission ('19, or'21'), a site abbreviation (e.g. 'HU' for Huneschans), and a serial number for thin sections from that site (1-11). For the sample names, see Appendix E. Terms for the estimations of surface area taken up by particles: Predominant >70%, Dominant = 70-50%, Frequent = 50-30%, Common = 30-15%, Few = 15-5%, Very Few = 5-2%, Rare = 2-0.5%, Very Rare <0.5%, Absent 0% (cf. Quinn 2013 pp. 89–90). Codes for angularity: v.a. = very angular, a. = angular, s.a. = sub-angular, s.r. = sub-rounded, r. = rounded, w.r. = well-rounded (Quinn 2013 pp. 83–4). For void shapes, see Quinn (2013 pp. 97–100), for heterogeneities Ho and Quinn (2021 p. 5). * = Thin section too thin, but particles identifiable.

	Fabric group	1	2	3	4			Total
Body of knowledge	Subgroup	-	-	-	1	2	Total	
Funnel Beaker West	Amphora-like vessel	0	0	0	6	6	12	**12**
	Beaker	0	0	0	8	14	22	**22**
	Bowl	0	0	0	11	11	22	**22**
	Bucket shape	0	0	0	0	2	2	**2**
	Collared flask	0	0	0	0	1	1	**1**
	Jug	0	0	0	1	1	2	**2**
	Shouldered vessel	0	0	0	0	1	1	**1**
	Miscellaneous	0	0	0	0	2	2	**2**
	Total	0	0	0	26	38	64	**64**
Corded Ware	Amphora-like vessel	0	0	2	0	0	0	**2**
	Beaker	10	4	8	1	2	3	**25**
	Bowl	0	0	0	0	1	1	**1**
	SWM	0	2	2	0	0	0	**4**
	Total	10	6	12	1	3	4	**32**
Total		**10**	**6**	**12**	**27**	**41**	**68**	**96**

Table 8.3: Composition of the four fabric groups and subgroups (see Tab. 8.2) by body of knowledge and vessel type (see Fig. 2.7).

Group 3: Compact Fabric with Grog, Coarse Sand, and Grit

The third group is characterised by compactness, matrix colour, and inclusion types (see Fig. 8.1E-F). The matrix tends to be compact with porosity between 20-5% of the surface area, but usually around 10% of the surface area (see Tab. 8.2). Elongated, sinusoid voids are the most common voids (see Tab. 8.2). The interference colour of the matrix is pale red-brown, lighter and/or darker sections occur towards the margins and core (see Tab. 8.2, Fig. 8.1E-F). The coarse fraction of the inclusions consists of two components. The first, most common component is angular grog (5-0.5% of the surface area, see Tab. 8.2). The second component is rounded, igneous rock, or grit, in the size range from coarse sand to gravel. These inclusions occur at low frequencies only (<5% surface area, see Tab. 8.2). In addition to grog and gravel, the coarse fraction of the inclusions may feature abundant clay lumps and coarse sand, which consists of quartz, quartzite, and chert (see Tab. 8.2). Three thin sections exhibit traces of charred plant matter.

The vessels in this group are Corded Ware vessels of three types: beakers, amphora-like vessels, and short-wave moulded wares (see Tab. 8.3). Similar to the previous groups, the vessels stem from multiple sites.

Group 4: Poorly Homogenised, Bimodal Fabric with Grit and Organics

The fourth group is the largest petrographic group (see Tab. 8.2) and has two subgroups, discussed below (see also Fig. 8.2).

Fabrics in this group are highly bimodal and typically exhibit evidence for two types of temper. The first type is a broad range of angular igneous, metamorphous, and sedimentary rock fragments, or grit (commonly 10% surface area, but values fluctuate for individual rock types; see Tab. 8.2). The igneous rocks are mainly felsic and plutonic: granitic rocks are particularly common; fragments of granodiorite, and diorite less so. Mafic rocks such

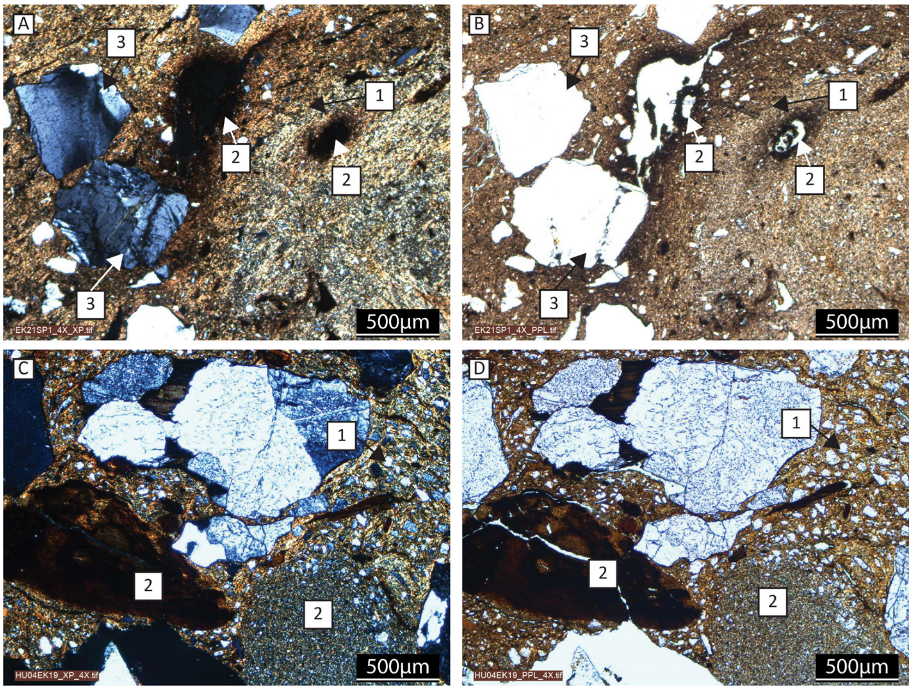


Figure 8.2: Micrographs of representative samples from the first and second subgroup of group 4. A: EK21SP1 in cross polarised light. This sample falls into group 4 and is typical for the first subgroup. The matrix is yellow-brown with large streaks (1). The vesicles and voids are filled with charred matter (2), indicative of tempering with plant material. Moreover, the fabric exhibits pronounced bimodality and coarse angular granitic rock fragments (3). B: EK21SP1 in plane polarised light. The charred material in the vesicles and voids (2) is evident in this view. See A for further description. C: HU04EK19 in cross polarised light. This sample falls into the second subgroup of group 4. The colour and heterogeneity of the clay matrix, presence of organic matter, bimodality, and composition of the coarse fraction of the inclusions are comparable to EK21SP1 (see A-B). However, the fine fraction exhibits abundant fine sand (1), and several clay lumps are present (2). D: HU04EK19 in plane polarised light. See C for a description.

as gabbro and ultramafic rocks also occur but are rare. Metamorphic rocks include felsic, metamorphic rocks, and quartzite. Sedimentary rocks include chert, sandstone, mudstone, and limestone (see Tab. 8.2). The size range of the rock fragments varies from coarse sand to fine gravel. The second temper consists of plant material visible as charred matter in vesicles, channel voids, and vughs. Traces of organic temper are present in ca. 65% of the samples in this group (see Tab. 8.2). Furthermore, samples are often highly heterogeneous with laminations, streaks, or coarse clay lumps, indicating incomplete homogenisation of the matrix (see Tab. 8.2). The clay matrices generally exhibit pale yellow-brown interference colours which are indicative for a calcareous composition. However, a small number of thin sections within this group exhibits a matrix with red-brown interference colours, which is more typical for ferruginous clays (see Tab. 8.2). The matrices vary in porosity from 20-5%, with planar voids, elongated voids, channel voids, and vesicles being most abundant (see Tab. 8.2).

The fourth fabric group has two subgroups which differ in the abundance of the inclusions of the fine fraction (see Fig. 8.2; Tab. 8.2). These are primarily silicate inclusions in the size range of silt and, to a lesser degree, fine sand (see Tab. 8.2). In the first subgroup, these inclusions typically make up only 10% of the surface area, but they are more abundant in the second subgroup (ca. 20% of the surface area). As a result, samples in the first subgroup typically consist of ca. 70% matrix, 20% inclusions, and 10% voids. In contrast, those in the second subgroup commonly exhibit 60% matrix, 30% inclusions, and 10% voids (see Tab. 8.2, Fig. 8.2).

Fabric group 4 contains all Funnel Beaker West vessels regardless of shape, type or site, as well as a small number of beakers and bowls from the Corded Ware body of knowledge (see Tab. 8.3). The primary characteristics of this petrographic group, as well as the subgroups, closely resemble the results of other petrographic analyses of Funnel Beaker West ceramics in the Netherlands and Northwest Germany (Struckmeyer 2017, 2018, 2019; Struckmeyer and Van Os 2022; Voss 1980 Appendix B).

8.2 Traces of Techniques

The description of the fabric groups in the previous section illuminates several aspects of pottery production in the Corded Ware and Funnel Beaker West body of knowledge. This section discusses these aspects, specifically the use and preparation of raw materials, for which petrography is the primary source of information. In addition, the petrographic analysis provides complementary evidence for the techniques used during roughing out, decoration, surface treatment, and firing.

Raw Materials Use and Preparation

The petrographic analysis demonstrates clear patterns in the (preparation of) raw materials used for Funnel Beaker West and Corded Ware vessels. The chief difficulty in interpreting these patterns lies in the absence of information about emic classifications of raw materials among the potters who produced these vessels (cf. Arnold 1971, 2018). For example, the potters who made Funnel Beaker West vessels often used of felsic, plutonic rock fragments as temper (see fabric group 4). However, the principle(s) behind these choices are unknown (cf. Kuijpers 2018 for an approach to this problem), therefore, the focus here is on the patterns in the petrographic data without speculation about their meaning.

The petrographic analyses enable four conclusions about the clay and temper. The combination of these factors suggests different paste recipes existed among the potters who produced Funnel Beaker West and Corded Ware vessels.

Firstly, there is a preference for the use of calcareous clays in both Corded Ware and Funnel Beaker West vessels. This property is evident from the interference colour of oxidised sections of the matrix. These interference colours sit on a spectrum from yellow-brown (e.g. Fig. 8.1A), which is indicative for a calcareous composition of the clay, to red-brown (cf. Fig. 8.1E), which indicates a ferruginous clay composition (Quinn 2013 pp. 93–4). Around 70-90% of the Funnel Beaker West and Corded Ware vessels studied here has a matrix with an interference colour more towards the calcareous end of this spectrum (see Tab. 8.4). By contrast, more red-brown colours appear in less than 5% of the vessels in both bodies of knowledge (see Tab. 8.4), whereas intermediate interference colours are more common among Corded Ware vessels than among Funnel Beaker West vessels (ca. 25% vs. 8%, see Tab. 8.4, fabric group 3). As such, there is a clear preference for calcareous clay sources among the potters who produced Funnel Baker West and Corded Ware vessels. We return to the question whether this might indicate a specific clay source in Section 8.3.

Body of knowledge		Funnel Beaker West		Corded Ware		Total	
Paste recipe	Description	*n*	%	*n*	%	*n*	%
Clay	Calcareous	30	46.9	7	21.9	37	38.5
	More calcareous	26	40.6	15	46.9	41	42.7
	In between	5	7.8	8	25.0	13	13.5
	More ferruginous	0	0	1	3.1	1	1
	Ferruginous	3	4.7	0	0	3	3.1
	Indeterminate	0	0	1	3.1	1	1
	Abundant silt	38	59.4	9	28.1	47	49
	Sparse silt	26	40.6	23	71.9	49	51
Homogenisation	Wet	51	79.7	11	34.4	62	64.6
	None	1	1.6	0	0	1	1
	Dry	10	15.6	20	62.5	30	31.3
	Indeterminate	2	3.1	1	3.1	3	3.1
Tempers	Grit	64	100	16	50.0	80	83.3
	Plant matter	46	71.9	9	28.1	55	57.3
	Sand	10	15.6	22	68.8	32	33.3
	Grog	0	0	22	68.8	22	22.9
Total		**64**	**100**	**32**	**100**	**96**	**100**

Table 8.4: Raw materials use and preparation in Funnel Beaker West and Corded Ware bodies of knowledge. All percentages relative to the total of thin sections in the bottom row. Vessels may contain multiple tempers. Classification of hydric state of the paste during homogenisation following indicators in Ho and Quinn (2021). 'Indeterminate' cases lack such indicators, for example due to dark interference colours of the matrix. 'None' indicates high heterogeneity in diffuse and erratic configurations.

The second conclusion about the choice of clay in both bodies of knowledge relates to the amount of silt in the fine fraction. Clays with abundant silt and clays with sparse silt occur in both Funnel Beaker West and Corded Ware ceramics (see Fig. 8.2; Tab. 8.2). However, there is a difference between both bodies of knowledge. Funnel Beaker West vessels show a slight preference for clays rich in silt (ca. 60%, see fabric group 4, subgroup 2), as opposed to clays with sparse silt (ca. 40%, see Tab. 8.4; fabric group 4, subgroup 1). Vessels made with these different clays appear within the same assemblages, indicating this is a general pattern rather than a local one (see Tab. 8.2).

The matter lies differently for Corded Ware ceramics. Again, both clays rich in silt (e.g. fabric group 2) and poor in silt (e.g. fabric group 1) occur, but a clear preference for the latter clays is evident. Over 70% of the Corded Ware vessels were made from clay with relatively low silt levels (see Tab. 8.4; 8.2). As such, the potters who made Corded Ware vessels preferred clays without much silt, whereas the potters who produced Funnel Beaker West vessels had a slight preference for clays rich in silt.

The third conclusion relates to paste homogenisation. All clay matrices are heterogeneous, especially those in fabric group 4 (see Tab. 8.2). These heterogeneities imply incomplete homogenisation of the clay body during paste preparation. Ho and Quinn (2021) discuss an experiment to determine the origins of heterogeneities in clay matrices. They argue clay mixing and natural variation in clays can result in similar patterns of heterogeneity. However, the type of heterogeneity can indicate whether homogenisation of the paste involved wet or dry clay. An abundance of clay lumps with sharp boundaries and relatively few streaks or laminations indicates homogenisation of the clay in a dry state. By contrast, homogenisation of a clay paste in a wet state results in a proliferation of streaks and laminations with diffuse boundaries over clay lumps. Unworked pastes appear highly heterogeneous with chaotic, diffuse heterogeneities (cf. Ho and Quinn 2021 Fig. 2). Therefore, these heterogeneities can indicate whether potters chose to homogenise clay, and whether this process involved wet or dry clay.

Following the definitions from Ho and Quinn (2021), the occurrence of typical signs for homogenisation on moist and dry clay occur in all petrographic groups and both bodies of knowledge (see Tab. 8.2; 8.4), but again with strong preferences. Around 80% of the Funnel Beaker West vessels show signs of homogenisation on wet clay (e.g. Fig. 8.3A-B), whereas indicators for homogenisation on dry clay occur in around 15% of the sampled vessels. Only one vessel appears to have an unhomogenised clay matrix (see Tab. 8.4, Fig. 8.3B-C). The Corded Ware vessels almost show an inversion of this pattern (see Tab. 8.4). Roughly 30% of the Corded Ware vessels show signs of homogenisation on wet clay. However, ca. 60% of the vessels feature signs of homogenisation on a dry clay paste (e.g. Fig. 8.3E-F, see Tab. 8.4). By implication, paste preparation is diverse in both bodies of knowledge, but the potters behind Funnel Beaker West vessels preferred to homogenise wet clay pastes. In contrast, those who produced Corded Ware vessels preferred to work with dry clay during paste preparation.

Apart from clay, the second raw material for clay pates is temper. All fabric groups are bimodal (see Tab. 8.2), indicating widespread temper use. However, there is a contrast in the temper materials potters chose to use. All Funnel Beaker West vessels, and a small number of Corded Ware vessels, fall in fabric group 4. This means they feature crushed rock fragments as temper, often combined with organic matter such as plant material (see Tab. 8.2; 8.4). Sand only occurs in ca. 15% of the Funnel Beaker West vessels as a temper, and grog is absent (see Tab. 8.2; 8.4). In other words, the potters who produced Funnel Beaker West vessels strongly preferred grit and plant matter as tempers.

Corded Ware vessels are more varied in terms of tempers. As shown above, some Corded Ware vessels exhibit temper with grit and organics, similar to Funnel Beaker West. However, temper with sand and/or grog is more common (see Tab. 8.4; fabric groups 1 and 2 in Tab. 8.2). In addition, a third group of Corded Ware vessels (fabric group 3) combines grog and sand with a low amount of grit (see Tab. 8.2). Organic material is scarce as a temper in Corded Ware vessels, but not absent (see Tab. 8.2; 8.4).

In sum, Funnel Beaker West vessels are relatively homogeneous in terms of choices for temper. There is a clear preference for grit and plant matter (see Tab. 8.4). The Corded Ware body of knowledge is more diverse. Corded Ware vessels may exhibit one of three patterns: 1) temper with grog, sand, and rarely organics; 2) temper with grit and organics identical to Funnel Beaker West vessels; or 3) a combination of all forms with grit, grog, sand, and organics (see Tab. 8.4).

The above conclusions about clay composition, silt contents, homogenisation, and temper inform us about the paste recipes potters used. The paste recipe for Funnel Beaker West ceramic production is relatively homogeneous (see Tab. 8.4). This recipe involves calcareous, silty clays, which are preferentially homogenised while wet together with crushed rock fragments and plant matter. Knowledge about this paste recipe was widely shared among Funnel Beaker potters because fabric group 4 strongly resembles fabrics of

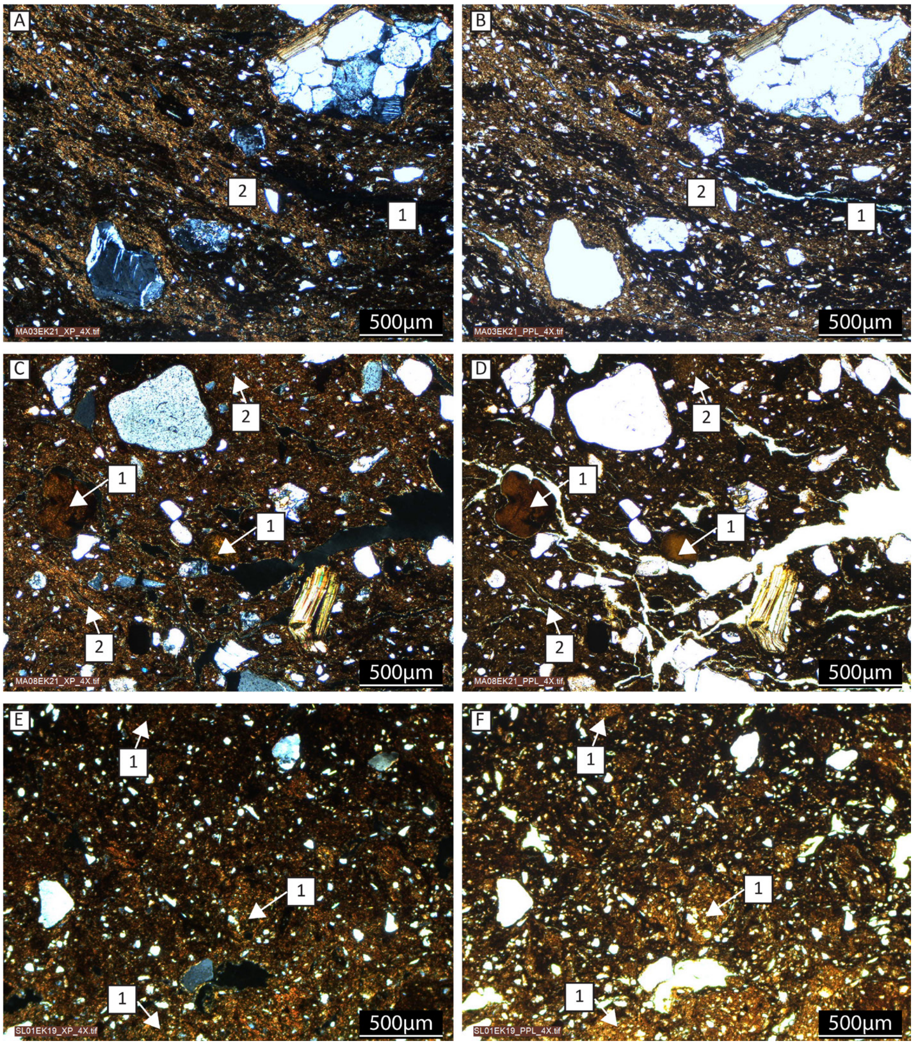


Figure 8.3: Differences in paste preparation. A: MA03EK21 with crossed polars. The fabric shows laminations of dark brown (1) and light brown (2) streaks due to incomplete homogenisation on a wet paste. B: MA03EK21 in plane polarised light, see A for description. C: MA08EK21 in cross polarised light. Several rounded clay lumps (1) and some streaks (2) in a chaotic matrix indicate a lack of homogenisation. D: MA08EK21 in plane polarised light, see C for description. E: SL01EK19 in cross polarised light. Rounded clay lumps with sharp boundaries (1) are abundant, indicating homogenisation on a dry clay. F: SL01EK19 in plane polarised light, underlining the abundance of clay lumps, see E.

Funnel Beaker vessels in Germany and the Netherlands (cf. Struckmeyer 2017, 2018, 2019; Struckmeyer and Van Os 2022; Voss 1980 Appendix B).

The sampled Corded Ware vessels follow multiple paste recipes. Some of these vessels follow the paste recipe described for Funnel Beaker West above. Others vessels were made with more or less calcareous clays, often with low silt contents, and dry homogenisation. The tempers are sand and grog, or more rarely grit and plant matter. This variation indicates that the potters who produced Corded Ware vessels learned multiple paste

Body of knowledge	Funnel Beaker West		Corded Ware		Total	
Coil joint	*n*	*%*	*n*	*%*	*n*	*%*
None detected	45	70.3	31	96.9	76	79.2
Bevelled	15	23.4	1	3.1	16	16.7
U-shaped	4	6.3	0	0	4	4.2
Total	**64**	**100**	**32**	**100**	**96**	**100**

Table 8.5: Overview of coil joints observed in thin section. Terminology following Roux (2019a p. 161; Fig. 3.26; see also Fig. 6.5).

recipes, among others the recipe commonly found in Funnel Beaker West vessels. In addition, knowledge about a specific paste recipe for beakers was shared more broadly among Corded Ware potters because the same paste recipe also appears in Corded Ware beakers from other parts of the Netherlands (see fabric group 1; Kroon *et al.* 2019).

These paste recipes feature again in Chapter 9. In addition to evidence for paste recipes, the petrographic analysis also provides evidence for techniques during other stages of the production process and for the provenance of vessels. These outcomes are discussed below.

Roughing-out Techniques

Several thin sections exhibit indicators for coiling (see Tab. 8.5). These indicators are local changes in the orientation of elongated particles and voids, which indicate the boundaries of reworked coils (cf. Quinn 2013 Figs. 6.31–2; Roux 2019a p. 167).

Two types of coil joints appear: 1) bevelled joints in which the orientation of elongated particles and joints are oblique relative to the sample margin (see Fig. 8.4A-B); and 2) U-shaped coil joints in which particles and voids form an arc perpendicular to the sample margin (see Fig. 8.4C-D). The total number of samples with traces of coil joints is low in all groups (Tab. 8.5), but the types of coil joints match those seen in the macroscopic data.

Decorative Techniques

23 thin sections feature cross-sections of decorative depressions (see Tab. 8.6). These cross-sections further substantiate arguments in Chapters 6 and 7 for the application of decorative techniques to wet and leather-hard clay because they provide a 2-dimensional view of the microrelief (cf. Roux 2019a p. 204). Unfortunately, the total number of cases is too low to draw distinctions between bodies of knowledge (see Tab. 8.6).

The surfaces of most cross-sections (n=22) of these decorative depressions show irregular outlines, with a parallel orientation of the adjacent elongated voids and coarse inclusions (see below; Fig. 8.5A). Therefore, the application of decorative techniques likely occurred on wet clay and warped the surrounding matrix.

By contrast, one vessel exhibits a decorative depression with a smooth outline and parallel orientation among adjacent, elongated particles in the fine fraction. These traces are identical to surfaces worked by friction while leather-hard (see Fig. 8.5B; cf. Quinn 2013 Fig. 6.35). Therefore, this indicates the application of decorative techniques to leather-hard clay.

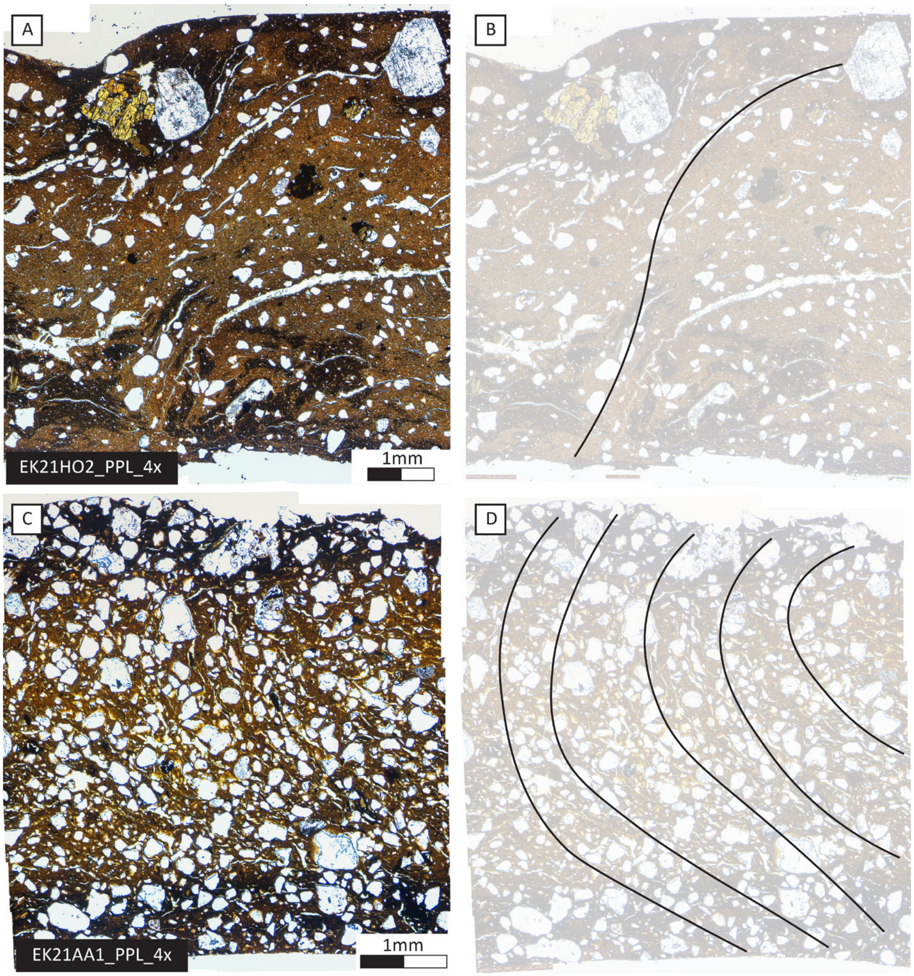


Figure 8.4: Coil joints in thin section (composite images). A: Bevelled coil joint in EK21HO2 (plane polarised light). Localised zone with parallel orientation of elongate particles and voids oriented oblique relative to the sample margin. B: Greyed-out image from A with line drawing of the bevelled coil joint. C: U-shaped coil joint in EK21AA1 (plane polarised light). Localised zone with elongated particles and voids forming several arcs perpendicular to the sample margin. D: Greyed-out image from C with line drawing of the of the hollow joint.

Body of knowledge	**Funnel Beaker West**		**Corded Ware**		**Total**	
Outline depression	*n*	*%*	*n*	*%*	*n*	*%*
Irregular	16	25	6	18.8	22	22.9
Smooth	1	1.6	0	0	1	1
None observed	47	73.4	26	81.3	73	76
Total	**64**	**100**	**32**	**100**	**96**	**100**

Table 8.6: Overview of decorative depressions by body of knowledge. The outline of the depressions (if present) is scored as irregular or smooth (see Fig. 8.5).

Surface Treatment

The macroscopic analysis indicates three surface treatment techniques occur in Funnel Beaker West and Corded Ware ceramics (see Ch. 6 and 7). These techniques are burnishing, shining, and smudging. Evidence for these surface treatments also appear in thin section, but the microscopic indicators for these surface treatments are not all equally well understood.

The appearance of the sample margin is the point of departure for detecting surface treatment in ceramic petrography. Irregular margins would indicate (wet) smoothing, whereas smooth margins with a parallel orientation of adjacent, elongated particles in the fine fraction would result from burnishing (cf. Ionescu and Hoeck 2020 specifically Fig. 6; Quinn 2013 p. 182, Fig. 6.34). This distinction is identical to irregular and compact microtopographies in macroscopic observations (cf. Roux 2019a). Problematically, no studies examine the full range of interactions between clay paste and tools during finishing and surface treatment (cf. Roux 2019a for an overview). For example, finishing can also involve using hard tools on leather-hard pastes, leaving a compact microtopography. Moreover, surface treatments can involve either soft tools (shining) or hard tools (burnishing) on leather-hard and dry clays. All of these operations leave compact microtopographies and might result in smooth margins of the thin section.

Given this uncertainty, this study only distinguishes between irregular and smooth margins (see Tab. 8.7). Irregular surfaces are assumed to indicate an operation on wet clay, and smooth surfaces an operation on clay which is at least leather-hard (see Fig. 8.6C-E). Given that macroscopic analyses reveal only one case of finishing operations on leather-hard clay (see Ch. 6), these smooth margins most likely result either from burnishing or shining.

Table 8.7 shows a clear tendency in Funnel Beaker West vessels to exhibit at least one smooth margin, often two. By contrast, Corded Ware vessels exhibit more variation: many vessels fall into all three categories. These differences in frequency correspond to the macroscopic analyses (cf. Fig. 6.13; Fig. 7.13), which show surface treatment of interior and exterior surfaces is more common in Funnel Beaker West vessels than in Corded Ware vessels.

The third form of surface treatment is smudging. Smudging involves subjecting ceramics to smoke after or during firing. This operation enriches the outer margins with carbon (cf. Roux 2019a p. 101). No microscopic analyses of smudging exist, but studies of carbon coating show surface enrichment of carbon can be observed in thin sections

Body of knowledge		**Funnel Beaker West**		**Corded Ware**		**Total**	
Technique	Margins	*n*	*%*	*n*	*%*	*n*	*%*
Surface treatment by friction	Both margins smooth	31	48.4	8	25	39	40.6
	Single margin smooth	25	39.1	12	37.5	37	38.5
	Both margins irregular	8	12.5	12	37.5	20	20.8
Smudging		8	12.5	0	0	8	8.3
Total		**64**	**100**	**32**	**100**	**96**	**100**

Table. 8.7: Overview of indicators for surface treatments by friction (burnishing and shining) and smudging. A smooth margin indicates the occurrence of surface treatment by friction, whereas an irregular margin indicates absence of such surface treatment. The table does not distinguish between interior and exterior margins. All percentages are relative to totals in the bottom row. Vessels may exhibit multiple surface treatments.

as local accumulations of opaque particles (cf. Łaciak *et al.* 2019), whereas macroscopic studies suggest this effect should only appear at the margins (cf. Drieu *et al.* 2020). Traces of local carbon enrichment near the margins are visible in eight thin sections (Tab. 8.7). These traces are elongated, sinusoid voids filled with opaque matter which only occur near the sample margins (see Fig. 8.5D). These traces as interpreted here as indicative of

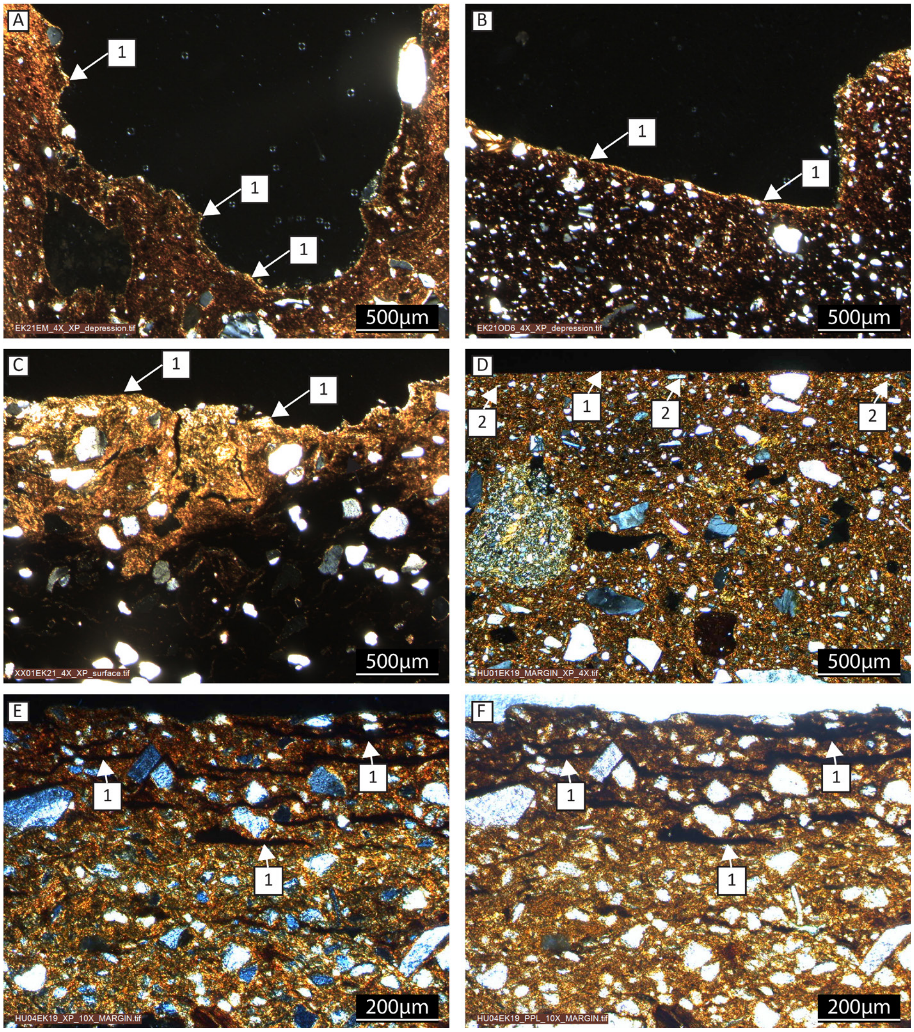


Figure 8.5: Traces of decorative techniques (A-B) and surface treatment (C-F). A: EK21EM6 in cross polarised light. The depression in the vessel wall has irregular boundaries (1), indicating an action on wet clay (see C). B: EK21OD6 in cross polarised light. The depression has smooth margins with parallel orientation of the adjacent elongated inclusions in the fine fraction (1), indicating an operation on leather-hard clay (see D). C: XX01EK21 in cross polarised light. Smoothing on wet clay has left the margin of the sample irregular (1). D: HU01EK19 in cross polarised light. The margin is smooth (1) and adjacent particles exhibit parallel orientation (2). These traces indicate a surface treatment by friction on a surface which was at least leather-hard. E: HU04EK19 in cross polarised light. Several elongated sinusoid voids near the margin exhibit fills with opaque matter (1), which could indicate smudging. F: HU04EK19 in plane polarised light, see E for a description.

smudging. The distribution of these cases across Funnel Beaker West and Corded Ware vessels (see Tab. 8.7) resembles the incidence rate of smudging in the macroscopic data (see Tab. 6.7; 7.6). However, the microscopic and macroscopic data rarely coincide due to differences in samples and analytical scale. Further experimentation with microscopic studies of surface treatment techniques would be preferable.

Firing

Ceramic petrography can provide information about the equivalent firing temperature of vessels (cf. Tite 1995) by mapping the thermal alteration of minerals (cf. Quinn 2013). However, there are two complications. Firstly, many factors influence the behaviour of minerals during the firing process, including firing temperature, clay composition, and soaking time (cf. Gliozzo 2020). Moreover, firing temperatures may differ within the vessel wall depending on the firing technique and wall thickness (Maggetti *et al.* 2011; Thér *et al.* 2019a). As such, there is no straightforward correlation between mineral behaviour and firing temperature.

Secondly, and specifically for the studied vessels, minerals indicative of changes at low temperatures (e.g. calcite) are generally absent in the dataset. The most frequently observed minerals are quartz and feldspars (see Tab. 8.2), for which thermal alterations generally occur at very high temperatures (cf. Gliozzo 2020). As a result of both factors, the estimates for equivalent firing temperatures provided here are coarse-grained and indicative rather than absolute.

The petrographic analyses yield two indications for firing temperature. The first indicator is the optical activity of the matrix. Optical activity disappears due to the sintering of the matrix at high temperatures. Gliozzo (2020 and further references) states that sintering can occur between 800°C and 1000°C depending on clay mineralogy and the presence of calcium and magnesium. All studied thin sections exhibit optical activity, despite appearing calcareous (see Tab. 8.2). Therefore, the maximal equivalent firing temperatures are likely in the lower ranges of 800°C-1000°C.

The second indicator is quartz. Larger quartz particles in the thin sections tend to exhibit ring voids. These voids result from the expansion and shrinkage of quartz during reversible crystallographic changes. The exact temperatures at which these changes occur depend on the size and purity of quartz grains. However, the first volume expansion of quartz generally occurs from 573°C onward (Gliozzo 2020 and further references). As such, the minimal equivalent firing temperature can be set to 573°C.

Lastly, the sporadic presence of hornblende crystals with oxidised margins requires a brief discussion. Quinn (2013 p. 191) states oxidation of hornblende occurs around 750°C in oxidising firing atmospheres. However, oxidised margins might also relate to a volcanic origin of the minerals (MacKenzie and Guilford 2013 pp. 46–7). Therefore, the attribution of these oxidised margins to firing temperatures is uncertain.

In sum, most vessels exhibit evidence for equivalent firing temperatures between 573°C and the lower ranges of 800-1000°C. These ranges are typical for prehistoric firing regimes, both in ovens or bonfires (cf. Thér *et al.* 2019a).

8.3 Provenance

Provenance analysis for Funnel Beaker West and Corded Ware ceramics is vital in light of the interpretations of these ceramic assemblages. Prior studies of Funnel Beaker West ceramics argue that the producers of these assemblages are small, local groups who

Depositional environment	Name	Origin	Age	Potential clay source	Potential gravel source
Fluvial	Echteld Formation	Meuse and Rhine river system	Holocene	Yes	Yes
	Beegden Formation	Meuse river system	Late Pliocene - Holocene	No	No
	Kreftenheye Formation	Meuse and Rhine river system	Late Middle Pleistocene - Early Holocene	Yes (Zutphen Member, Wijchen Bed)	Yes
	Appelscha Formation	Eridanos river system	Middle Pleistocene	No	Yes
Glacial	Drente Formation	Saalien glaciation	Late Middle Pleistocene	Yes (Gieten Member, Uitdam Member)	Yes
	Peelo Formation	Elsterien glaciation	Middle Pleistocene	Yes (Nieuwolda Member)	Yes
Streams	Boxtel Formation	Local	Middle Pleistocene-Holocene	Yes (Singraven Member)	No
Marine	Naaldwijk Formation	North Sea	Holocene	Yes (Wormer Member, Velsen Bed)	No

Table 8.8: Overview of lithostratigraphic units mentioned below (TNO-GDN 2023a). The columns 'potential clay source' and 'potential gravel source' indicate whether a formation is discussed as source of clay and/or gravel in the text. The columns mention specific members of the formation for potential clay sources.

exploit local (glacial) clay deposits (cf. Brindley 2022 p. 120; Struckmeyer and Van Os 2022; Voss 1982). By contrast, studies of Corded Ware ceramics stress connections with distant regions through provenance analysis (cf. Holmqvist *et al.* 2018; Kroon *et al.* 2019). These interpretations feed directly into narratives about the third millennium BCE (see Ch. 1, 2). However, these studies often do not compare the observed properties of vessels to those of clay sources and instead rely on an impression of homogeneity among samples (e.g. Struckmeyer and Van Os 2022). Such an approach is problematic because perceived homogeneity means little without comparison against geological references. For example, a clay deposit might outcrop in multiple areas, producing homogeneous signatures among vessels produced at different locations.

Therefore, the properties of the fabric groups (see Tab. 8.2) are compared to petrological studies of surface clay and gravel deposits in the Netherlands (see Tab. 8.8). This comparison is complex, because the Netherlands is a sedimentary basin in which fluvial, aeolian, marine, and glacial action have continuously deposited (and reworked) sediments from various sources over the course of the Quaternary (cf. Berendsen and Stouthamer 2001). There are mineralogical differences between these deposits, but these are often gradual due to these complex depositional processes (cf. Doppert *et al.* 1975). As a result, the comparison below is not conclusive, but does exclude a number of these deposits as potential raw material sources and suggests a difference in raw material sources for Corded Ware and Funnel Beaker West vessels.

Gravel Analysis and Coarse Inclusions

The first step in the provenance analysis is a comparison of the composition of the inclusions in the coarse fraction of the fabric groups (see Tab. 8.2) against the composition of gravel deposits in the Netherlands (see Tab. 8.8, Fig. 8.6). Potters are likely to obtain both clay and temper at relatively short distances to the production site (Arnold 1985 p. 49). However, there are notable exceptions in which raw materials are transported over longer distances, for example because raw material extraction is combined with other activities in the landscape (e.g. Cootes and Quinn 2018; Michelaki *et al.* 2015; Roux 2019a pp. 23–4 and further references). Therefore, the provenance of tempers and clays is discussed separately here. An important caveat in the comparison is that past potters may have selected specific rocks from gravel deposits, thus creating a bias. However, the comparison below shows that, even if this is the case, specific gravel deposits are more likely sources than others.

Gravel analysis looks at the relative proportions of different rock types in the size range 3-5mm in gravel deposits. This method can distinguish between four sources of gravel in Quaternary deposits in the Netherlands (Berendsen 2010 pp. 111–2, 2011 pp. 120–1; Zandstra 1959, 1978; see Tab. 8.8).

The first major source of gravel in the Netherland is the Eridanos river system, which deposited sediments in the northern Netherlands during the Middle Pleistocene (Appelscha Formation; Berendsen 2011 p. 139; cf. TNO-GDN 2023b). Typical for these gravel deposits is a high percentage of transparent quartz from eroded rock formations in the Baltic (see Fig. 8.6). We can exclude these gravel deposits as source material for all fabric groups. Fabric group 4 contains more metamorphic and igneous rock fragments than is typical for the Appelscha Formation, whereas fabric groups 1, 2, and 3 may contain much quartz, but also other silicates such as quartzite and chert which are a-typical for these gravel deposits (see Fig. 8.8).

The second potential source of gravel is the river Meuse (Beegden Formation). Meuse gravel contains relatively high amounts of limestone, flint, and Revin quartzite. These rocks stem from the erosion of local cretaceous deposits and rock formations in the Vosges and Ardennes (cf. Bosch 1998; Felder 1989; TNO-GDN 2023c). None of the fabric groups feature rocks such as limestone and flint in abundance (see Tab. 8.2). Therefore, we can exclude these gravel deposits as sources for temper.

The third primary source of gravel in the Netherlands is the Echteld formation. This formation consists of Holocene deposits from the rivers Rhine and Meuse, in which Rhine deposits are dominant (Berendsen 1982; TNO-GDN 2023d; see Fig. 8.6). This means the gravel is rich in vein quartz from Belgian, German, and French rock formations, as well as quartzite, flint, and various sandstones from the Rhenish Massif and Ardennes (see Fig. 8.6; cf. Berendsen 2011 pp. 121, 266; Zandstra 1993). These gravel deposits are unlikely to be the source for the coarse inclusions in fabric group 4, because of the diversity and amount of igneous and metamorphic rocks in this group (see Tab. 8.2). However, it is not possible to exclude the possibility that the coarse mineral inclusions in fabric groups 1 to 3 do stem from these gravel deposits. The mineral inclusions in these fabric groups are predominantly rounded silicates: quartz, quartzite, and chert. These characteristics could indicate a fluvial gravel source in the Echteld formation. However, this interpretation remains tentative due to the absence of typical rock types such as sandstone, and the smaller grain size (<1mm) of the coarse fraction in this group.

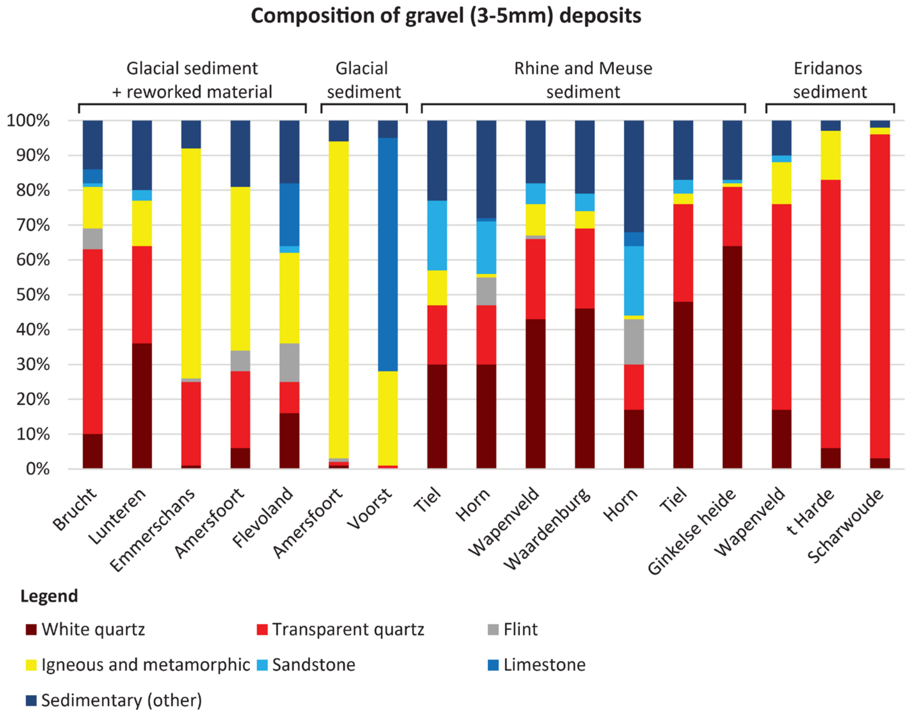


Figure 8.6: Composition of gravel deposits (grain size: 3-5mm) from glacial and fluvial sources (after: Berendsen 2011 p. 112; Zandstra 1978 Tab. A). Sites listed at the bottom. High proportions of igneous and metamorphic rocks indicate a glacial source of gravel. This signal also occurs in glacial deposits with reworked fluvial material and in fluvial deposits with reworked glacial material. In addition, some glacial deposits are rich in limestone. Gravel from fluvial deposits is rich in quartz. White quartz, or vein quartz, is more common in Rhine and Meuse gravel, whereas high amounts of transparent quartz are typical for deposits of the Eridanos river system. The Rhine and Meuse sediments also stand out due to the relatively high percentage of sandstone.

The last source of gravel are deposits from the Saalien glaciation (the Drente Formation). A key characteristic of these deposits is a high percentage of diverse metamorphic and igneous rocks (see Fig. 8.6). These rocks stem from various areas in Scandinavia (Hesemann 1930a, 1930b; Zandstra 1983b, 1983a). This signature of glacial gravel deposits remains distinct even in reworked deposits (see Fig. 8.6). Looking at the diversity of rock types in fabric group 4, which encompasses diverse igneous (primarily felsic, plutonic, but also mafic and ultramafic), metamorphic, and sedimentary rocks, we should conclude this diversity and these specific rock types are strong indicators for the use, or selection, of gravel with a glacial origin.

In sum, the mineral temper in fabric group 4 likely stems from gravel with a glacial origin, whereas the mineral temper in fabric groups 1 to 3 suggests a fluvial source. Therefore, the potters who made Funnel Beaker West vessels (fabric group 4), and Corded Ware vessels (primarily fabric group 1 to 3) may have extracted temper from different raw material sources.

Sources of Clay

Surface clay deposits in the Netherlands stem from several major sources: marine clays, fluvial clays, and glacial clays (De Mulder *et al.* 2003; see Tab. 8.8). These clay sources are (among others) distinct in terms of heavy and light mineral contents, and in some cases bioclasts (cf. Berendsen 2010 pp. 107–9; Griffioen *et al.* 2016; Weerts *et al.* 2000). For example, a relatively high percentage of the heavy mineral augite is typical for the Echteld formation (cf. Berendsen 2011 pp. 145–6, 266; Doppert *et al.* 1975), whereas a high proportion of the light mineral albite is typical for glacial sediments (Van Baren 1934; Van Gijzel *et al.* 1959). In addition, marine clay deposits are generally rich in shell fragments (cf. De Mulder *et al.* 2003 on the Naaldwijk Formation; TNO-GDN 2023e).

Ceramic petrography can detect the above-mentioned minerals and bioclasts. However, a direct comparison with geological samples is challenging because identifying a specific deposit requires establishing relative proportions of heavy and light minerals by counting and identifying up to 300 particles in a size range of 0.5-0.05mm (Berendsen 2010 pp. 107–8; Edelman 1933; Zonneveld 1958). Such large samples are necessary because the constant reworking of sediments in the Netherlands means no single, reliable guide mineral exists (cf. Doppert *et al.* 1975).

The issue is that the thin sections do not yield sufficient quantities of heavy minerals to establish relative proportions of these minerals (see Tab. 8.2). Also, this study has no quantitative data for the light minerals. None of the thin sections contains shell fragments, which excludes the possibility that Funnel Beaker West and Corded Ware potters used marine clays. However, it is not possible to distinguish between the remaining fluvial and glacial clay sources.

Other aspects of the matrix, such as the ferruginous or calcareous composition (see Tab. 8.2), are not suited for provenance analysis. In part because bulk chemistry would be needed for a better assessment of calcium and iron levels (cf. Quinn 2013 p. 94) and in part because calcite levels in Dutch sediments depend on a great number of factors other than sediment sources (Berendsen 1982; Berendsen and Stouthamer 2001 pp. 37–8).

Given the above difficulties, the use of geochemistry to provenance the clays would be preferable. However, this would require a separate investigation of potential geochemical markers in Dutch subsoils. Various geological studies have sought to characterise specific deposits (see Griffioen *et al.* 2016 for a recent overview). However, there are no studies of the differences between (f.e.) the Drente and Echteld Formations. Therefore, geochemical analysis of the thin sections would require new investigations of potential geochemical markers which distinguish the clay deposits mentioned above. Such an investigation is beyond the scope of the current project but would greatly benefit archaeological investigations of ceramics from the Netherlands.

8.4 Final Remarks

Ceramic petrography sheds light on a set of choices past potters made while selecting and preparing raw materials for the production of Funnel Beaker West and Corded Ware vessels. As shown, the potters who made Funnel Beaker West and Corded Ware vessels generally follow specific patterns, or paste recipes, in these choices.

Both Funnel Beaker West and Corded Ware vessels generally consist of more calcareous clays, with a minor number of vessels employing either ferruginous clays, or clays with a composition in between calcareous and ferruginous. However, the potters who made

Funnel Beaker West vessels preferred clays with high silt contents, and homogenised these in a wet state with added crushed rocks and plant matter for temper. By contrast, the potters who made Corded Ware vessels had a preference for clays with sparse silt, chose sand and grog as tempers, and preferred dry paste homogenisation. Corded Ware paste recipes also appear more varied than Funnel Beaker West, and some Corded Ware vessels have been made with the typical Funnel Beaker West paste recipe. The fact that similar choices appear in vessels from other areas (f.e. Corded Ware in the coastal area of the Netherlands, and Funnel Beaker West in Germany) shows us these paste recipes are part of broadly shared knowledge among prehistoric potters about what materials to use for pottery production, and how to prepare them. We return to these paste recipes in in Chapters 9, 12 and 13.

The petrographic analysis also contributes to the evidence for operations in other parts of the ceramic production process. Several thin sections exhibit traces of U-shaped and bevelled coil joints. Moreover, microscopic observations of the sample margins corroborate the macroscopic identification of surface treatments by friction and smudging, as well as the application of decorative techniques to wet and leather-hard pastes. Lastly, the regular appearance of ring voids around quartz, in combination with the optical activity of the matrices, suggests the vessels were exposed to equivalent firing temperatures between 573°C and the lower ranges of 800°C-1000°C.

In addition to information about technical operations, the petrographic analysis also suggests a difference in the provenance of temper materials in Funnel Beaker West and Corded Ware vessels. The diversity and types of rocks found in Funnel Beaker West ceramics indicate the use of glacial gravel deposits as source material for mineral temper. By contrast, the relatively high amount of rounded silicate inclusions in Corded Ware vessels suggests that these coarse inclusions stem from fluvial deposits. Further geochemical analysis is needed to confirm whether the clay sources differ between Corded Ware and Funnel Beaker West vessels.

9

Abductive Comparison of Specific *Chaînes Opératoires*

The evidence for the reconstructed specific *chaînes opératoires* in the Funnel Beaker West, and Corded Ware body of knowledge is presented in Chapters 6, 7, and 8. This chapter is the first of two in which these bodies of knowledge are compared. The central question in these comparisons is whether the technical knowledge behind these two different groups of vessels is shared. Do we see indications that potters learned similar procedures for pottery production?

The comparison in this chapter follows the common, abductive approach to compare the Funnel Beaker West and Corded Ware bodies of knowledge. A comparison with the probabilistic approach from Chapter 4 is the subject of the next chapter. These two approaches are complementary, and Chapters 9 and 10 are best read together. Both approaches yield similar outcomes: significant, but not complete, overlap exists in the technical knowledge of potters who produced the specific *chaînes opératoires* in the Funnel Beaker West and Corded Ware bodies of knowledge. The implications of these findings are discussed in Chapters 11 to 13.

The first part of this chapter is a discussion of the techniques used in the various stages of the ceramic production process (see Section 9.1). The second part is an exploration of potential differences in production methods between different vessel types and shapes (see Fig. 2.7) within the bodies of knowledge (see Section 9.2). Lastly, Section 9.3 is a discussion of the findings in this chapter.

Bodies of knowledge and their subsets are referred to throughout this chapter and the next. Table 9.1 is an overview of these different groups of vessels and the corresponding

Body of knowledge	Subset	Abbreviation	Number of specific *chaînes opératoires*	Number of thin sections
Funnel Beaker West	Megalith inventories	MI	95	64
	Early flat graves	EFG	62	
	Late flat graves	LFG	30	
Corded Ware	-	CW	89	32

Table 9.1: Overview of the bodies of knowledge, the subsets, and the number of specific *chaînes opératoires* and thin sections therein.

number of specific *chaînes opératoires* and thin sections. These numbers differ between the macroscopic and petrographic analysis because the destructive and time-consuming nature of ceramic petrography meant not all vessels studied through macroscopy could also be sampled to produce thin sections (see Ch. 5). This difference in sample volume also meant subdividing the petrographic dataset into the same subsets as the macroscopy would result in unrepresentative sample sizes. Therefore, the comparison of petrographic data looks at the overarching bodies of knowledge and the comparison of macroscopic data at bodies of knowledge and subsets thereof (see Ch. 5).

9.1 Abductive Comparison

Abductive comparisons of ceramic technology are common (e.g. Roux 2019a, 2019b). These comparisons construct an abstract, idealised *chaîne opératoire* from technical traces on many vessels or sherds (hence the name abductive). This *chaîne opératoire* takes on the form of a categorical, textual description of the techniques which are present. These narratives are then compared to determine similarities in techniques (see Section 4.3).

The chief advantage of the abductive method lies in the flexibility to incorporate nuance and different levels of resolution (see Section 4.3). It is possible to shift the comparison back and forth between techniques such as coiling, modalities of techniques (e.g. coiling by pinching), or stages (i.e. roughing out). However, abductive comparisons poorly capture the syntax of the ceramic production process because these comparisons break up *chaînes opératoires* into discrete stages. Moreover, the relation between the idealised specific *chaîne opératoire* and the base data is indirect, and the outcomes of abductive comparisons tend to be framed in the binary presence or absence of specific technical operations (see Section 4.3). The network analysis in Chapter 10 remedies these issues but at the cost of a fixed level of resolution. All specific *chaînes opératoires* are analysed at the level of techniques to render them comparable (see Section 4.3). Therefore, the abductive comparison below is complementary to the probabilistic comparisons in the next chapter: it emphasises the finer details and so contextualises the outcomes.

Similar to Chapters 6, 7, and 8, the comparison below follows the stages of the ceramic *chaîne opératoire* from Roux (2019a): raw materials and paste preparation, roughing out, preforming, finishing, decoration, surface treatment, drying, and firing.

Raw Materials and Paste Preparation

The significance of raw materials is the subject of a long-standing debate in archaeological studies of ceramics. Raw materials would either be pivotal in the production process and dictate all other stages or be subject to the same cultural processes as other stages of the *chaîne opératoire* (cf. Gosselain and Livingstone Smith 2005; Van der Leeuw 1993). Regardless, ethnographic studies show that the choice and preparation of raw materials relate to emic knowledge and perceptions of materials (Arnold 2018; Gosselain 2014), as well as factors such as relative distance (Arnold 1985). Therefore, the selection and preparation of raw materials tie into the knowledge of past potters.

The petrographic analyses of Funnel Beaker West and Corded Ware vessels shows the potters who fashioned these vessels follow patterns in their selection and preparation of raw materials (see Ch. 8). These patterns are the paste recipes past potters used.

Funnel Beaker West vessels are homogeneous in terms of paste recipe (see Fig. 9.1; Section 8.2; Tab. 8.4). The recipe for these vessels most often employs calcareous clays.

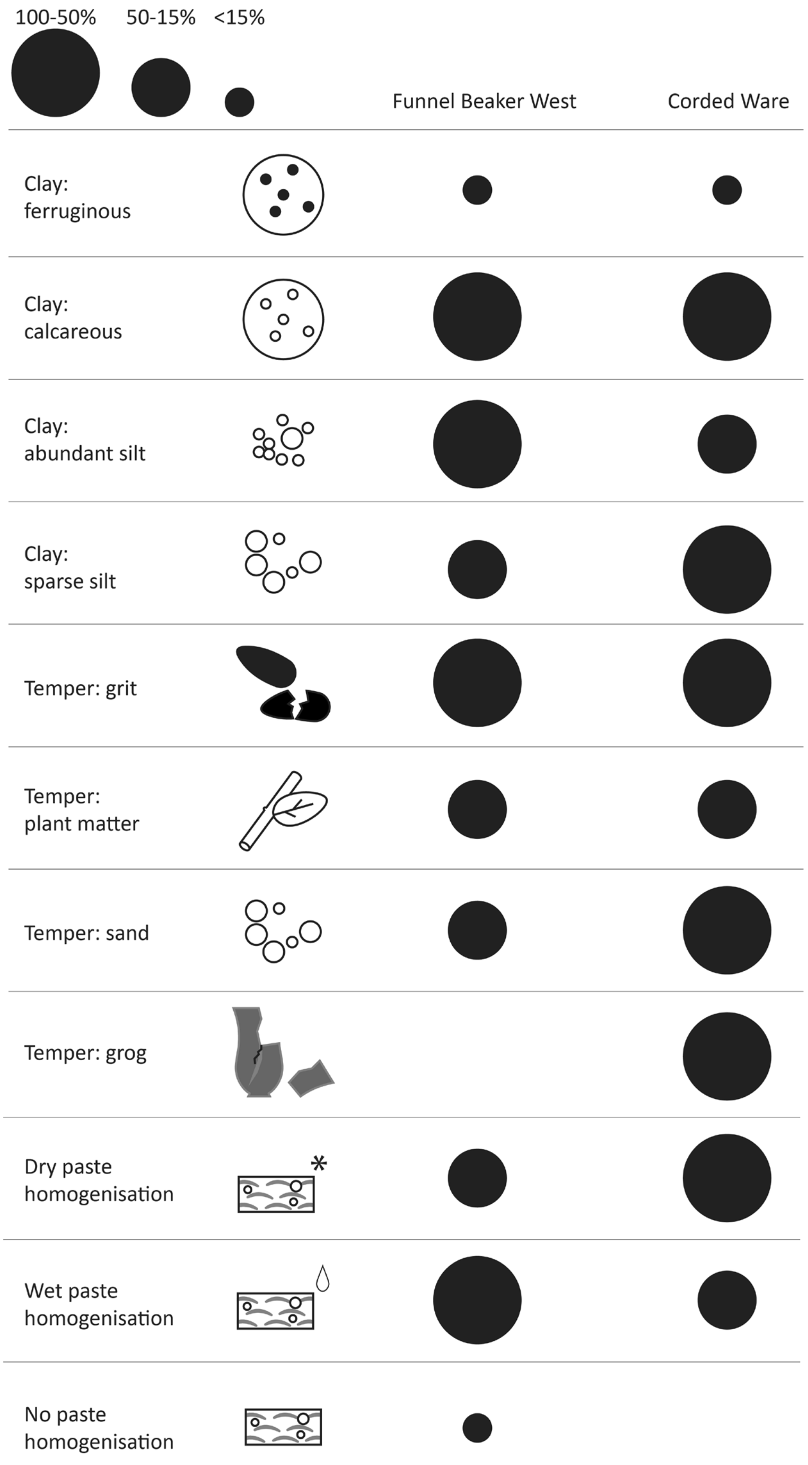


Figure 9.1: Paste recipes in Funnel Beaker West and Corded Ware vessels. The graph shows the frequency (size of the circles) of specific technical choices about the selection and preparation of raw materials (rows).

Clays with a ferruginous composition or a composition in between ferruginous and calcareous are rare. In addition, potters preferred clays with a high silt content instead of a low silt content. The temper always consists of crushed igneous, metamorphic, or sedimentary rocks, likely sourced from glacial gravel deposits. Potters often combined these crushed rocks with plant matter, rarely with sand. Paste homogenisation is often incomplete and usually performed on wet clays. Signs of dry paste preparation or lack of paste preparation occur in only 11 vessels (see Tab. 8.4). Interestingly, this paste recipe consistently appears in different studies of Funnel Beaker West ceramics in the Netherlands and Germany (Struckmeyer 2017, 2018, 2019; Struckmeyer and Van Os 2022; Voss 1980 Appendix B).

The paste recipes of Corded Ware vessels vary (see Fig. 9.1). Several vessels adhere to the recipe described for Funnel Beaker West vessels (see Tab. 8.3; 8.4), but the other Corded Ware vessels show alternate recipes. Calcareous clays are prevalent, but there is a fabric group in which clays with a composition in between ferruginous and calcareous appear (see Tab. 8.2). Similarly, most Corded Ware vessels were made from clays with a low silt content. However, one group of vessels was made with silty clays (see Tab. 8.4). Coarse sand and grog are the most common tempers. There are also combinations with small amounts of grit and plant matter (see Tab. 8.4). The mineral composition and roundedness of the coarse sand point towards the use of fluvial sediments as a temper source. In terms of paste preparation, there is a preference for working with dry clays (see Tab. 8.4). One of these paste recipes (calcareous clay with sparse silt, addition of sand and grog, dry paste homogenisation) also appears in Corded Ware vessels from the western Netherlands (cf. Kroon *et al.* 2019).

In sum, the Funnel Beaker West body of knowledge shows evidence for a distinct practice regarding paste recipes. Interestingly, a small number of Corded Ware vessels follow this practice. However, on the whole, the potters who made Corded Ware vessels opted for multiple different paste recipes and selected different raw materials.

This distinction in paste recipes with little overlap shows differences in knowledge exist between Funnel Beaker West and Corded Ware potters, but also that some potters involved in the production of Corded Ware vessels learned the Funnel Beaker West paste recipe. The homogeneity of the Funnel Beaker West paste recipe in all subsets and across the Netherlands and Northwest Germany also demonstrates that all potters active in these regions and periods are connected through the learning and practicing of specific technical knowledge.

Roughing out

Roughing-out techniques, especially for vessel bases (Livingstone Smith and Viseyrias 2010; cf. Pétrequin 1993 p. 48), are central to discussions about knowledge transmission in ceramic technology. Various authors argue that these techniques are the most specialised and most challenging to learn steps in the ceramic production process. Learning them would require literal hand-holding during one-to-one contact between master and apprentice (cf. Dietler and Herbich 1998; Gosselain 1992 p. 582, 2000 pp. 192–3, 2008b p. 77, 2018; Roux 2015 p. 7, 2019a p. 311; Thebe and Sadr 2017; Wallaert 2012). As a result, similarity in roughing-out techniques is often seen as the best indicator for direct knowledge transmission between potters.

A comparison of roughing-out techniques in Funnel Beaker West and Corded Ware specific *chaînes opératoires* illustrates shared knowledge (see Fig. 9.2-3). The potters who

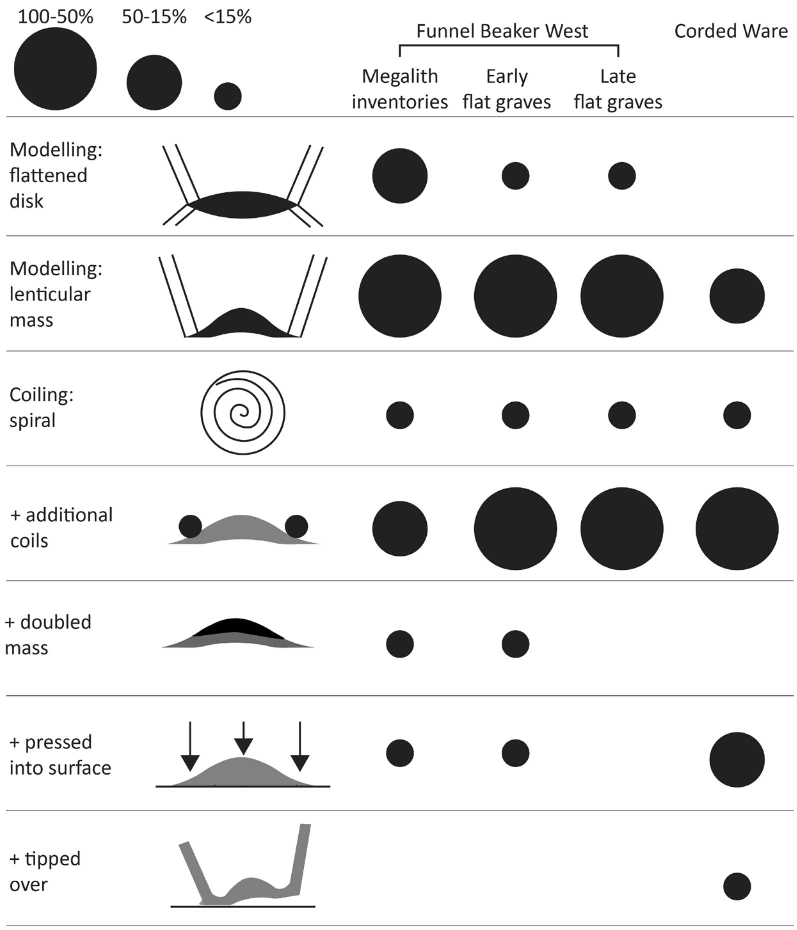


Figure 9.2: Roughing-out techniques in the bases of Funnel Beaker West vessels from megalith inventories, early flat graves, and late flat graves, as well as Corded Ware vessels. The size of the circles indicates the percentage of vessels with traces of a specific technique (row) in a body of knowledge or subset (columns).

made these vessels used similar roughing-out techniques for the bases. Bases in both bodies of knowledge often exhibit signs of modelling and, more rarely, of coiling (see Tab. 6.1; 7.1).

The same pattern appears in the modalities of techniques (see Fig. 9.2-3). The Funnel Beaker West body of knowledge features two modalities of the modelling technique for the fashioning of the base (see Fig. 9.2). These are pinching a lenticular mass and pinching a flattened clay disk (see Tab. 6.1). The modality of the coiling technique is spiral coiling (see Tab. 6.1). One of these modalities of the modelling technique (i.e. pinching a lenticular mass) also appears in the Corded Ware body of knowledge, but the pinching of flattened disks does not (see Tab. 7.1). A single Corded Ware vessel shows signs of spiral coiling on the vessel base (see Tab. 7.2; Fig. 9.2).

Apart from these basic techniques, Funnel Beaker West and Corded Ware vessel bases may exhibit signs of one or more additional techniques (see Tab. 6.1; 7.1; Fig. 9.2). Together with the coiling and modelling techniques described above, these complementary techniques form the base fashioning procedure. The most common complementary technique is the placement of adjacent coils on the modelled base. Evidence for this operation regularly occurs across all subsets of Funnel Beaker West and in Corded Ware (see Tab. 6.1; 7.1; Fig. 9.2). The second most common complementary technique consists of pressing the base into a flat surface. Traces of this technique are common in Corded Ware vessels but less so in Funnel Beaker West vessels from megalith inventories and early flat graves and altogether absent in vessels from late flat graves (see Tab. 6.1; 7.1; Fig. 9.2). However, the distinction is not clear-cut due to the regular application of surface treatment to vessel bases in Funnel Beaker West, which could mask traces of this operation (see Section 6.2). The third complementary technique consists of doubling the clay mass of the base and only features in a small number of vessels from Funnel Beaker West megalith inventories and early flat graves (see Tab. 6.1; see Fig. 9.2). The low number of observable base cross-section in the Corded Ware body of knowledge again impedes a direct comparison (see Tab. 7.1). Lastly, a small number of Corded Ware vessel bases has been tipped over while plastic (see Tab. 7.1; Fig. 9.2). Similar traces are absent on Funnel Beaker West vessel bases. However, the decorations and surface treatment of Funnel Beaker West vessels do indicate that these vessels spent part of the production procedure upside down or at an oblique angle (see Section 6.2).

To conclude, the potters who made Corded Ware and Funnel Beaker West vessels mostly learned and applied similar techniques and procedures to fashion vessel bases. The most common procedure (a modelled lenticular mass with additional coils) is shared between the bodies of knowledge. However, there are also differences between the bodies of knowledge. For example, less common techniques and procedures (such as the modelling of flattened disks or the doubling of the base mass) are not shared between bodies of knowledge or common in one but rare in the other (i.e. pressing the base into a surface). As a result, Funnel Beaker West specific *chaînes opératoires* resemble each other more than they do Corded Ware ones.

The roughing-out techniques applied in the fashioning of the vessel walls are also comparable in Funnel Beaker West and Corded Ware vessels (see Tab. 6.2; 7.2; 8.5; Fig. 9.3), but low tallies for (often re-fit) Corded Ware vessels prohibit numeric comparisons.

At the level of techniques, most vessels in both bodies of knowledge and subsets exhibit signs of coiling, and a smaller number of vessels are fully modelled. A finer resolution reveals more similarities. All potters used segment or ring coiling procedures and applied a similar range of coil joining methods. The joining procedures involve coiling by pinching (flattened or U-shaped coil joints) or coiling by pinching or spreading (coil joints with internal and external bevels). In addition, both the Funnel Beaker West and Corded Ware body of knowledge feature a specific fashioning procedure for complex vessel shapes in which coil joints in the lower body show internal bevels and coil joints in the upper body external bevels (see Tab. 6.2; 7.2; Fig. 6.5).

As such, roughing-out techniques for vessel walls are highly similar between Funnel Beaker West and Corded Ware vessels (see Fig. 9.3). These similarities add to those in the roughing-out techniques of vessel bases (see above). In general, vessels in megalith inventories and early flat graves bear the closest resemblance, followed by vessels from late flat graves and Corded Ware. Therefore, the roughing-out techniques indicate that the potters who produced these vessels all learned and put into practice similar technical knowledge, but that knowledge sharing is most pronounced among potters who produced Funnel Beaker West vessels. As shown below, a similar pattern appears in the other stages of the *chaîne opératoire*.

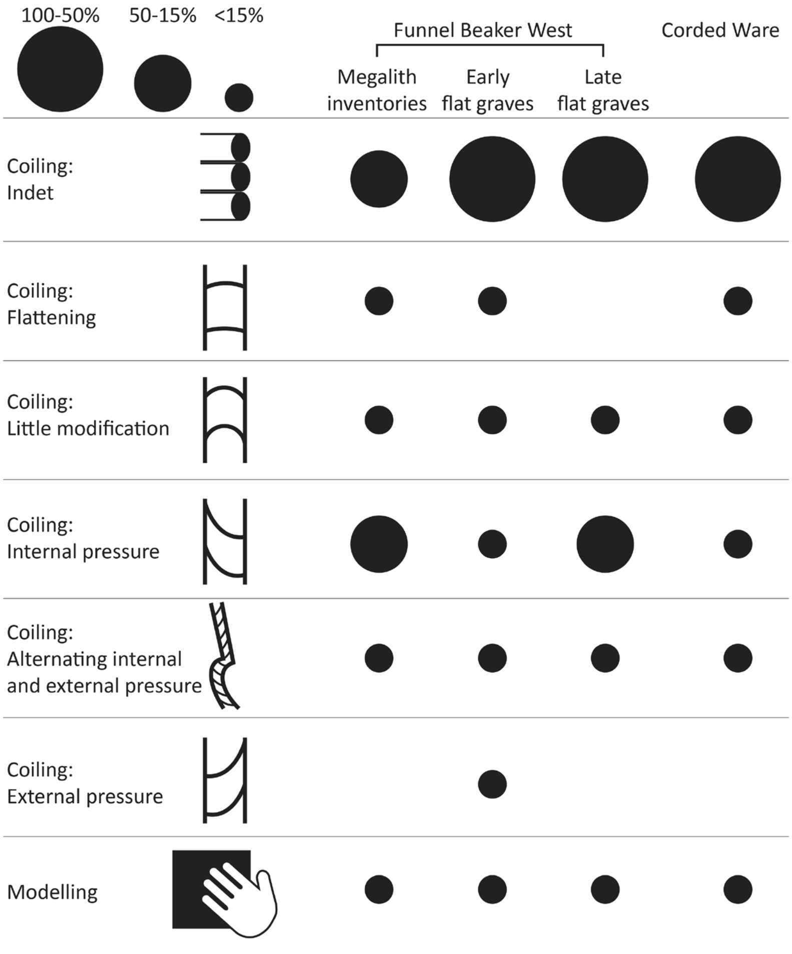


Figure 9.3: Roughing-out techniques (rows) for vessel walls in the Funnel Beaker West megalith inventories, early flat graves, late flat graves, and Corded Ware vessels (columns). The size of the circles indicates the percentage of vessels with traces of the technique.

Preforming

The potters who made Funnel Beaker West and Corded Ware vessels knew and applied the same range of preforming techniques, but different preferences, and a few exceptions are evident from the specific *chaînes opératoires*.

Funnel Beaker West and Corded Ware vessels feature the same preforming techniques for the vessel wall (see Tab. 6.3; 7.3; Fig. 9.4). The most common technique is continuous pressure exerted with hands. The resulting elongated hollows frequently appear around the upper body and base in diagonal or vertical orientation. The second preforming technique consists of scraping, and is less common (see Tab. 6.3; 7.3). The location and direction of scraping operations is generally similar: bands of sub-horizontal traces occur on interior surfaces, specifically the shoulder. However, Corded Ware vessels stand out from Funnel Beaker West vessels due to the frequent appearance of traces in vertical or diagonal orientation on the lower exterior surface (see Fig. 6.7; 7.6). A comparison of

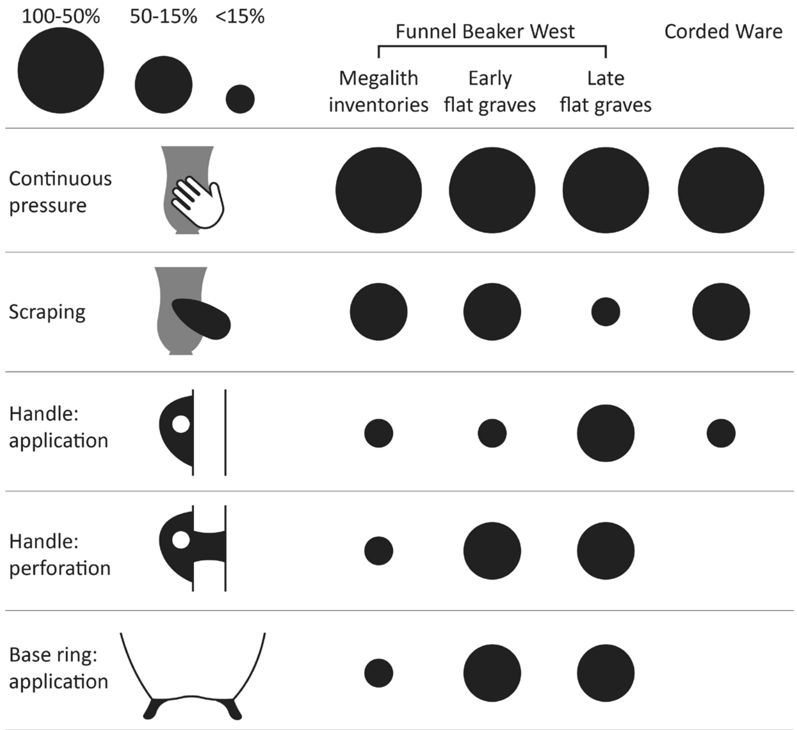


Figure 9.4: Preforming techniques (rows) in the Funnel Beaker West and Corded Ware bodies of knowledge and subsets (columns). The size of the circles indicates the percentage of vessels with traces of a technique.

absolute numbers is difficult due to the frequent and intensive application of surface treatment in Funnel Beaker West vessels (see Section 6.2).

The application of separate elements such as handles and base rings is a point of divergence for the Corded Ware and Funnel Beaker West bodies of knowledge (see Tab. 6.3; 7.3; Fig. 9.4). Funnel Beaker West vessels from megalith inventories, and especially early and late flat graves, exhibit applied base rings relatively often, but no equivalent operations occur in the studied Corded Ware vessels. Further differences appear in handles. Funnel Beaker West vessels feature these separately applied handles more often than Corded Ware vessels (see Tab. 6.3; 7.3). Moreover, the range of fashioning methods for handles differs. Funnel Beaker West vessels feature both handles which are applied with the use of plugs in the vessel wall, and handles which are directly applied to the vessel wall (see Tab. 6.3; Fig. 9.4). The opening in these handles may result from perforations or a modelling operation. By contrast, the application of handles in Corded Ware vessels is only through pressure, and the openings in the handles only result from perforations (see Tab. 7.3).

To conclude, the potters who made Funnel Beaker West and Corded Ware vessels applied comparable techniques, tools, and gestures to preform vessels. However, there are subtle differences in the procedures, such as the scraping of the lower exterior on Corded Ware vessels. A similar conclusion can be drawn for the application of separate elements. The potters who fashioned Funnel Beaker West vessels more commonly performed this

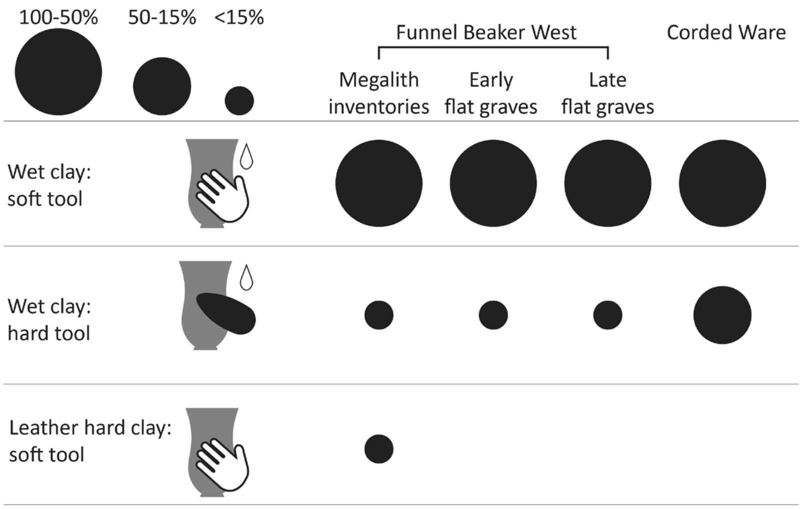


Figure 9.5: Overview of finishing techniques (rows) in Funnel Beaker West megalith inventories, early flat graves, and late flat graves, as well as Corded Ware vessels (columns). The size of the circles indicates the percentage of vessels with traces of a technique.

operation, and in more diverse ways than those who fashioned Corded Ware vessels. Given the functional aspects of handles and base rings, a study of mechanical wear on these applied vessel parts would be informative for interpreting this difference. In terms of technical knowledge, the similarities in preforming further add to the argument in favour of shared knowledge and practices among the producers of vessels in megalith inventories, early flat graves, and late flat graves, and a more partial, but still close overlap in knowledge with the producers of Corded Ware ceramics.

Finishing

The specific *chaînes opératoires* in the Funnel Beaker West and Corded Ware bodies of knowledge do not differ substantially in terms of finishing techniques (see Tab. 6.4; 7.4; Fig. 9.5). Vessels most often feature traces of smoothing wet clay with a soft tool; a similar action with hard tools occurs less frequently. A comparison of the locations and frequencies at which particular tool marks appear is difficult due to the prevalence of surface treatment on Funnel Beaker West vessels. Lastly, two vessels from megalith inventories are exceptions: one shows traces of smoothing a leather-hard paste, and the other shows no traces of finishing techniques.

As such, the potters who made Funnel Beaker West and Corded Ware vessels were familiar with the same range of techniques, with few exceptions.

Decoration

Comparing the decorative techniques in the Funnel Beaker West and Corded Ware bodies of knowledge requires nuance. A technical perspective on decoration is outside the scope of typological classification, but the similarities in this stage of the production process are ambiguous because the attribution of vessels to Funnel Beaker West or Corded Ware is mainly based on decoration (see Ch. 2). For example, use of cord as a tool for simple

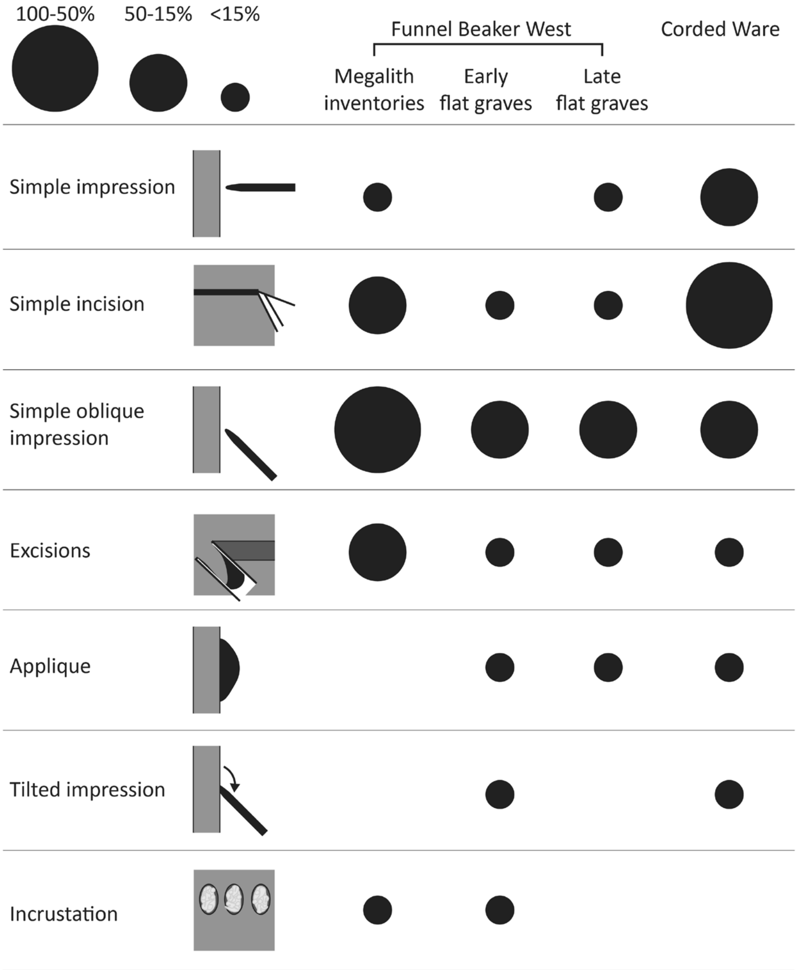


Figure 9.6: The frequency of specific decorative techniques (rows). The size or the circle indicates the percentage in a body of knowledge or subset (columns) with traces of a specific technique.

impressions is unique for Corded Ware specific *chaînes opératoires*, but also a defining element of Corded Ware.

Furthermore, the transmission of knowledge about decorative techniques is subject to some discussion. Gosselain (1992 p. 582, 2000 p. 191, 2008a p. 173, 2018) argues imitation, innovation, and indirect contacts play a central role in learning decorative techniques (contrast his views on roughing-out techniques above), whilst the resulting decorations can be engines for social distinction, or fashion. By contrast, Mayor (2010) argues transmission of knowledge about the tools and techniques for making decorations is similar to the transmission of other production techniques, but that the motifs can be copied. As such, there is no unambiguous interpretation for the outcomes of the comparisons below.

From a general point of view, the potters who made the vessels in the Funnel Beaker West and Corded Ware body of knowledge drew from a similar spectrum of techniques, but with different preferences (see Tab. 6.5-6; 7.5; Fig. 9.6-7). There are three exceptions to this pattern. The first is incrustation, which only appears in Funnel Beaker West specific *chaînes opératoires*. However, taphonomy and restauration severely impact the chances of detecting incrustation (see Chapter 6). Therefore, absence of evidence for this technique is not evidence of its absence.

Tilted impressions with spatula, and applied cordons are the other two exceptions: these decorative techniques are a rare, but shared element in Funnel Beaker West early and late flat graves, and Corded Ware vessels (see Tab. 6.5-6; 7.5; Fig. 9.6).

Apart from the above exceptions, the range of decorative techniques found in Funnel Beaker West and Corded Ware vessels is identical: simple incisions, simple (oblique) impressions, and excisions (see Fig. 9.6). The main differences between the bodies of knowledge lie in the relative proportions, state of the paste, tools, and order of application for these techniques (see Fig. 9.7).

The relative proportions of these techniques show Funnel Beaker West and Corded Ware potters knew the same techniques, but had different preferences. Funnel Beaker West ceramics most often exhibit simple (oblique) impressions (ca. 60% of vessels) and less often simple incisions (ca. 20% of vessels; cf. Tab. 6.5). Excisions occur in ca. 10% of the vessels (see Tab. 6.5). These choices from the potters who made Funnel Beaker West vessels contrast with those from the potters who made Corded Ware vessels. The latter potters apply simple incisions as often as simple (oblique) impressions (i.e. in ca. 50% of the Corded Ware vessels). Excisions are rare (see Tab. 7.5; Fig. 9.6). Consequently, the potters who produced Corded Ware and Funnel beaker West vessels knew similar decorative techniques, but had different preferences within this shared spectrum.

Interestingly, different preferences also appear among the potters who produced the vessels in megalith inventories, early flat graves, and late flat graves. Looking at the vessels from megalith inventories (see Tab. 6.5; Fig. 9.6), around 75% of these vessels features decoration, and the decorative techniques are varied. Simple (oblique) impressions, simple incisions, and excisions all feature in a substantial percentage of vessels. Two things then happen in the subset for early flat graves. Firstly, the percentage of vessels with decoration falls to just over 50%. Secondly, the percentage of vessels with simple incisions and excisions falls, but simple (oblique) impressions continue to be prominent (ca. 40% of the vessels; see Tab. 6.5, Fig. 9.6). This contrast becomes more pronounced in late flat graves. Less than half of the vessels features decoration, and whereas simple (oblique) impressions remain common (ca. 40% of the vessels), all other decorative techniques fall to less than 15% (see Tab. 6.5; Fig. 9.6).

We know the vessels in subsets megalith inventories and early flat graves are generally older than those in the subset late flat graves (see Ch. 2; 5). Therefore, this data shows Funnel Beaker West potters knew the same decorative techniques, but over time went from applying a broad range of techniques to a strong preference for a single technique, namely simple (oblique) impressions. In other words, there is a standardisation in the Funnel Beaker West body of knowledge. This standardisation is especially evident when comparing megalith inventories to late flat graves, but already visible a comparison of early flat graves and megalith inventories. This standardisation of decorative techniques is discussed in more detail in the next chapter. For now, let us look at the tools which potters used to make decorations.

The potters who made the vessels in the Funnel Beaker West and Corded Ware body of knowledge used a different spectrum of tools for producing decorations (see Tab. 6.5; 6.6; 7.5; Fig. 9.7). The Funnel Beaker West tool spectrum prominently features conical tools,

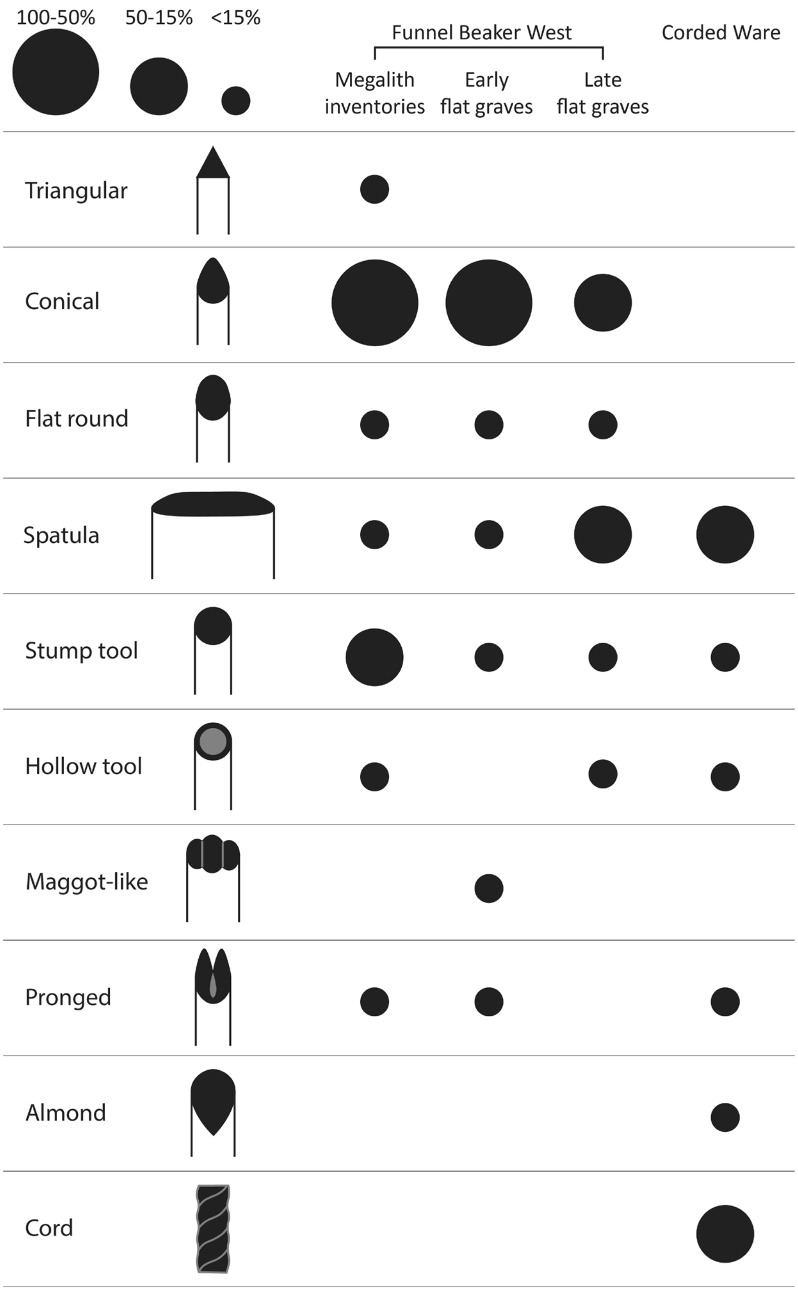


Figure 9.7: The spectrum of tools used for simple (oblique) impressions (rows) in Funnel beaker West and Corded Ware. The columns indicate the bodies of knowledge and subsets. The size of the circles is indicative for the percentage of decorated vessels with impressions of a tool type.

as well as stump tools, flat round tools, spatulae, pronged tools, hollow tools, maggot-like tools, and triangular tools (see Tab. 6.5; 6.6). The tool spectra of megalith inventories, early flat graves, and late flat graves again show a development towards standardisation. Megalith inventories and early flat graves exhibit the broadest variation in tool types with an emphasis on conical tools (see Fig. 9.7; Tab. 6.6). However, the vessels in late flat graves show a narrower spectrum of tools (see Fig. 9.7) in which conical tools are most common, but spatulae also appear relatively often (see Tab. 6.5-6; Fig. 9.7). Consequently, the standardisation of decorative techniques goes hand in hand with a standardisation of the tools which potters used to make these decorations.

The Corded Ware tool spectrum for making simple (oblique) impressions is dominated by cord and spatula, with almond-shaped, stump, pronged, and hollow tools occurring more rarely (see Tab. 7.5). Some of these tools (i.e. cord and almond-shaped tools) do not appear in the Funnel Beaker West body of knowledge and others are rare (see Fig. 9.7). In other words, the potters who made Funnel Beaker West and Corded Ware vessels had different 'favourite' tools to apply decoration (i.e. conical tools and cord) but were familiar with some of the same, rarer tools. Spatulae are an exception: these tools are among the most common to make decorations on Corded Ware vessels and were also used on vessels from early and especially late flat graves (even if rarely so, see Tab. 6.6).

Despite the differences in tools, the potters who produced Funnel Beaker West and Corded Ware vessels did both prefer to apply these tools and techniques to wet clay. There are few exceptions in megalith inventories and Corded Ware, where potters applied excisions or simple incisions to leather-hard clay (see Tab. 6.5; 7.5; 8.6).

Three subtle but crucial differences between the Funnel Beaker West and Corded Ware body of knowledge appear in the procedure for applying decorative techniques. These differences are: the layering of decoration, the positioning of the vessel during decoration, and the ordering of decorative techniques.

Firstly, Funnel Beaker West vessels often exhibit layering of decorative techniques: potters applied one or more tools in successive operations to create complex fields of decoration (e.g. Fig. 6.10E). A similar layering of decorative techniques is absent in Corded Ware specific *chaînes opératoires*.

Secondly, several Funnel Beaker West vessels appear to have been decorated in an upside-down position, or at the very least while held at an oblique angle (see Fig. 6.10A-B). Evidence for a similar procedure is scant in Corded Ware ceramics, apart from previously discussed signs on vessel bases.

The last aspect in which the decorative procedures differ between the Corded Ware and Funnel Beaker West body of knowledge is the sequence of decorative techniques. The decorations of several Corded Ware vessels show signs that the application of decorative techniques started near the rim and proceeded down towards the base (see Chapter 7). Evidence for such a procedure is rare in Funnel Beaker West vessels.

These differences in the procedure for applying decoration are relevant because motifs and techniques may be copied, but one has to see or be told about a procedure to learn it.

The general pattern which emerges from the above comparison of decorative techniques is that the potters who made Funnel Beaker West and Corded Ware vessels learned and applied a similar spectrum of techniques but made different choices within that spectrum. Moreover, the differences in tools and procedures hint at subtle divergences in the knowledge of potters. The standardisation of decorative techniques within the Funnel Beaker West body of knowledge is of equal interest. The potters who made these vessels were aware of the same techniques but adopted a standardised procedure to make the vessels in early, and especially late, flat graves compared to those in megaliths.

Surface Treatment

The next stage of the ceramic *chaîne opératoire* is surface treatment. Ignoring a small number of possible exceptions in megalith inventories (see Chapter 6), the potters who made Corded Ware and Funnel Beaker West vessels used the same three surface treatment techniques: burnishing, shining, and smudging (see Tab. 6.7; 7.6; 8.7; Fig. 9.8). Moreover, a similar percentage of vessels (around 80-90%) exhibits traces of surface treatment in all bodies of knowledge. However, the potters did have different preferences for the use of burnishing and shining (see Tab. 6.7; 7.6), as well as the surfaces on which to apply these techniques (see Fig. 6.13; 7.13).

The potters who fashioned Funnel Beaker West vessels most often applied burnishing. Traces of this technique appear on 80-90% of the vessels from the subsets in this body of knowledge (see Tab. 6.7; 8.7). These traces appear on all vessel surfaces, including the base exterior, but the number of positive detections is generally highest on upper exterior surfaces (see Fig. 6.13). By contrast, the number of vessels with shining traces is marginal, and traces of this operation are limited to the exterior surface (see Tab. 6.7; 8.7; Fig. 6.13). Interestingly, vessels from late flat graves only show traces of burnishing (see Tab. 6.7; Fig. 9.8), again hinting at a standardisation of vessel production for this subset.

Corded Ware ceramics depart from the above pattern in two ways. Firstly, burnishing remains the most prevalent surface treatment technique, but the number of burnished and shined vessels differ by a fraction, and neither technique appears on more than 50% of the studied vessels (see Tab. 7.6; Fig. 9.6). Moreover, traces of surface treatment most often occur on the lower exterior surfaces and exterior shoulder, and less often on the upper exterior and interior. Corded Ware vessels rarely exhibit traces of surface treatment below the shoulder on the interior (see Fig. 7.13, Tab. 8.7).

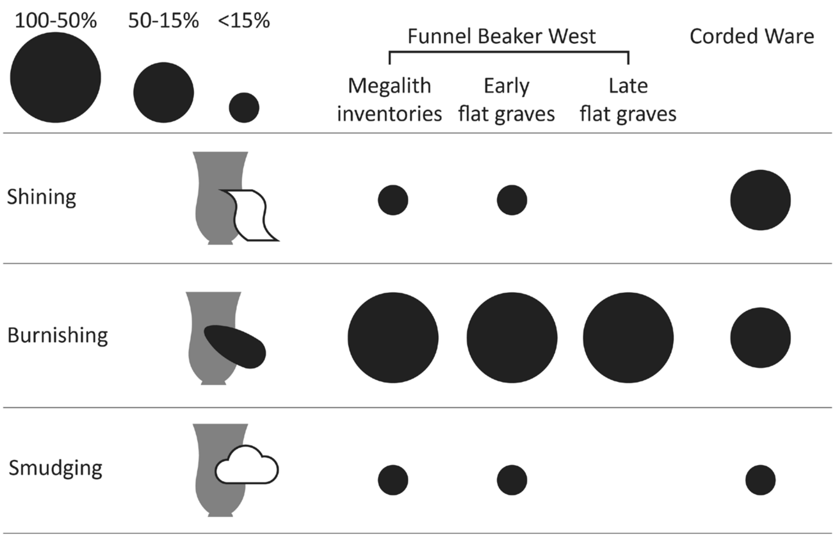


Figure 9.8: The range of surface treatment techniques in the Funnel Beaker West and Corded Ware body of knowledge and subsets (columns). The size of the circles indicates the percentage of vessels with traces of a technique (rows).

The third surface treatment technique, smudging, is an exception to the above pattern. Macroscopic traces of smudging occur in roughly equal proportions on Funnel Beaker West and Corded Ware vessels (see Tab. 6.7; 7.6). In addition, local carbon enrichment near surfaces occurs in some Funnel Beaker West vessels (see Tab. 8.7). However, the absolute number of positive detections is marginal in both bodies of knowledge.

In sum, the potters who produced Funnel Beaker West and Corded Ware vessels were familiar with the same surface treatment techniques but chose to apply these to different vessel parts and in different proportions.

Firing

The last stage of the ceramic *chaîne opératoire* in this comparison is firing. Ethnographic studies show that a substantial amount of knowledge and practices plays a role during firing (e.g. Arnold 2018). However, archaeological reconstructions of the firing process are limited. The firing atmosphere is the only variable which can be reconstructed from macroscopic observations, whereas ceramic petrography offers some information on equivalent firing temperatures.

Funnel beaker West and Corded Ware are comparable in terms of firing atmosphere (see Tab. 6.8; 7.7; Fig. 6.15; 7.15; 9.9). The firing atmosphere either did not allow for the combustion of carbon or was reducing, but the firing process ended on rapid cooling with an influx of oxygen which reached the exterior surfaces of the pots, but not always the interior, especially not the lower interior. These traces could indicate various different firing processes, such as firing vessels without open access to the atmosphere in an oven,

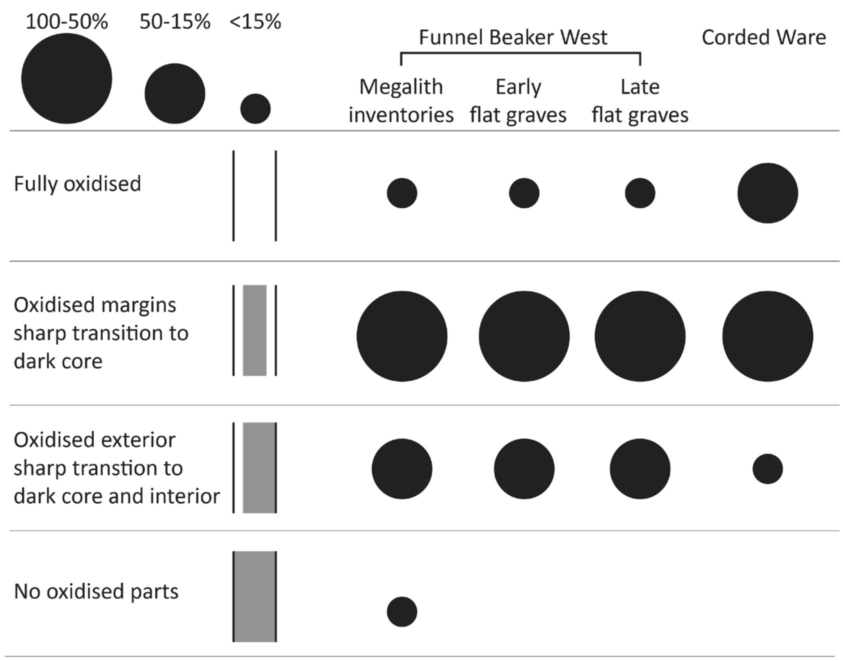


Figure 9.9: An overview of the firing cores (rows) which occur in subsets of the Funnel Beaker West and Corded Ware ceramics. The size of the circle indicates the percentage of vessels with a specific firing core.

or with vessels stacked up, placed sideways, or fuel covering the vessels. If so, the influx of oxygen and cool air may relate to the breaking open of the oven, or the removal of other vessels or fuel. In some cases, the appearance of reducing surfaces on the upper exterior indicates vessels may have been positioned side-ways during firing (see Fig. 6.15; 7.15).

The above description applies to three-quarters of the vessels in all subsets and bodies of knowledge, not accounting for unknown cores (see Tab. 6.8; 7.7). By contrast, fully oxidised vessels (which may result from the same procedure or firing with much oxygen) are relatively rare and make up 10-15% of the vessels in both bodies of knowledge (see Tab. 6.8; 7.7; Fig. 9.9). Lastly, a single vessel from a megalith exhibits a fully reduced core (see Tab. 6.8; Fig. 9.9), and stands as an exception within the dataset. Apart from this exception, all three groups of vessels are comparable in terms of firing atmosphere.

The equivalent firing temperatures of Funnel Beaker West and Corded Ware vessels all fall into the same bracket (see Section 8.2). The minimal equivalent firing temperature falls around 573°C, and the maximum equivalent firing temperature is probably in the lower regions of 800-1000°C.

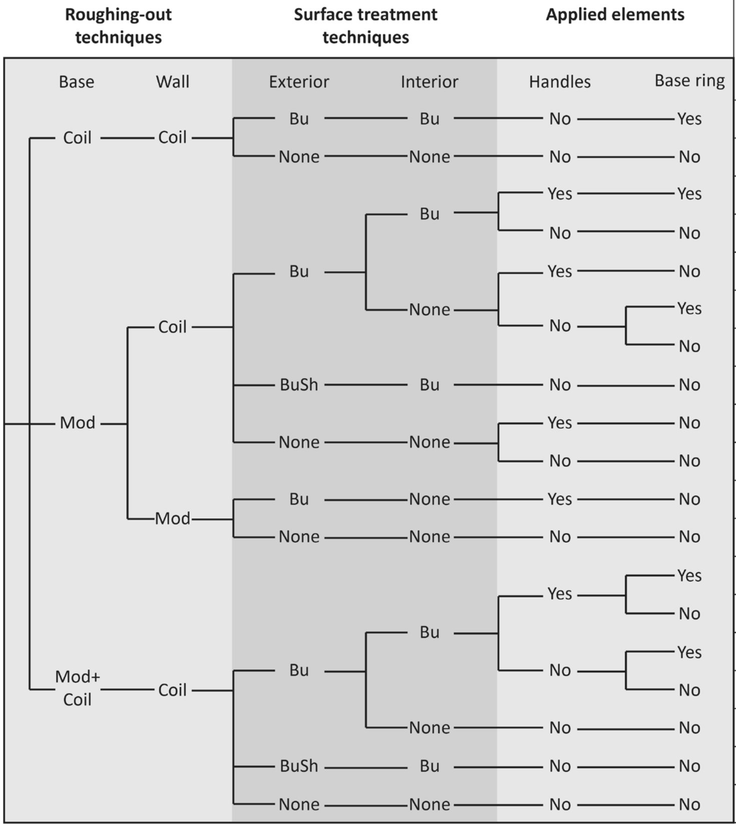
Both the reconstructed firing atmospheres and equivalent firing temperatures are generic for prehistoric firing regimes (see Section 8.2) and do not provide evidence for specific firing architecture (cf. Thér *et al.* 2019a).

9.2 Are There Specialised Production Methods?

A key question for abductive comparisons of ceramic technology is whether or not specialised production methods can be attested for specific vessel types or shapes (Roux 2019a pp. 230–1). Detecting these patterns involves exploring the coherence between vessel types and shapes on the one hand and (combinations of) the production techniques applied during roughing out, preforming, finishing, surface treatment of the interior and exterior surfaces, and firing on the other hand. The aim of this exploration is to produce a dendrogram which shows the filiation of different variants of the production method and vessel types or shapes (cf. Roux 2019a p. 219).

Attempts to detect (variants of) production methods which are specific to one or more of the vessel types and shapes as defined in Fig. 2.7 do not yield significant results for the Funnel Beaker West and Corded Ware ceramics studied here. A brief excursion to the base data for vessels in the subset early flat graves serves to explain this outcome. The patterns discussed below apply to all other subsets and bodies of knowledge but the subset early flat graves is best-suited to illustrate these patterns because it contains a fair number of vessels (n=62, see Tab. 9.1) of various shapes and types (see Section 5.3).

Figure 9.10 is a dendrogram which splits the vessels in the subset early flat graves by roughing-out techniques used to shape the vessel base and wall, surface treatment techniques applied to the exterior and interior vessel wall, and lastly application of separate elements for handles and base rings. The techniques used during the preforming, finishing, and firing stage of the ceramic production process are not shown because these are uniform across all vessels and would therefore not contribute to the clustering (see Section 9.1; Ch. 6; 7). The focus on techniques rather than modalities of techniques is because this data is available for all vessels (see also Section 4.1). Moreover, further splits of the data along modalities of techniques would contribute to, rather than resolve the problems with the clustering which are discussed below.



Base	Wall	Exterior	Interior	Handles	Base ring	Open: Bowl	Open: Misc.	Closed: Bowl	Complex: Amphora-like	Complex: Beaker	Complex: Bowl	Complex: Collared flask	Complex: Shouldered vessel
Coil	Coil	Bu	Bu	No	Yes	1	-	-	-	-	-	-	-
Coil	Coil	None	None	No	No	-	-	-	-	-	-	1	-
Mod	Coil	Bu	Bu	Yes	Yes	-	-	-	3	-	-	-	-
Mod	Coil	Bu	Bu	No	No	1	-	-	-	4	-	-	-
Mod	Coil	Bu	None	Yes	No	-	-	-	2	-	-	-	-
Mod	Coil	Bu	None	No	Yes	2	-	-	-	-	-	-	-
Mod	Coil	Bu	None	No	No	2	-	-	-	-	-	1	-
Mod	Coil	BuSh	Bu	No	No	1	-	-	-	-	-	-	-
Mod	Coil	None	None	Yes	No	-	-	-	-	-	-	-	1
Mod	Coil	None	None	No	No	-	1	-	1	-	-	-	-
Mod	Mod	Bu	None	Yes	No	-	-	-	1	-	-	-	-
Mod	Mod	None	None	No	No	2	-	-	-	-	-	-	-
Mod+Coil	Coil	Bu	Bu	Yes	Yes	-	-	-	3	-	-	-	-
Mod+Coil	Coil	Bu	Bu	Yes	No	1	-	1	6	-	-	-	2
Mod+Coil	Coil	Bu	Bu	No	Yes	1	-	-	-	-	-	-	-
Mod+Coil	Coil	Bu	Bu	No	No	8	-	-	1	7	1	-	2
Mod+Coil	Coil	Bu	None	No	No	1	-	-	-	1	-	-	1
Mod+Coil	Coil	BuSh	Bu	No	No	1	-	-	-	-	-	-	-
Mod+Coil	Coil	None	None	No	No	-	-	1	-	-	-	-	-

Figure 9.10: Dendrogram of roughing-out techniques, surface treatment techniques, and application of separate elements in vessels from early flat graves. The table on the right shows the number of vessels of specific vessel types and shapes (see Fig. 2.7) on each leaf of the dendrogram. Abbreviations have been used for the names of techniques: coil = coiling, mod = modelling, mod+coil = a combination of modelling and coiling, Bu = burnishing, BuSh = a combination of burnishing and shining. The dendrogram shows that that if we fit the production methods of these vessels onto a dendrogram, technical decisions have to be repeated in the different branches. This means that the clusters do not consist of vessels with unique production methods but follow from permutations of the same set of technical choices. Moreover, the clusters at the leaves generally contain vessels of various different types and shapes.

The purpose of a dendrogram in an abductive comparison of specific *chaînes opératoires* is twofold. Firstly, the dendrogram shows clusters of vessels characterised by a unique production methods at the leaves. Secondly, the topology of the dendrogram shows at what stage of the production process differing technical choices gave rise to these clusters. For example, Roux (2019a Fig. 4.2) depicts a dendrogram in which all vessels are roughed out by coiling, but some vessels are preformed with rotary kinetic energy while others are not. Within these two branches, further variants emerge due to differing choices in finishing and surface treatment techniques. The composition of these clusters in terms of vessel shapes and types then informs further interpretations. In other words, the dendrogram is a means to detect and display set production methods followed by potters during ceramic production. Crucially, the dendrogram also depends on the existence of set production methods to be plotted.

The problem for the specific *chaînes opératoires* studied here is that they cannot be fitted onto a dendrogram due to the absence of set production methods for specific types or shapes of vessels. This is illustrated in Figure 9.10 with the vessels from early flat graves. Consider the topology of this dendrogram. Various technical choices, such as the application of handles or burnishing of the interior surface, are repeated across the different branches. This means the clusters at the leaves of the dendrogram do not feature vessels with unique production methods. Handles and burnished interiors will appear in vessels from various clusters, irrespective of the other technical choices in the dendrogram (see Fig. 9.10). Adding more variables, such as modalities of the coiling technique, would further increase this repetition of technical choices by introducing additional splits in branches with coiling. Moreover, the clusters at the leaves of the dendrogram are not homogeneous in terms of vessel shapes and types. Apart from clusters with single vessels, most clusters contain vessels of various types and shapes of vessels (see Fig. 9.10). Consequently, the dendrogram does not yield evidence for the existence of specialised ceramic production methods associated with specific vessel types or vessel shapes.

Despite the lack of meaningful clusters, the topology of the dendrogram is informative for the nature of ceramic production processes. The repetition of technical choices in different branches in Fig. 9.10 shows potters did not follow set recipes, but knew a range of different production techniques (e.g. burnishing, shining, coiling, and modelling) and opted in or out of using these techniques during the production process. In other words, the topology of the dendrogram in Figure 9.10 is precisely what we would expect to find when potters draw from broader technical repertoires for each ceramic production process (see Ch. 3). This does not mean that no patterns exist in the choices of potters for specific techniques (see Section 9.1) but it underlines the need for an analysis which can accommodate recombination of techniques from a larger set (see Ch. 4).

9.3 Discussion and Conclusion

The sections above are an abductive comparison of the specific *chaînes opératoires* in the Funnel Beaker West and Corded Ware bodies of knowledge. This comparison has three aims: 1) to determine whether specialised production methods exist for certain vessel shapes or types, 2) to assess the extent of the technical knowledge which circulated among the potters who produced these specific *chaînes opératoires*, and 3) to detect potential overlaps in knowledge and production methods. Such overlaps would indicate these potters learned (however direct or indirect) from each other (see Ch. 3). This, in turn, is informative for understanding the interactions between migrating and indigenous communities 5,000 years ago.

No specialised production methods for specific vessel types or shapes can be attested in the Funnel Beaker West or Corded Ware body of knowledge (see Section 9.2). This is because potters recombine the ceramic production techniques known to them to create many different specific *chaînes opératoires*. Therefore, looking at the coherence of techniques requires the probabilistic comparison from Ch. 4. However, the abductive comparison does point to patterns in the individual techniques which potters learned and chose to use (see Section 9.1).

Based on these patterns, I argue the potters who made Funnel Beaker West and Corded Ware vessels learned and put into practice the same technical knowledge. There are also subtle differences, to which we return below and in Chapter 13.

The foremost argument for my position is the similarity in roughing-out techniques, because learning these techniques requires personal interactions (Gosselain 1992 p. 582, 2000 pp. 192–3; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29). The potters who made Funnel Beaker West and Corded Ware vessels draw upon the same range of coiling and modelling techniques for roughing out vessel bases and walls. Moreover, these similarities go beyond the techniques: the exact procedures and modalities of the techniques are similar. The vessels walls are fashioned with the same coiling procedures and joining methods, including a specific procedure for roughing out complex shapes. The modelling of the base often involves pinching a lenticular mass and supplementing this mass with adjacent coils. Vessels from Funnel Beaker West megaliths, early flat graves, and late flat graves do resemble each other more than they do Corded Ware vessels. For example, a second procedure for fashioning the base which consists of modelling a flattened clay disk, only appears in Funnel Beaker West vessels. Nevertheless, the overlap observed in techniques, procedures, and modalities of techniques, strongly suggests the potters who produced Funnel Beaker West and Corded Ware learned and put into practice the same technical knowledge, and are therefore connected by learning events.

The second argument is the repetition of the above-mentioned pattern throughout the entire ceramic production process. Funnel Beaker West and Corded Ware specific *chaînes opératoires* consistently feature the same range techniques, be it during preforming, finishing, decoration, surface treatment, or firing. This is not to say the specific *chaînes opératoires* are identical in all respects: there are subtle differences. For example, the potters who made Corded Ware vessels more often chose to apply shining during surface treatment, whereas the potters who fashioned Funnel Beaker West vessels primarily applied burnishing. Another example is the fashioning of handles during preforming: Funnel Beaker West vessels exhibit handles with modelled and perforated openings, which may be attached to the vessel wall through plugs or pressure. By contrast, Corded Ware vessels rarely exhibit handles, and the handles which do occur are affixed to the vessel wall by pressure and perforated to create openings. Both examples illustrate the conclusion that a similar range of techniques appears in Funnel Beaker West and Corded Ware specific *chaînes opératoires*, but that the potters who Funnel Beaker West and Corded Ware vessels select different options within this range (e.g. for shining instead of burnishing). The examples also illustrate why the subsets of Funnel Beaker West resemble each other more than they do Corded Ware: these potters more often made similar choices within that same range of techniques.

However, there are also stages of the ceramic production process where differences occur: primarily decoration and paste recipes. Corded Ware specific *chaînes opératoires* feature a similar range of decorative techniques as Funnel Beaker West vessels, but there are differences in the tools (e.g. cord for simple impressions) and procedures (i.e. decoration from the rim downward rather than with the vessel upside down and a lack of layered decorative techniques). Not all tools and decorative techniques differ. See, for

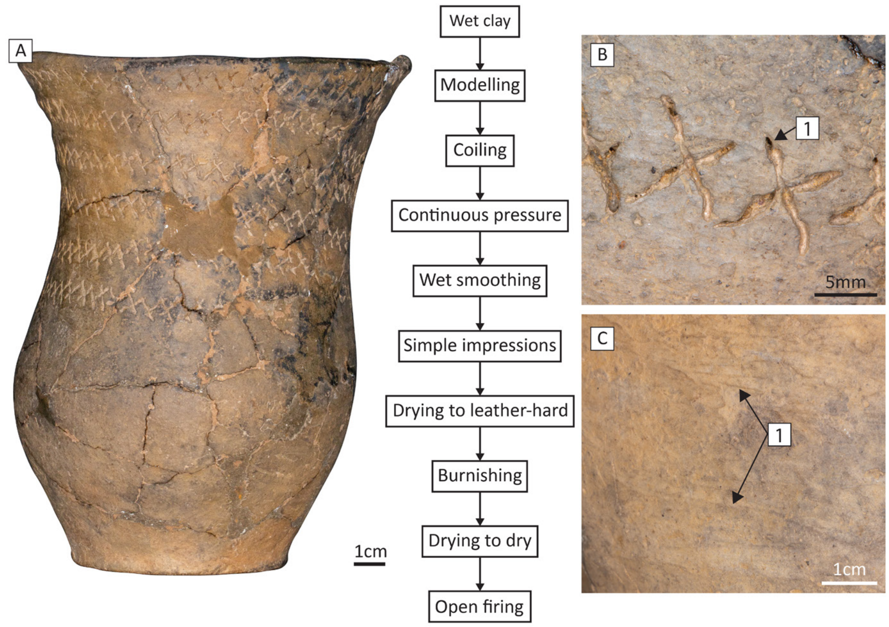


Figure 9.11: Vessel 18. A: The vessel exhibits the S-shaped profile and decoration in discrete horizontal zones on the upper body of Corded Ware vessels. The specific *chaîne opératoire* is depicted to the right. B: The decorations consist of simple, oblique impressions with a stump tool (1). The irregular microrelief at the bases of the depressions indicate the clay was wet during the application of decoration. Surface treatment reworked the edges of the impressions. C: Traces of a burnishing operation on the vessel surface. The surface has a compact microtopography, glossy aspect, inserted particles, and parallel, sub-horizontal bands of striations with scalloped edges (1).

example, the making of excisions or the use of spatulae, but new techniques and tools do appear in Corded Ware vessels relative to Funnel Beaker West vessels.

A similar pattern appears with paste recipes. The potters who made Funnel Beaker West vessels follow a strict recipe, and this recipe is shared by all subsets (from megalith inventories to late flat graves) and across the Netherlands and Germany. However, Corded Ware vessels show a more variable paste recipe. These alternate recipes often involve one or more shifts in the preferences for specific raw materials (e.g. in the silt contents of clay) or new raw materials (e.g. grog) relative to Funnel Beaker West. Crucially, there are also Corded Ware vessels which adhere to the strict Funnel Beaker West paste recipe. These differences in paste recipes and decorative techniques show that the potters who made Corded Ware vessels dispose of 'new' knowledge and practices relative to the Funnel Beaker West body of knowledge but also appear to learn the typical Funnel Beaker West paste recipe.

Thus, the specific *chaînes opératoires* of Funnel Beaker West and Corded Ware vessels draw upon similar spectra of techniques throughout the production process, with some new additions. Techniques in key stages of the specific *chaînes opératoires* are highly similar, such as the roughing out of the vessel walls and bases. Differences between bodies of knowledge do occur due to different choices within the shared range of techniques, as well as novel techniques and procedures. In all such cases, Funnel Beaker West vessels in megalith inventories, early flat graves, and late flat graves share more similarities with each other than with Corded Ware vessels. These overlaps indicate the potters who produced Corded

Ware, and (*a fortiori*) Funnel Beaker West specific *chaînes opératoires* put into practice the same technical knowledge about ceramic production. This learned technical knowledge cuts across the typological distinction between Funnel Beaker West and Corded Ware.

Figure 9.11 exemplifies the above interpretation. The depicted vessel (vessel ID 18) is (in terms of typology) Corded Ware: it exhibits an S-shaped profile and decorations restricted to the upper body in distinct, horizontal zones (see Fig. 9.11A; cf. Van der Waals and Glasbergen 1955 p. 7). However, the decoration consists of simple oblique impressions with a stump tool (see Fig. 9.11B), and the motif best resemble Brindley's (1986b Fig. 2) 'incised lozenges' on Funnel Beaker West ceramics. The specific *chaîne opératoire* of this vessel would fit equally well in the Corded Ware or Funnel Beaker West body of knowledge (see above; Fig. 9.11A): it features a base from a modelled, lenticular mass with adjacent coils, coiled walls, preforming by continuous pressure with hands, smoothing on wet clay, decoration through simple oblique impressions (see Fig. 9.11B), partial surface treatment by burnishing (see Fig. 9.11C), and a firing atmosphere with oxidised margins which transition sharply into a dark grey core (see Appendix C and D for textual and photographic documentation).

Vessel 18 resembles Corded Ware in one way and Funnel Beaker West in another. Nevertheless, it is not a hybrid; and whether or not it results from a Funnel Beaker potter imitating Corded Ware vessels (or vice versa) is unverifiable. The comparisons above show that we should not consider this vessel as *either* Funnel Beaker West *or* Corded Ware. Instead, the language of probability applies: How much does this specific *chaîne opératoire* differ from specific *chaînes opératoires* in a given set? Furthermore, given the variation in that set, does that difference fall within the range one would expect for any of the members, or does it exceed this range? At what point is the difference such that we should assume the potters shared no knowledge about ceramic production? The strength of the probabilistic comparisons in the next chapter is the ability to resolve the above questions.

10

Probabilistic Comparison of Specific *Chaînes Opératoires*

This chapter is a continuation of the comparison between the Funnel Beaker West and Corded Ware bodies of knowledge (see also Ch. 9), but with the probabilistic method from Chapter 4. This approach goes beyond the variation in techniques discussed in the previous chapter. It looks at the variability and frequency of techniques, as well as the syntax of the production process.

The comparison has two parts. The first part, in Section 10.1, compares the Funnel Beaker West and Corded Ware bodies of knowledge. Did these potters not only use similar techniques but also integrate these techniques in the same manner during the production process? The outcomes of this comparison underline the conclusions from the previous chapter: These potters most probably shared technical knowledge.

The central questions in part two (Section 10.2) are: What does 'most probably' mean? Moreover, how did this knowledge come to be 'shared'? To address these questions, we turn to guided random path generation and the subsets of the Funnel Beaker West body of knowledge (see Tab. 9.1). Guided random path generation allows for the simulation of specific *chaînes opératoires* for (e.g.) Funnel Beaker North vessels. The distance between Funnel Beaker West and sister group Funnel Beaker North can then be used to evaluate how exceptional the close match between Funnel Beaker West and Corded Ware is. We then build a diachronic comparison by also integrating the subsets of Funnel Beaker West. This comparison shows whether technical knowledge becomes more or less similar over time. A summary of the findings in this chapter is available in Section 10.3.

10.1 Probabilistic Comparison of Funnel Beaker West and Corded Ware

This section is a comparison of all the specific *chaînes opératoires* in the Funnel Beaker West (n=187) and Corded Ware (n=89) body of knowledge taken together (see Tab. 9.1; 10.2). The point of departure are the network representations of these specific *chaînes opératoires* (see Fig. 6.16; 6.17; 6.18; 7.16). These network representations combine all specific *chaînes opératoires* within a body of knowledge and plot this overview in the total *chaîne opératoire*. The visualisation captures the variation within a body of knowledge: it shows which combinations of techniques potters commonly applied, and which are exceptional. This variation can be converted into a probability distribution by taking the edge weights of all edges in the network (see Ch. 4). The more paths pass along a given edge, the higher the probability of the edge. For example, if more specific *chaînes opératoires* pass from 'drying to leather-hard' to 'burnishing' than from 'drying to leather-hard' to 'shining', the former link has a higher probability. The probability distribution captures all of these choices in the entire network in one overview.

Two such probability distributions are then compared with the Wasserstein distance. This method determines the minimal number of changes necessary to transform one probability distribution into another (see Ch. 4). In this context, changes to the probability distribution mean alternate choices during the production process or new (combinations of) techniques to be learned. For example, performing 'shining' instead of 'burnishing' after 'drying to leather-hard'. The more of these changes are necessary for the transformation, the higher the Wasserstein distance, but also the further removed the technical knowledge of past potters (see Fig. 4.2).

The Wasserstein distance expresses the separation between bodies of knowledge as a single number. In order to interpret that number, we compare the distance between two bodies of knowledge for which shared knowledge is an open question (A and B) to the distance between two bodies of knowledge for which no knowledge is shared (A and C; see Section 4.2). This latter distance would result if potters had to familiarise themselves with a completely new pottery production process from scratch. If the Wasserstein distance between A and B equals or exceeds the distance between A and C, then it is also unlikely that the potters behind bodies of knowledge A and B shared knowledge. If, on the other hand, the distance is smaller, then this implies the potters shared technical knowledge and are connected by learning events, even if only distant (see Tab. 4.1).

Table 10.1 is a matrix which reports the Wasserstein distances between the bodies of knowledge for Funnel Beaker West and Corded Ware, as well as to a group of 1,000 randomly generated paths. The number 1,000 is a practical balance between a representative sample of random paths (and thus a robust outcome), and the processing time required to generate and compare these (see Section 4.2). Randomly generated paths are used here as outgroup, because these paths by definition do not result from the same technical knowledge as the specific *chaînes opératoires* made by prehistoric potters.

Figure 10.1 is a visualisation of the matrix in Table 10.1. The figure presents a line which starts at 0 for Funnel Beaker West (obviously no changes are needed to transform Funnel Beaker West into Funnel Beaker West) and ends at the largest distance relative to this body of knowledge in Table 10.1. The distance to the Corded Ware body of knowledge is projected onto that line. A similar figure for Corded Ware is not necessary because the comparison between Corded Ware and Funnel Beaker West is symmetrical (see Tab. 10.1): the figure would only switch the position of Funnel Beaker West and Corded Ware with a marginal adjustment of the distance to randomly generated paths.

The Wasserstein distances in Table 10.1 concurs with the outcomes of the abductive approach in Ch. 9. The distance separating Funnel Beaker West from Corded Ware is around a factor 7 lower than the distance separating either body of knowledge from a set of randomly generated paths (see Fig. 10.1; Tab. 10.1). This outcome indicates some differences in the choice of techniques and their ordering do exist between Corded Ware and Funnel Beaker West specific *chaînes opératoires*. However, these differences pale in comparison to the differences which would occur if no knowledge had been shared at all. The high distance to randomly generated paths shows that, out of all possible

Table 10.1: Matrix of the Wasserstein distances between the Funnel Beaker West (FBW) and Corded Ware (CW) body of knowledge, as well as a body of 1,000 randomly generated paths (Random). The matrix is symmetrical: the minimal number of changes to transform FBW into CW is equal to those needed to transform CW into FBW. The diagonal is empty because the Wasserstein distance of a probability distribution to itself is always zero: No changes are necessary to transform a distribution into itself.

	FBW	**CW**	**Random**
FBW	0	0.35	2.41
CW	0.35	0	2.48
Random	2.41	2.48	0

Figure 10.1: Visualisation of the Wasserstein distance from FBW to CW and Random (see Tab. 10.1). FBW sits at the zero point of the line because the Wasserstein distance of a body of knowledge to itself is 0. The line ends at the largest Wasserstein distance to FBW in Tab. 10.1, in this case Random. The distance from FBW to CW is projected onto this line (to scale). The figure shows the Corded Ware body of knowledge is substantially more similar to Funnel Beaker West body of knowledge than a body of randomly generated specific *chaînes opératoires*.

paths through the total *chaîne opératoire*, Funnel Beaker West and Corded Ware potters consistently picked a similar, select set of specific *chaînes opératoires*.

A brief return to the base data (see Fig. 6.16; 6.17; 6.18; 7.16; Ch. 9) illustrates this outcome. Both Funnel Beaker West and Corded Ware specific *chaînes opératoires* tend to start with a modelled base, followed by coiled or modelled vessel walls which are preformed through pressure and/or scraping. These roughing-out techniques can be followed by the application of separate elements, but tend to lead on to wet smoothing, followed by the application of decorative techniques (if any). Most of the distance between the bodies of knowledge stems from alternate choices in, and ordering of, these decorative techniques, which can include simple incisions, simple impressions, excisions, tilted impressions, incrustation, and applied decoration (see Ch. 9). However, these alternate operations are in the same general position in the production process: between finishing and drying to leather-hard. Drying to leather-hard is followed by surface treatment, where again some variation occurs (i.e. no surface treatment, shining, or burnishing). Following surface treatment, the next steps are drying to dry, and firing. Past the firing stage, alternate choices for smudging, and incrustation add to the variability, but again occur in a similar position in terms of syntax.

In other words, Funnel Beaker West and Corded Ware specific *chaînes opératoires* show a similar syntax with limited variation in the roughing-out, preforming, finishing, drying, and firing stages and higher variation in decorative and surface treatment techniques. By contrast, the random paths follow no such stable syntax nor a limited variation of decorative and surface treatment techniques (see Section 4.2). The probabilistic comparison accurately captures this complex pattern as a comparatively low Wasserstein distance between Funnel Beaker West and Corded Ware bodies of knowledge and a higher distance to the randomly generated body (see Tab. 10.1; Fig. 10.1). The implication of this comparatively low Wasserstein distance is that the potters who made these specific *chaînes opératories* learned and applied similar notions on how to make pottery, on what techniques to use, and on when to use these techniques during the production process (see Ch. 9).

This brings us to a crucial question. How similar is 'similar'? What does a Wasserstein distance of 0.35 mean? Would the conclusions be radically different if the distance was 0.42? These questions are at the heart of the next section.

10.2 Expanding the Scope of the Comparisons

This section aims to arrive at a better understanding of how close the resemblances between ceramic technology in Funnel Beaker West and Corded Ware are when compared to other groups in the archaeological record. Furthermore, the aim is to discern whether there is a temporal development leading to this resemblance.

In order to shed light on these questions, the Funnel Beaker West body of knowledge is split into subsets in the comparisons below (megalith inventories, early flat graves, and late flat graves, see Tab. 10.2; 9.1). In addition, sister groups and outgroups for Funnel Beaker West were simulated based on previous studies of ceramic technology. A brief introduction to these sister groups and outgroups precedes the comparisons.

Simulation, Sister Groups, Outgroups, and Subgroups

As stated in Chapter 4, no comparable datasets of specific *chaînes opératoires* exist for comparison against Funnel Beaker West and Corded Ware. Therefore, guided random path generation is applied here to simulate three bodies of knowledge. The random seeds for this procedure are base datasets on ceramic technology from prior studies. The three simulated bodies of knowledge are two sister groups of Funnel Beaker West, namely Funnel Beaker North and Vlaardingen, and one outgroup, which is based on modern ceramic production in Odisha, India (see Tab. 10.2). The simulation procedure and base datasets are discussed in detail in Appendix F. This section is limited to a brief introduction of the three groups, the motivation for their selection, and a remark on the representativity of the randomly generated specific *chaînes opératoires* relative to the base datasets.

The first simulated sister group of Funnel Beaker West is based on Koch's (1998) study of ceramic technology in Funnel Beaker North vessels (see Section 6.1). These vessels stem from wetland deposits on the Danish islands of Zealand, Møn, Lolland, and Falster. Koch (1998 p. 15) dates these vessels between 3950 and 2900 BCE. This broad geographic and temporal scope means the dataset captures the variation in Funnel Beaker North ceramic production on the aforementioned islands. This is crucial for the comparisons below: a dataset based on a single site might introduce a bias towards a specific local production process, but the broad scope mitigates this issue (see Section 3.2).

In terms of the overarching aim in this section, a comparison against Funnel Beaker North is of interest because Funnel Beaker North is considered both the source and 'closest relative' of Funnel Beaker West in the culture-historical framework of Northwestern Europe (cf. Louwe Kooijmans 2018 pp. 494–5; see Section 2.1). As such, the distance from Funnel Beaker West to Funnel Beaker North brings us closer to an overview of technical knowledge which circulated among potters in Funnel Beaker groups. If the distance from

Dataset	Full name	Description	Size
FBW	Funnel Beaker West	Specific *chaînes opératoires* from Funnel Beaker West vessels.	187
MI	Megalith inventories	Subset of Funnel Beaker West with specific *chaînes opératoires* from vessels found in megaliths, not being LFG vessels.	95
EFG	Early flat graves	Subset of Funnel Beaker West with specific *chaînes opératoires* from vessels found in early flat graves.	62
LFG	Late flat graves	Subset of Funnel Beaker West with specific *chaînes opératoires* from late flat graves.	30
CW	Corded Ware	Specific *chaînes opératoires* from Corded Ware vessels.	89
Sim_FBN	Simulated Funnel Beaker North	Acquired by guided random path generation with base data from Koch (1998; see Appendix F).	1,000
Sim_Vl	Simulated Vlaardingen	Acquired by guided random path generation with base data from Stet (2021; see Appendix F).	1,000
Sim_Odisha	Simulated Odisha	Acquired by guided random path generation with base data from Behura (1978; see Appendix F).	1,000
Random	Randomly generated	Randomly generated specific *chaînes opératoires*.	1,000

Table 10.2: Overview of the datasets in the comparisons in Section 10.2. The table reports the abbreviated names, full names, sizes, and origins of the datasets.

Funnel Beaker West to Corded Ware is smaller than the distance Funnel Beaker West to Funnel Beaker North, Corded Ware may be part of the variation already present in Funnel Beaker ceramic production.

The second sister group is based on a study of ceramic technology at the Vlaardingen site Vlaardingen-Arij Koplaan by Stet (2021; cf. Van Beek 1990). Vlaardingen is another culture-historical entity in the Dutch Neolithic, composed of groups with an extended broad-spectrum economy which occupied the wetland areas of the Netherlands between 3400 and 2200 BCE (see Section 2.1). These groups have deep roots in the Mesolithic (Amkreutz 2013; Beckerman and Raemaekers 2009; Fokkens *et al.* 2016 pp. 281–2). The studied ceramics from Vlaardingen-Arij Koplaan stem from a single occupation layer. Radiocarbon dates on charcoal from this layer have 2-sigma ranges between (at earliest) 2671 cal BCE and (at latest) 2129 cal BCE (cf. Stet 2021 pp. 24–5). The use of a single site implies that the base data may not be representative of the variation in Vlaardingen ceramic production as a whole. However, a comparison against less-detailed studies of Vlaardingen ceramic technology with a broader scope (i.e. Beckerman 2015; Kroon *et al.* 2019) shows the production techniques at the site are at least typical for Vlaardingen groups.

Regarding the present aims, Vlaardingen communities, together with Funnel Beaker West, make up the indigenous groups present in the Netherlands during the third millennium BCE (cf. Fokkens *et al.* 2016; see Section 2.1). Therefore, a comparison between the two is indicative of the variation in ceramic production which exists in the study area upon the arrival of migrating communities in the third millennium BCE.

The last dataset is an outgroup relative to Funnel Beaker West. The base data is an ethnographic survey of local pottery production in the Indian state of Odisha by Behura (1978; cf. Mahias 1993; Saraswati and Behura 1966 for broader context). This survey is ideal as outgroup for two reasons. Firstly, the broad scope of the survey (the entire state of Odisha) implies compatibility with the concept body of knowledge: the survey shows the variation in ceramic production in a given area at a given time. Secondly, the intervening geographic and temporal distance between modern Odisha and the European Neolithic means potters will unlikely have learned the same technical knowledge. Therefore, ceramic technology in Odisha is a suitable outgroup in comparing Funnel Beaker West and Corded Ware.

None of the base datasets above contain complete specific *chaînes opératoires*, which could feed directly into a probabilistic comparison. Therefore, guided random path generation (see Section 4.2) is applied to these base datasets to create bodies of specific *chaînes opératoires* (see Appendix F). It should be emphasised that the resulting specific *chaînes opératoires* express the variability possible within the confines of the base data and the rules for random path generation (see Section 4.2). They are not perfect representations of the specific *chaînes opératoires* one would find in the ethnographic or archaeological record. The prefix 'sim_' indicates this status in the comparisons below. The Funnel Beaker North dataset becomes sim_FBN, the Vlaardingen dataset sim_Vl, and the Odisha dataset sim_Odisha (see Tab. 10.2). Each dataset consists of a 1,000 specific *chaînes opératoires* to ensure a representative outcome for the potential variability within the base datasets without incurring overly long processing time (see Section 4.2). Future studies of ceramic technology in the groups involved will be vital in verifying the outcomes below.

In Depth Comparison of Funnel Beaker West and Corded Ware

The Wasserstein distances between the subsets, outgroups, and sister groups are reported in Table 10.3. Figure 10.2 is a visualisation of this matrix which follows the same format as Figure 10.1. A line is drawn in Figure 10.2 for each dataset with archaeological vessels. This line starts at 0 (the Wasserstein distance of a dataset to itself) and ends at the largest distance relative to this dataset which is observed in Tab. 10.3. The Wasserstein distances to all the other datasets in Tab. 10.3 are then projected onto this line. This also means the intervening distances between these other datasets on the line do not correspond to their mutual distances. For example, the distance separating CW and EFG in Figure 10.2A is not

	FBW	MI	EFG	LFG	CW	Sim_Vl	Sim_FBN	Sim_Odisha	Random
FBW	0	0.21	0.13	0.36	0.35	0.49	0.57	1.3	2.41
MI	0.21	0	0.27	0.43	0.44	0.54	0.54	1.25	2.36
EFG	0.13	0.27	0	0.24	0.38	0.37	0.58	1.41	2.48
LFG	0.36	0.43	0.24	0	0.61	0.3	0.81	1.65	2.62
CW	0.35	0.44	0.38	0.61	0	0.71	0.41	1.12	2.48
Sim_Vl	0.49	0.54	0.37	0.3	0.71	0	0.88	1.78	2.57
Sim_FBN	0.57	0.54	0.58	0.81	0.41	0.88	0	0.92	2.55
Sim_Odisha	1.3	1.25	1.41	1.65	1.12	1.78	0.92	0	2.37
Random	2.41	2.36	2.48	2.62	2.48	2.57	2.55	2.37	0

Table 10.3: Matrix with the Wasserstein distances between the datasets (see Tab. 10.2). See Tab. 10.1 for the structure of this matrix. The distances between datasets which result from guided random path generation (sim_FBN, sim_Odisha), and Random are relatively small. This means guided random path generation probably increases variability. Sim_Vl is an exception: The random seed for this dataset shows little variation, resulting in more homogeneous output.

the actual Wasserstein distance between these two (cf. Fig. 10.2B; D), but only the relative difference in their Wasserstein distance to MI.

Three conclusions stand out from Tab. 10.3 and Fig. 10.2. Each conclusion is discussed in a separate section below and illustrated with references to Table 10.3, Figure 10.2, and practical examples from Chapters 6 to 9.

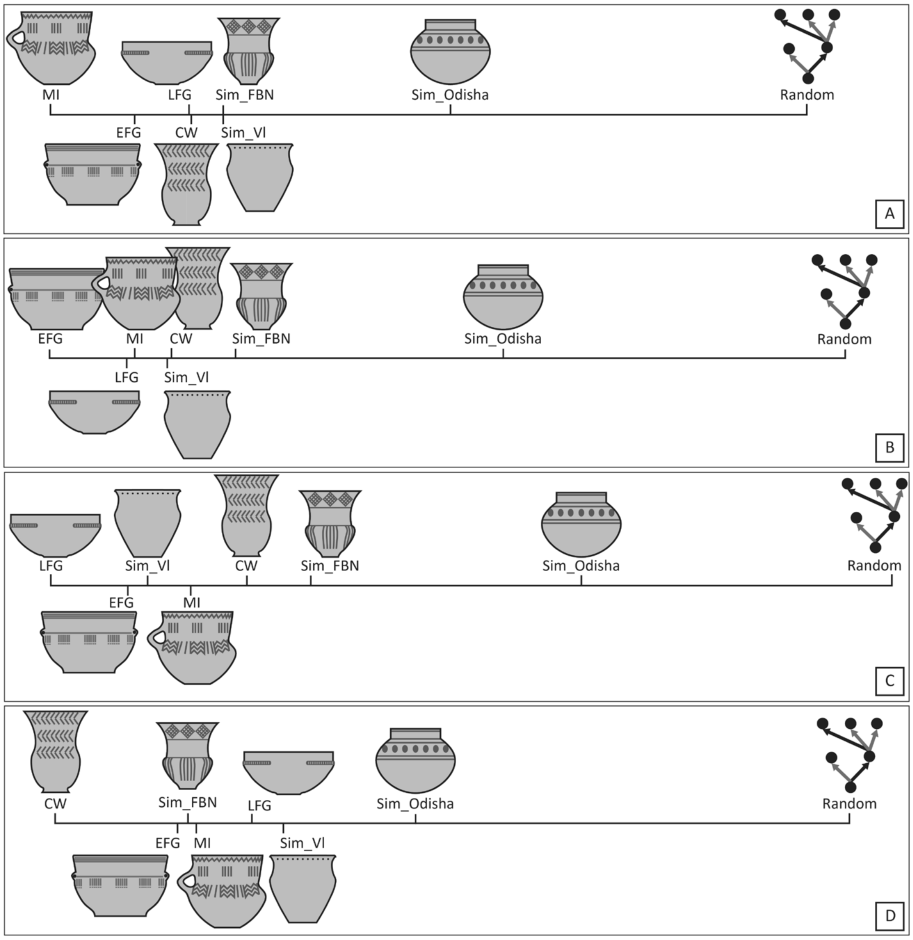


Figure 10.2: Visualisation of the Wasserstein distances for all datasets with archaeological vessels (see Tab. 10.2; 10.3), except FBW (see Fig. 10.1). Each panel takes one of these datasets as the base of comparison (see Tab. 10.2 for abbreviations). This dataset sits at the zero point of the line because the Wasserstein distance of a probability distribution to itself is 0. The length of the line (to scale) is the Wasserstein distance to the most dissimilar dataset in Tab. 10.3. Then, the Wasserstein distances from the base dataset to all other datasets in Tab. 10.3 are plotted on this line (to scale). A: Wasserstein distances relative to Funnel Beaker West subset megalith inventories. B: Wasserstein distances relative to Funnel Beaker West subset early flat graves. C: Wasserstein distances relative to Funnel Beaker West subset late flat graves. D: Wasserstein distances relative to the Corded Ware body of knowledge.

Conclusion 1: Where Did the Variation Go?

The first conclusion is about the cohesion between all datasets. In Figure 10.2, Random and sim_Odisha invariably occupy the most distant positions (see Tab. 10.3). This is a telling result. It always takes less new knowledge and changes for a potter to go between any of the Middle or Late Neolithic bodies of knowledge than to go to these two outgroups. In other words, all of these Middle and Late Neolithic bodies of knowledge are similar in terms of learned techniques and the ordering of these techniques.

This outcome reflects a feature of the base data in Chapters 6, 7, 9, and Appendix F. All Middle and Late Neolithic specific *chaînes opératoires* share a 'basic structure' in terms of techniques and syntax. This structure is the same sequence as described above for Corded Ware and Funnel Beaker West: Modelled bases, coiled vessel walls, preforming by pressure and/or scraping, optional application of separate elements, wet smoothing, variable decorative techniques, drying to leather-hard, variable surface treatment, drying to dry, firing, and possible post-firing surface treatment and decorative techniques (see Section 10.1).

This shared structure explains the high Wasserstein distances to random data and modern ceramic production techniques in Odisha (see Tab. 10.3; Fig. 10.2). Modern ceramic production in Odisha features some of the same techniques but often in a different syntax. For example, coiling occurs as roughing-out technique for vessel walls but is followed by drying to leather-hard and preforming through beating (see Appendix F). Randomly generated paths take variation even further: these paths exhibit no consistent selection of techniques and syntax. Therefore, Random always exhibits the highest Wasserstein distance to bodies of knowledge, followed at some distance by sim_Odisha (see Fig. 10.2).

The major implication for the Neolithic in Europe is that all potters active during the Middle and Late Neolithic learned the same production process for ceramic vessels. This is despite substantial diversity between these groups. For example, Vlaardingen and Funnel Beaker West differ significantly in monumentality, settlement location, ancestry, and subsistence economy (see Section 2.1). To find such low Wasserstein distances between them is like finding hippos are the closest relatives of whales. It illustrates the ability of learning to cut across culture-historical boundaries. We will return to this finding and its implications for the European Neolithic in Chapter 11.

Despite the basic structure underlying all of the bodies of knowledge, variation also exists. The information value of this variation for the relation between Corded Ware and Funnel Beaker West is discussed in the next two conclusions.

Conclusion 2: Standardisation in Funnel Beaker West

The second conclusion is about the subsets of the Funnel Beaker West body of knowledge. The Wasserstein distances indicate a chronological trend from megalith inventories and early flat graves to late flat graves (see also Ch. 9). This chronological trend also affects the distances to other (simulated) datasets, hence the discussion of this conclusion ahead of the comparisons to Corded Ware.

Despite the differences discussed below, the Funnel Beaker West body of knowledge is a coherent group. This is evident from the Wasserstein distances between the parent group (FBW) and the subsets (MI, EFG, and LFG) in Tab. 10.3. These distances are lower than the distances to sister groups and outgroups (sim_Vl, sim_FBN, sim_Odisha, Random). Therefore, the differences discussed below make each subset a variation on a theme rather than a separate phenomenon entirely.

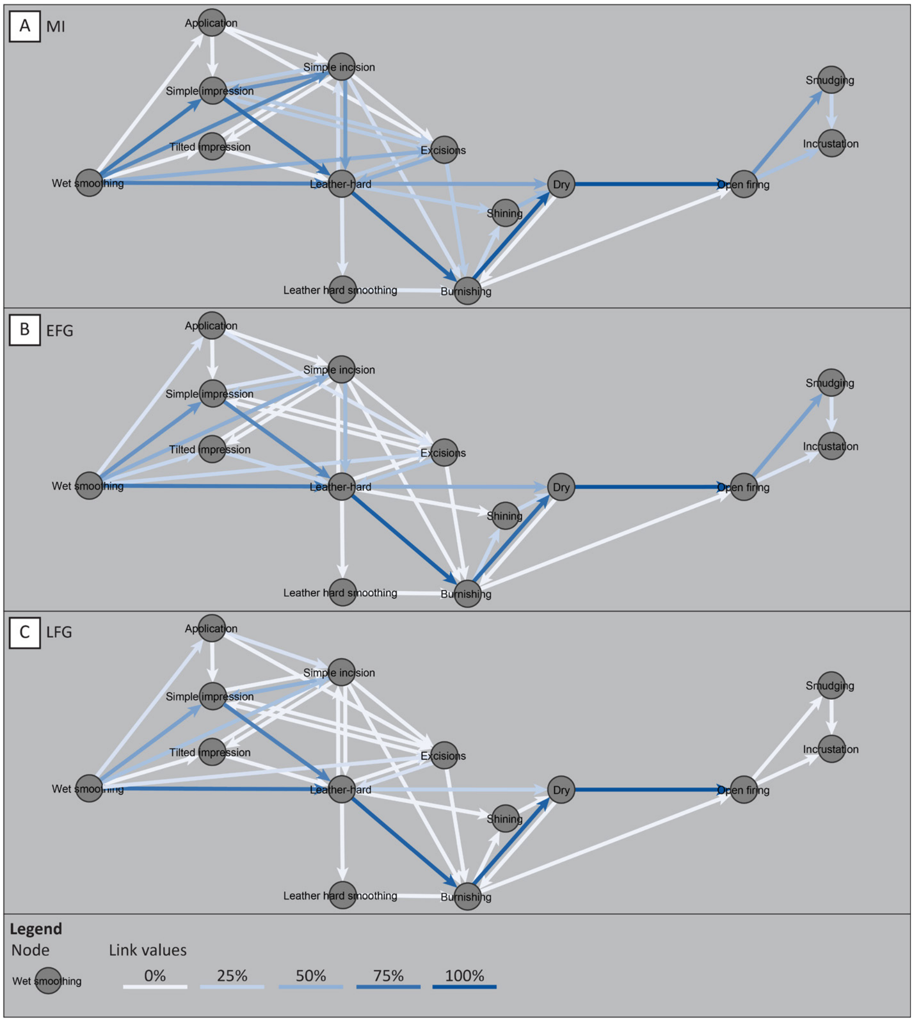


Figure 10.3: Standardisation of Funnel Beaker West decorative techniques and surface treatment over time. Segments of the total *chaîne opératoire* for combinations of techniques after the finishing stage (wet smoothing). The figure only shows edges from the total *chaîne opératoire* which occur at least once in the Funnel Beaker West and Corded Ware body of knowledge (see Tab. 10.2 for abbreviations). The darker the blue of the edges, the more common a combination of techniques. A: the specific *chaînes opératoires* in Funnel Beaker West megalith inventories (MI) exhibit the broadest variation in (combinations of) decorative and surface treatment techniques. B: specific *chaînes opératoires* in Funnel Beaker West early flat graves (EFG) begin to show standardisation relative to megalith inventories (see A). There are more edges with zero values, which means less over-all variation in (sequences of) techniques. Moreover, a single sequence of decorative and surface treatment techniques becomes most prevalent: wet smoothing, simple impressions, leather-hard, and burnishing. C: The specific *chaînes opératoires* for Funnel Beaker West late flat graves (LFG) continue the trend towards standardisation of decorative techniques and surface treatment. More edges with zero values appear relative to megalith inventories and early flat graves (see A; B). The only sequence with substantial numbers which appears is 'wet smoothing, (simple impressions,) leather-hard, and burnishing', whereby simple incisions sometimes appear between wet smoothing and simple impressions.

Figure 10.2 shows the different subsets of Funnel Beaker West almost appear as sister groups. For example, vessels from late flat graves are closer to Vlaardingen ceramic production than to megalith inventories (see Fig. 10.2C; Tab. 10.3). Similarly, ceramic production in megalith inventories is only marginally closer to that in late flat graves than to Corded Ware specific *chaînes opératoires* (see Fig. 10.2A, Tab. 10.3). This is despite the fact that these vessels may in some cases stem from the same contexts (i.e. megaliths) and even be contemporaneous (see Section 2.4).

What gives rise to these oddly high Wasserstein distances within the Funnel Beaker West body of knowledge? Turning to Chapter 9, the source of this development is the standardisation of decorative techniques and surface treatment within these subsets. Remember that the subsets from megalith inventories and early flat graves consist of vessels which date until ca. 2925 BCE at latest, whereas the subset late flat graves contains vessels from flat graves and megalith inventories which date between ca. 3000 and 2675 BCE (see Section 2.4).

The specific *chaînes opératoires* from megalith inventories exhibit the most variation in decorative techniques and surface treatment out of all subsets (see Ch. 6; 9). Potters decorated these vessels with simple incisions, simple impressions, excisions, incrustations, and tilted impressions and applied burnishing, shining, and smudging during surface treatment. Moreover, the specific *chaînes opératoires* from megalith inventories also feature the most variation in the ordering of these techniques (see Fig. 10.3A). The effect of this variation in techniques and their ordering is enormous variability. This is visible in the distance to randomly generated paths (see Fig. 10.2A). The Wasserstein distance from megalith inventories to these random paths is comparatively low (see Tab. 10.3). This is a tell-tale sign of high variability within a body of knowledge because randomly generated specific *chaînes opératoires* follow no structure and thus exhibit near maximum variability. For the same reason, megalith inventories are also comparatively close to all other simulated datasets (see Fig. 10.2A; Tab. 10.3). This subset exhibits nearly all possible variation there is in Middle and Late Neolithic ceramic production.

Crucially, the two other Funnel Beaker West subsets do not exhibit this variation in decorative techniques and surface treatment (see Fig. 10.3). The specific *chaînes opératoires* of vessels from early flat graves feature many of the same techniques as those in megalith inventories (see Ch. 6; 9), but a single decorative technique (simple oblique impressions with conical tools) and surface treatment technique (burnishing) become more prominent, while the application of alternative techniques decreases (see Ch. 9). The probabilistic comparison shows that, in addition, potters increasingly apply these techniques in a specific sequence. Namely, wet smoothing, followed by simple impressions (with conical tools), then drying to leather-hard and finally burnishing. This is the most common path in Fig. 10.3B.

This trend is even more pronounced in specific *chaînes opératoires* from late flat graves. The potters who made these vessels almost exclusively applied simple oblique impressions (especially with conical tools and spatula), if they applied decoration at all, and followed up with burnishing (see Ch. 6, 9). The network visualisation of these specific *chaînes opératoires* demonstrates these techniques are always applied in the same order: wet smoothing, simple impressions (if at all), drying to leather-hard, and burnishing (see Fig. 10.3C). As a result, the variability in these younger Funnel Beaker West specific *chaînes opératoires* is much lower than that in the older specific *chaînes opératoires* from megalith inventories and early flat graves.

In sum, ceramic production in Funnel Beaker West became increasingly standardised over time. The potters who produced the vessels in megalith inventories and early flat graves (before ca. 2925 BCE) applied various techniques in different orders, but the potters who produced vessels for late flat graves (after ca. 3000 cal BCE) consistently picked the same techniques in the same order. It is not possible to state whether early flat graves are younger than megaliths (see Ch. 2), but regardless the standardised production process seen in vessels from late flat graves appears grounded in the choices of potters who made the vessels in early flat graves.

The standardisation of specific *chaînes opératoires* in Funnel Beaker West affects the Wasserstein distances to all other datasets. This is because the Wasserstein distance expresses the number of choices potters would have to change to produce another set of specific *chaînes opératoires*. If all potters make the same choices, as is almost the case for vessels from late flat graves, and we compare this set against another set which does not follow those exact choices, then more changes are required and a higher Wasserstein distance results. Again, this effect is visible in the Wasserstein distances to the dataset Random, which is comparatively large from late flat graves, and comparatively small in megalith inventories (see Fig. 10.2; Tab. 10.3).

The last observation on Funnel Beaker West ceramic technology relates to Vlaardingen. The Wasserstein distance from late flat graves to Vlaardingen is smaller than that between Vlaardingen and the other two Funnel Beaker West subsets (see Fig. 10.2, Tab. 10.3). This is not a fluke. A look at the base data for sim_VL (see Appendix F) shows these specific *chaînes opératoires* have the same combinations of techniques as those in late flat graves, except that excisions are more common than simple impressions. This suggests the standardisation in Funnel Beaker West ceramic technology is part of a shared development among indigenous Middle Neolithic potters in the Netherlands. Care should be taken here due to the small size of the random seed for sim_Vl, but verification of this trend would be an interesting goal for future studies of Middle and Late Neolithic ceramic technology. We will return to this observation in Chapter 12.

To conclude, the comparisons between Funnel Beaker West subsets show a trend towards standardisation of pottery production. These subsets already share a basic structure in stages other than decoration and surface treatment, but over time the variability in the latter two stages also decreases. From the broad variation in tools, techniques, and syntax in megalith inventories and early flat graves, there is a move towards a single combination of tools, decorative techniques, and syntax in late flat grave inventories (see Fig. 10.3). Moreover, the comparisons suggest this process is already present in early flat graves and shared among Funnel Beaker West and Vlaardingen potters in the Netherlands. This trend towards standardisation is also crucial for the relationship between Funnel Beaker West and Corded Ware.

Conclusion 3: The Meaning of 0.35

The outcomes of the probabilistic comparison support only one conclusion about the relation between Corded Ware and Funnel Beaker West. Corded Ware is consistently closer to Funnel Beaker West subsets than outgroups sim_Odisha and Random (see Fig. 10.2; Tab. 10.3). Moreover, relative to the Funnel Beaker West subsets, Corded Ware is closer than sister group Funnel Beaker North (see Fig. 10.2A-C; Tab. 10.3; Vlaardingen is discussed below). Therefore, Corded Ware potters learned the same ceramic production processes as potters from indigenous Funnel Beaker West groups.

However, the detailed comparisons also show the close Wasserstein distance between Funnel Beaker West and Corded Ware leads to a paradox. Corded Ware ceramic production least resembles the Funnel Beaker ceramic production process which migrating potters would have encountered most.

Figure 10.2D shows this paradox. Vessels from Corded Ware, late flat graves, and Vlaardingen are certainly contemporaneous and were produced side-by-side for several centuries (see Ch. 2). Yet, these vessels actually have the highest Wasserstein distances relative to Corded Ware apart from the outgroups (see Fig. 10.2D; Tab. 10.3). The closest matches for Corded Ware specific *chaînes opératoires* are vessels from megalith inventories, Funnel Beaker North, and early flat graves (see Fig. 10.2D; Tab. 10.3) with which they have comparatively little temporal overlap (see Ch. 2). If we look at the Wasserstein distances to sister groups Corded Ware only appears as an in-group relative to megalith inventories (see Fig. 10.2A; Tab. 10.3). This means that, from a purely probabilistic perspective, Corded Ware potters are more likely to have learned ceramic technology from the dead ancestors of the indigenous potters they met, than from these indigenous potters themselves.

What causes this paradox? The answer lies in part with the standardisation in Funnel Beaker West specific *chaînes opératoires* (see conclusion 2) and in part with the variation within the Corded Ware body of knowledge.

The standardisation in Funnel Beaker West involves a sequence of wet smoothing, simple impressions (if any decoration is applied), drying to leather-hard, and burnishing (see Fig. 10.3). This sequence replaces a broader variation in sequences of decorative and surface treatment techniques over time (see above). The crux of the paradox is that around half the Corded Ware specific *chaînes opératoires* exhibit this same or a highly similar sequence of techniques. For example, vessel 18, discussed in Section 9.2, has a specific *chaîne opératoire* which is identical to some of the Funnel Beaker West vessels in late flat graves. Other Corded Ware vessels may feature highly similar sequences of techniques, such as a sequence of wet smoothing, simple incisions, drying to leather-hard, and burnishing (see Fig. 10.4A). The occurrence of these specific *chaînes opératoires* indicates the potters who made Corded Ware vessels did learn the standardised production process seen in late flat graves, causing the moderate Wasserstein distance to these subsets when compared to (f.e.) Funnel Beaker North in which these sequences do not feature (see Tab. 10.3; Fig. 10.2; see also conclusion 1).

It is the other half of Corded Ware specific *chaînes opératoires* which causes the divergence relative to contemporary Funnel Beaker West vessels from late flat graves. These specific *chaînes opératoires* show more variation in decorative and surface treatment techniques, as well as in the sequences of techniques. For example, there are various combinations of tilted impressions, simple incisions, and shining (see Ch. 7; Fig. 10.4A). These techniques do not occur among the standardised specific *chaînes opératoires* in late flat graves, but they do occur in early flat graves and megalith inventories (see Ch. 9). Remember the Wasserstein distance tracks the number of different choices and new techniques necessary to transform one body of knowledge into the other. This means that as Funnel Beaker West subsets become more standardised (see Fig. 10.3), more alternate choices are needed to match this second half of the Corded Ware body of knowledge, resulting in a higher Wasserstein distance.

Does this mean Corded Ware potters derive their knowledge from the potters who made the vessels in early flat graves or megalith inventories? The results point towards a more complex process. Compare Figure 10.3A and 10.3B to Figure 10.4A. The potters who

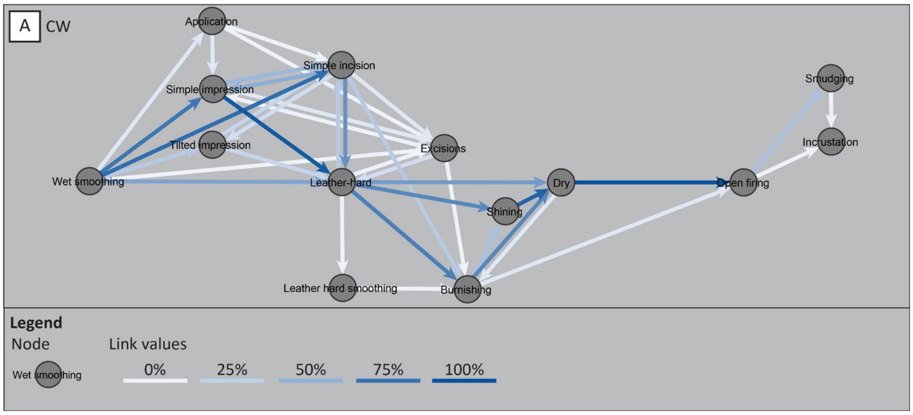


Figure 10.4: Decorative and surface treatment techniques in the Corded Ware body of knowledge. This is the same segment of the total *chaîne opératoire* post-finishing as depicted for Funnel Beaker West subsets in Fig. 10.3. A: a substantial number of Corded Ware specific *chaînes opératoires* exhibit the same standardised sequences as early and late Funnel Beaker West vessels, namely wet smoothing, simple impression, leather-hard, and burnishing (see Fig. 10.3C). However, these specific *chaînes opératoires* are part of a broader variation which exhibits various other (combinations of) decorative and surface treatment techniques. This variability makes the Corded Ware body of knowledge a close match for megalith inventories and early flat graves (see Fig. 10.3A-B) but to a lesser extent for late flat graves (see Fig. 10.3C).

made the vessels in Corded Ware burials use many of the same decorative and surface treatment techniques as those who made the vessels in megalith inventories and early flat graves, but the ordering of these techniques is different, as are the preferences for certain techniques (see also Ch. 9). For example, combinations with excisions, incrustation, and burnishing play a far more prominent role in Funnel Beaker West vessels than in Corded Ware vessels, which feature more combinations with shining, tilted impressions, and simple incisions (see Fig. 10.3A; 10.4A). As a result, the Wasserstein distance between megalith inventories, early flat graves, and Corded Ware is comparatively low but not zero. The potters who made Corded Ware vessels appear aware of the same techniques as the potters who made vessels for megalith inventories and early flat graves, but they apply them according to a different syntax and different procedures (see Ch. 9). Therefore, Corded Ware potters may not have learned these procedures from the potters who made Funnel Beaker West ceramics, but instead from potters who held highly similar knowledge.

In sum, the paradoxical Wasserstein distances between Corded Ware and Funnel Beaker subsets results from the interplay of the variability in Corded Ware and the standardisation in Funnel Beaker West. The potters who made Corded Ware vessels learned and applied the standardised specific *chaînes opératoires* found in contemporary Funnel Beaker West vessels from late flat graves but also held knowledge about other (combinations of) decorative and surface treatment techniques. This additional variation results in a closer match with the more varied specific *chaînes opératoires* from megalith inventories and early flat graves. However, Corded Ware potters do not follow the same production process as these potters did but rather appear to have a different take on the same spectrum of techniques. We return to the implications of this conclusion in Chapter 13.

10.3 Summary

The probabilistic comparisons of the Corded Ware and Funnel Beaker West bodies of knowledge in this chapter shows the potters who made these vessels not only used similar techniques (see Ch. 9), but combined these techniques according to the same syntax when producing vessels. Therefore, these potters were not simply copying techniques, but learning and passing on similar technical knowledge (see Section 10.1).

To better understand that similarity, the subsets of Funnel Beaker West and the Corded Ware body of knowledge are compared to several simulated sister groups and outgroups in Section 10.2. This comparison enables the detection of developments over time, and allows us to determine how exceptional the close match between Funnel Beaker West and Corded Ware is when compared to sister groups of Funnel Beaker West (Vlaardingen and Funnel Beaker North), and outgroups such as pottery production in modern Odisha, India. Three conclusions stand out from this comparison

Firstly, there are similarities in ceramic technology between all Middle and Late Neolithic bodies of knowledge. These bodies are consistently closer together than the outgroups with randomly generated specific *chaînes opératoires*, and specific *chaînes opératoires* from modern Odisha. This is due to a shared structure in the roughing-out, preforming, finishing, drying, and firing stage of the production process. Decoration and surface treatment are more variable. The presence of this shared structure indicates all of these potters in the Middle and Late Neolithic learned similar ways of producing ceramics, regardless of the culture-historical distinctions we draw between them.

Secondly, there is a trend towards standardisation within the Funnel Beaker West body of knowledge. This standardisation is visible in decorative and surface treatment techniques. Megalith inventories exhibit most variation in these techniques and their ordering, but vessels from late flat graves feature a standardised sequence involving sparse application of simple impressions and burnishing. The same standardisation also appears in early flat graves, but is not as pronounced. Interestingly, potters among Vlaardingen communities produce similar, standardised specific *chaînes opératoires*, indicating this trend towards standardisation is a shared development among two indigenous groups which are otherwise considered to be distinct.

Lastly, the Corded Ware body of knowledge is consistently close to these Funnel Beaker West subsets in terms of ceramic technology. More so than ceramic production in modern India, Vlaardingen, or even Funnel Beaker North for the Funnel Beaker West subsets. Paradoxically, Corded Ware itself best matches the specific *chaînes opératoires* of vessels in megalith inventories, Funnel Beaker North, and early flat graves, but to a lesser extent those from contemporaneous late flat graves or Vlaardingen. These results indicate Corded Ware potters learned a ceramic production process which was highly similar to that used by Funnel Beaker West potters, but not directly from them.

What do these results contribute to our understanding of migrating and indigenous communities in the Netherlands during the third millennium BCE? The upcoming chapters look at implications of the outcomes above for our understanding of the emergence of ceramic technology in Europe (see Ch. 11), the indigenous communities in the Netherlands (see Ch. 12), and their interactions with migrating communities (see Ch. 13).

11

On the Origins of Neolithic Ceramic Technology

The relatively short Wasserstein distances between various Middle and Late Neolithic groups in Northwest Europe are among the most intriguing outcomes of this study (see Fig. 10.2; Tab. 10.3). The potters who made Funnel Beaker West, Funnel Beaker North, Vlaardingen, and Corded Ware vessels lived among communities which differed substantially, not just in terms of geographic area and period, but also in funerary practices, monumentality, subsistence economy, ancestry, and so forth. Yet, regardless of these differences, all of these potters learned and applied a similar ceramic production process. This outcome indicates all of these Middle and Late Neolithic potters can trace their knowledge back to a single source of ceramic technology. Moreover, that source is not Neolithic.

11.1 The Roots of Middle and Late Neolithic Ceramic Technology

The short Wasserstein distances between Funnel Beaker West, Funnel Beaker North, Vlaardingen, and Corded Ware bodies of knowledge are caused by a shared structure in the specific *chaînes opératoires* (see Section 10.2). A brief re-introduction of this structure follows because it is relevant to the discussion below. This basic structure consists of modelled bases, coiled vessel walls, preforming by continuous pressure, wet smoothing, various decorative techniques, drying to leather-hard consistency, various surface treatments, drying to dry consistency, and lastly, open firing. As a result of this shared structure, all of the bodies of knowledge cluster together relative to modern ceramic production in India, or randomly generated specific *chaînes opératoires* (see Fig. 10.2; Tab. 10.3).

Apart from the techniques, the potters in the above-mentioned groups also apply similar modalities of techniques during roughing out (e.g. coils with internal bevels, see Ch. 9) and similar procedures (e.g.: fashioning of the base often involves modelling a lenticular mass, and supplementing it with coils; see Ch. 9). These similarities during the roughing-out stage are highly relevant, because learning them requires one-to-one contact between potters and close supervision (Gosselain 1992 p. 582, 2000 pp. 192–3; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29). As a result, these techniques rarely change and can remain stable despite countless learning events (e.g. Livingstone Smith and Viseyrias 2010; Pétrequin 1993). Therefore, the shared roughing-out techniques

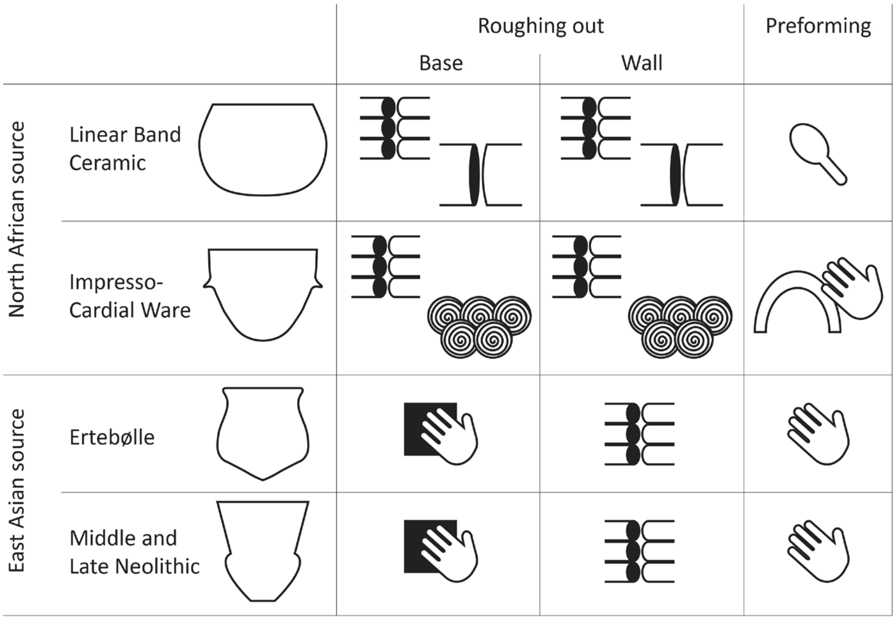


Figure 11.1: Schematic of roughing-out and preforming techniques in ceramics from early farming groups and hunter-gatherers in Europe. Linear Band Ceramic vessels involve roughing out of vessel bases and walls through coiling or slab building with preforming by beating. Vessels from Impresso-Cardial Ware are roughed out with the spiral patchwork procedure or coiling, and preformed with continuous pressure and internal supports. The ceramic production process in both of these early farming groups stems from the North African source of ceramic technology. Ceramic production processes in Ertebølle ceramics stem from the East Asian source of ceramic technology and involve modelled based, coiled vessel walls, and preforming by continuous pressure. The same procedure occurs in all Middle and Late Neolithic ceramics studied here, which suggests Neolithic potters can trace back their knowledge to hunter gatherer groups rather than early farming groups.

and structures suggest all Middle and Late Neolithic potters ultimately all use variants of the same practice in ceramic production. Can we identify the source of that practice?

Studies of the emergence and spread of ceramic technology across the Old World demonstrate that at least two sources of ceramic technology exist. Hunter-gatherers in North Africa and East Asia independently invented production methods for ceramic vessels towards the end of the Pleistocene (Jordan *et al.* 2016; Jordan and Zvelebil 2009). Technical knowledge from both of these sources reached Europe. Knowledge from the North African source spread via the Levant to Anatolia and ultimately into Europe with early farmer groups, such as Linear Band Ceramic and Impresso-Cardial Ware communities (Gronenborn 2003; Jordan *et al.* 2016). By contrast, technical knowledge about ceramic production from the East Asian source spread among hunter-gatherer groups on the Eurasian steppe and ultimately into Europe. Ertebølle groups are generally considered the westernmost of these hunter-gatherer groups (Dolbunova *et al.* 2022; Jordan *et al.* 2016; Piezonka 2015).

At present, there is no overview of complete specific *chaînes opératoires* from, or the technical variation within, pottery production associated with the East Asian and North African sources. However, there are data about the roughing-out and preforming techniques in vessels from Linear Band Ceramic, Impresso-Cardial Ware, and Ertebølle. A comparison of these data to the ceramic production techniques used by Middle and Late Neolithic potters suggests an intriguing explanation for the shared technical knowledge among Neolithic potters.

The roughing-out and preforming techniques of Impresso-Cardial Ware and Linear Band Ceramic vessels differ substantially from those detected in Middle and Late Neolithic ceramics (see Fig. 11.1). Impresso-Cardial Ware vessels are roughed out either through coiling or with the spiral patchwork procedure. In the latter procure, the potter takes a coil, rolls it up to form a disk, and then fits multiple of these disks together to fashion a vessel rough-out (cf. Gomart *et al.* 2017; Roux 2019a p. 57 for definitions). This rough-out (regardless of the use of coiling or spiral patchworks) is then placed over an internal support and preformed by continuous pressure while wet. Further spiral patches or coils may then be added to form the upper body of the vessel (Gomart *et al.* 2017, 2022a pp. 333–4, 2022b).

The roughing-out procedure for Linear Band Ceramic vessels involves either coiling or slab building (see Fig. 11.1). The rough-out is then preformed by beating, i.e. percussion on wet clay. Following this process, several coils can be affixed to the vessel to form the upper body (Gomart 2011; Gomart *et al.* 2017; Kreiter *et al.* 2017; Thér *et al.* 2019b). Evidence for this procedure occurs in Linear Band Ceramic vessels from Eastern Europe to France (Palaguta and Starkova 2021 p. 255) as well as in younger groups affiliated with Linear Band Ceramic, such as Blicquy/Villeneuve-Saint-Germain groups (Van Doosselaere *et al.* 2016).

Both the above ceramic production procedures from early farming communities differ from that found here for the Middle and Late Neolithic (see above; Fig. 11.1). However, the same does not apply to the ceramic production process found in Ertebølle vessels, which are the westernmost representatives of the East Asian source.

Koch (1987 pp. 109–10), Glykou (2010), and Povlsen (2013) show Ertebølle vessel bases are roughed out by pinching a clay mass into a pointed shape. This shape then forms the base, and potters begin to fashion the wall by initially placing coils adjacent to this base and then working upward. The coils in the upper and lower body are joined with different modalities of the coiling technique: the lower body most commonly features flattened or U-shaped break profiles from coiling by pinching, whereas the upper body features break profiles with external bevels from coiling by spreading or pinching. Potters then apply continuous pressure with their hands to the wet rough-out during preforming. Crucially, this production process has the same structure and techniques as the one we encounter in all Middle and Late Neolithic groups in Northwest Europe (see above; Fig. 11.1).

Roughing-out techniques, especially for vessel bases, tend to change little over time because they are learned in direct, personal interactions and under close supervision (Gosselain 1992 p. 582, 2000 pp. 192–3; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29). Therefore, the fact that all Middle and Late Neolithic potters learned and used the same roughing-out procedure as hunter-gatherer groups and not early farmer groups suggests all of these Neolithic potters can trace back their knowledge through a long line of learning events to these hunter-gatherer groups. All ceramic technology in the Middle and Late Neolithic of Northwest Europe stems from a single source. And that source was Mesolithic.

11.2 Final Remarks

Ceramic technology is held to be one of the hallmarks of the European Neolithic. Previous studies have already shown various hunter-gatherer societies in Europe knew ceramic technology before the arrival of early farming communities (Gronenborn 2003; Jordan *et al.* 2016; Piezonka 2015). This study adds a new dimension to these finds. Potters among early farming groups and hunter-gatherer communities practiced different ceramic production processes, and by the Middle and Late Neolithic, it is the production process associated with hunter-gatherer groups, and not early farmers, which has become dominant in Northwest Europe.

The reason for this development is unclear. It may be the production process from hunter-gatherers is more efficient or easier to learn, providing it with key 'evolutionary advantages' (cf. Roux 2010). However, it may equally be archaeologists have underestimated the role of hunter-gatherer groups in the European Neolithic. These societies did not disappear at the start of the Neolithic but appear well into the Late Neolithic, for example, Vlaardingen (Amkreutz 2013) and Pitted Ware (Iversen 2010; Larsson 2006). These groups might not be mere survivals in areas marginally suited for agriculture but key players during the Neolithic.

Regardless, the first step in better understanding this development is to accumulate data on specific *chaînes opératoires* throughout the European Neolithic. These data are necessary to verify the above conclusion and to determine when and why the ceramic production process associated with hunter-gatherers came to overshadow that associated with early farmer groups.

12

Here to Stay: Indigenous Communities in the 3rd Millennium BCE

This chapter highlights two crucial findings from this study about Funnel Beaker West and Vlaardingen. Together, these outcomes warrant a revision of current views on the Middle and Late Neolithic. The first outcome is the co-existence of indigenous and migrating communities during the third millennium BCE (Section 12.1). The second outcome is the knowledge exchange between Vlaardingen and Funnel Beaker West potters (Section 12.2). A summary is available in Section 12.3.

12.1 Reports of Funnel Beaker Wests' Death Are Greatly Exaggerated

The results of this study shed new light on a puzzling outcome of archaeogenetic studies: the resurgence of early farmer and hunter-gatherer genetic profiles during the Bronze Age. Several centuries after the arrival of migrants with steppe ancestry and the resulting population turnover at the start of the third millennium BCE, the genetic profiles of indigenous groups re-appear in the archaeological record from an unknown source (Haak *et al.* 2015; Mittnik *et al.* 2018). This study shows this unknown source might well consist of indigenous populations which are hidden in plain sight during the third millennium BCE.

Archaeologists who study European Prehistory tend to implicitly or explicitly adhere to a culture-historical narrative structure which sees the past as a continuous rise and fall of cultures. In particular for the third millennium BCE, this narrative structure has led them to reject the evidence for overlaps between indigenous and migrating groups and to construe neat successions (see Section 2.2). The findings from this study show no such neat transition occurred: the typical funerary rituals and technical knowledge of indigenous communities continued to be practiced in the first half of the third millennium BCE.

The archaeological record yields various cremation burials with (in terms of typology) Funnel Beaker West vessels. The radiocarbon dates of these cremated human remains fall between ca. 3000-2675 BCE (see Section 2.4). As such, these cremation burials are generally contemporaneous with Corded Ware burials in the Netherlands (see section 2.4). A Bayesian chronological model of the radiocarbon evidence supports this interpretation: there is an overlap of 150-500 years between Funnel Beaker West and Corded Ware during the first half of the third millennium BCE (see Section 2.3; 2.4; cf. Beckerman 2012; Furholt 2003 pp. 98–9). There are two arguments, separate from the typology, to connect these burials to Funnel Beaker West groups who lived in the Netherlands prior to the third millennium BCE.

Firstly, the ceramics in these burials follow the same paste recipe and the same production process as ceramics from Funnel Beaker West megaliths and early flat graves. The clay pastes show the same preferences for silty, calcareous clays and a combination of mineral and organic tempers, as well as a preference for wet homogenisation processes seen in earlier Funnel Beaker West vessels (see Ch. 9). In addition, the production process itself consists of similar sequences of roughing-out, preforming, finishing, decorative, and surface treatment techniques (see Ch. 10), as well as the same procedures, tools, and modalities of techniques (see Ch. 9), as Funnel Beaker West vessels found in megalith inventories and early flat graves which generally pre-date ca. 2925 BCE. This degree of similarity, down to the knowledge about what materials and tools to use, about which gestures to apply and when, almost certainly implies these potters learned by being involved in the ceramic production process of these older vessels (Gosselain 1992 p. 582, 2000 pp. 192–3; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29).

The specific *chaînes opératoires* of the vessels in late flat graves do differ from those in early flat graves and megalith inventories. In specific, they are more standardised with regard to the choices potters made during decoration and surface treatment (see Ch. 9; 10). However, the first indications of this standardised production process already appear in early flat graves (see Ch. 9; 10). Late flat graves are best seen as a continuation of this trend (see Ch. 10). Whosoever produced these vessels not only learned their craft from the potters who fashioned Funnel Beaker West vessels prior to ca. 3000 BCE, but continued along the same lines.

Secondly, the same conclusion applies to the funerary practices of these cremation burials. These funerary practices are based on those seen in Funnel Beaker West early flat graves. These early flat graves most often contain inhumation burials but on occasion feature burnt wooden structures which have been set ablaze during the funeral (cf. Bouma and Van der Velde 2022 pp. 50–2) or cremation burials (see Section 2.4 on Uddelermeer). In addition, the mourners who built these early flat graves selected specific vessel types as grave goods from the broader spectrum of vessel types found in megaliths. In particular, amphora-like vessels and bowls became common grave goods (see Section 2.4).

The cremation burials which post-date ca. 3000 BCE are a continuation of these two trends and partially overlap with them (see Fig. 2.9). Cremation of the deceased becomes the norm (cf. Bakker 1992 p. 93), and large, complex bowls feature almost exclusively as grave goods (see Section 2.4). Moreover, these cremation burials appear in the same flat grave cemeteries and megaliths as the earlier Funnel Beaker West burials (Bakker 1992 p. 93; e.g. Bouma and Van der Velde 2022 pp. 63–4). Learning about funerary rites again requires people to have been part of burials in which these practices were performed, to take that knowledge with them, and put it into practice at a later stage (cf. Bourgeois and Kroon 2017). Therefore, the fact that communities of mourners used and built on the funerary practices seen in Funnel Beaker West early flat graves, indicates their involvement with these communities.

Crucially, the patterns described above are not an isolated phenomenon in the Netherlands. The same funerary ritual and similar choices for ceramic grave goods appear in Northwest Germany (Kossian 2000) and in Central Germany (Wetzel 1979). There are no complete specific *chaînes opératoires* from ceramics in these areas, but the potters did follow the same paste recipes while making vessels (cf. Struckmeyer 2017, 2018, 2019). These similar practices across the North European Plain imply people in this area came together, learned (directly or indirectly) from each other, and took that knowledge with them to apply it at a later stage (see above). Archaeologists recognise this network as Funnel Beaker in the fourth millennium BCE, but tend to follow the culture-historical notion that Funnel Beaker West should decline before the rise of Corded Ware. In fact, this network, the practices, and the practitioners continue to exist during first half of the third millennium BCE, alongside Corded Ware.

Funnel Beaker West is not the only indigenous group to show such signs of continuity in the third millennium BCE. Similar interpretations have been proposed for groups across Europe (cf. Furholt 2003, 2021): Globular Amphora (Włodarczak 2017 pp. 286, 300–1), Salzmünde and Bernburg (Müller 2001 p. 252), Vlaardingen (Beckerman 2015 p. 214; Kroon *et al.* 2019), Pitted Ware (Holmqvist *et al.* 2018; Larsson 2009 pp. 260–1), and Funnel Beaker North (Iversen 2014, 2015, 2020). Across Europe, the arrival of migrating communities is not a moment of discontinuity but the point at which migrating and indigenous communities started to co-exist. The co-existence of indigenous and migrating communities is the rule, not the exception.

This conclusion solves the mysterious resurgence of early farmer and hunter-gatherer genetic profiles after the third millennium BCE. The individuals in Corded Ware burials are not representative of the entire European population during the third millennium BCE but co-exist with indigenous populations. Archaeologists either erroneously attribute the remains of these indigenous groups to earlier periods and/or cannot sample their skeletal remains for genetics due to their habit of cremating the dead. Both factors mean these indigenous groups are hidden in plain sight. The puzzling 'resurgence' of indigenous groups is simply the moment the distinction between co-habiting migrating and indigenous communities collapses in the funerary sphere.

12.2 Learning Prevails

Funnel Beaker West communities co-exist with Vlaardingen communities in the Netherlands for nearly a millennium (see Section 2.1, 2.3). Yet, these two entities are thought to interact little, or, if interaction occurs, Vlaardingen groups are thought to copy and acquire materials from 'superior' Neolithic Funnel Beaker West groups (cf. Bakker 1982 pp. 95–6; Drenth 2019 p. 832; Louwe Kooijmans 1983 pp. 58–60). The results from this study show this image is incorrect: potters are exchanging knowledge across this culture-historical boundary, and this knowledge exchange shapes ceramic technology in Funnel Beaker West and Vlaardingen vessels.

The notion that Vlaardingen and Funnel Beaker West form two 'closed systems' follows from the culture-historical contrast drawn between them (see Section 2.1). On the one hand, Funnel Beaker West communities would descend from Scandinavian migrants, lead an agricultural life, live in the uplands, build megalithic tombs, and have a broad range of ceramics. Vlaardingen communities on the other hand would descend from local Mesolithic populations, be hunter-gatherers who also practice some agriculture, live in the wetlands, and have different and less diverse ceramics (cf. Louwe Kooijmans 2018; Van Gijn and Bakker 2005). Within this framework, the evidence for interaction is limited to the appearance of Vlaardingen-style vessels at Funnel Beaker West settlements (Beckerman and Raemaekers 2009 p. 79), and vice versa (cf. Amkreutz 2013 p. 342; Drenth 2019). However, neither group is seen to adopt traits (e.g. monumentality, ceramic style) from the other, hence the notion of two 'closed systems' without significant interaction (Bakker 1982; Louwe Kooijmans 1983). My study of ceramic technology provides a more nuanced, bottom-up view of the boundary between these archaeological cultures.

The comparisons of Funnel Beaker West and Vlaardingen specific *chaînes opératoires* point to two diachronic trends. Firstly, the Wasserstein distances from Funnel Beaker West subsets to Funnel Beaker North increase over time. The Wasserstein distance between Funnel Beaker West vessels and Funnel Beaker North is shortest for vessels which pre-date ca. 2925 BCE, in particular vessels from megalith inventories (see Fig. 10.2A-B; Tab. 10.3). However, this distance increases considerably for vessels from late flat graves, which were produced after ca. 3000 BCE (see Fig. 10.2C; Tab. 10.3). In sum, the potters who made Funnel Beaker West vessels initially followed procedures and techniques closer to those of potters in Southern Scandinavia, but gradually adopted a distinct production process.

The second trend is that the ceramic production process of Funnel Beaker West and Vlaardingen potters becomes more similar over time. The specific *chaînes opératoires* from Funnel Beaker West vessels which pre-date ca. 2925 BCE, again especially those in megalith inventories, have relatively high Wasserstein distances to Vlaardingen vessels (see Fig. 10.2A-B; Tab. 10.3). However, the specific *chaînes opératoires* found in late flat graves, and to a lesser extent early flat graves, feature a shorter Wasserstein distance to Vlaardingen vessels (see Fig. 10.2B-C; Tab. 10.3). This change in Wasserstein distances is because both Funnel Beaker West and Vlaardingen potters adopt the standardised specific *chaînes opératoires* with sparse decoration and frequent application of burnishing (see Ch. 9; 10; Appendix F).

The chances are vanishingly small that potters in Vlaardingen and Funnel Beaker West potters independently invented and adopted this standardised production process out of all the possible ways they could fashion vessels. The convergence in ceramic technology more likely results from potters in both communities sharing experiences and learning from each other. For example, by seeing each other work, or by examining the finished vessels we find at settlements (cf. Gosselain 2018). Those direct and/or indirect interactions contributed to their notions about how to make ceramics, resulting in more similar specific *chaînes opératoires*.

In sum, the potters who made Funnel Beaker West vessels prior to ca. 2925 BCE, and in particular those who produced the vessels in megaliths, may have held technical knowledge and followed practices which were more similar to those of Funnel Beaker North potters, but distinct from those of potters in Vlaardingen communities. This underlines the connections drawn between Funnel Beaker West and North on the basis of funerary and depositional practices, as well as agricultural subsistence (cf. Louwe Kooijmans 2018; *contra* Ten Anscher 2012). An archaeogenetic study would be necessary to definitively prove that Funnel Beaker West communities migrated from Southern Scandinavia, but such a scenario does seem likely in light of the above-mentioned differences in practices. More important however, is the fact that these distinctions did not obstruct interactions. The potters in these communities learned from each other, leading to the adoption of a standardised production process with sparse decoration and intensive burnishing (see Ch. 9; 10). This production process is distinct from that in Funnel Beaker North vessels (see

Ch. 10). As such, the interactions between Funnel Beaker West and Vlaardingen potters may well be a contributing factor to the regionalisation of Funnel Beaker groups (see Section 2.1; Furholt 2014b).

The adoption of the standardised production process with extensive burnishing and sparse decoration among indigenous Middle Neolithic communities in the Netherlands is crucial for understanding their interaction with migrating groups (see Ch. 13). However, the outcomes also underline that learning processes can cut right across such distinctions and shape human choices (see Section 3.1). The fact that we find the large, complex bowls which are typical for late flat graves together with Corded Ware vessels on Vlaardingen settlements (e.g. Hazerswoude-Rijndijk N11 Diependaele and Drenth 2010; cf. Fokkens *et al.* 2016) hints at the prevalence, and complexity of learning in the past.

12.3 Revising the Neolithic of Northwest Europe

Two findings from this study on ceramic technology are highlighted above, as well as their impact on our understanding of indigenous communities in the Dutch Middle and Late Neolithic.

Firstly, Funnel Beaker West communities did not abruptly disappear around 2800 BCE. A Bayesian chronological model of the radiocarbon evidence shows Funnel Beaker West and Corded Ware communities co-existed for several centuries during the first half of the third millennium BCE. Moreover, the funerary practices in late flat graves from this period clearly show that the people who conducted these burials and fashioned these vessels learned, through direct involvement, from the Funnel Beaker West communities who lived in the Netherlands during the fourth millennium BCE. The fact that these practices occur across the North German Plain in the third millennium BCE, and that similar observations can be made for various other indigenous groups, including Vlaardingen, indicates indigenous communities throughout Europe did not disappear with the advent of migrating groups at the start of the third millennium BCE. Instead, migrating and indigenous co-existed throughout Europe during the first half of the third millennium BCE. These indigenous communities may well be the source populations for the resurgence of hunter gatherer and early farmer genetic profiles in Bronze Age Europe.

Secondly, Funnel Beaker West and Vlaardingen communities were not closed systems with minimal interaction. These communities may come from different regional backgrounds and differ in many respects of their everyday life, but potters did exchange knowledge across this boundary. This knowledge exchange shapes the specific *chaînes opératoires* associated with both groups. In particular, Funnel Beaker West potters over time diverge from a ceramic production process similar to that in ancestral Funnel Beaker North communities, and, together with Vlaardingen potters, adopt a production process with intensive burnishing and sparse decoration. The adoption of this standardised production process among all indigenous potters in the Netherlands plays a crucial role in the next chapter, which delves into the interactions between migrating and indigenous groups during the third millennium BCE.

13

Eager for Knowledge: Migrants in the Third Millennium BCE

Migrating Corded Ware and indigenous Funnel Beaker West communities co-existed in the Netherlands for 150-500 years at the start of the third millennium BCE (see Chapter 2; 12). What interactions took place during that time? And how did these interactions shape the changes in genetics, material culture, funerary rites, language, and connectivity we observe in the third millennium BCE?

The central argument in this chapter is that migrating and indigenous communities in the Netherlands gradually build up interactions during the third millennium BCE. During these interactions migrating communities adopted some of the funerary practices and technical knowledge from indigenous Funnel Beaker West groups, and incorporated these within their own, distinct practices (see Section 13.1). In addition, the comparisons of ceramic technology suggest a similar encounter with Funnel Beaker groups in Central Europe may have shaped the ceramic technology found in Corded Ware vessels in the Netherlands (see Section 13.2). A brief summary of these arguments and a discussion of their implications for broader views on migration in archaeology is given in Section 13.3.

13.1 Migrants Learned from Indigenous Communities…

Most explanatory accounts for the third millennium BCE propose migrating communities have the dominant role in their interactions with indigenous communities (see Section 1.3). Indigenous communities either adopt (Holmqvist *et al.* 2018; Kristiansen *et al.* 2017), or co-opt (Furholt 2021) Corded Ware practices and material culture, or simply disappear (Heyd 2021). This study of ceramic technology shows the opposite is true: migrating communities were the ones who learned from indigenous communities.

The most probable arrival date of migrating communities in the Netherlands falls around 2975 BCE. This date is based on a Bayesian chronological model of the radiocarbon evidence for Corded Ware burials in the Netherlands (see Section 2.3; Beckerman 2012; Furholt 2003). The model provides a two-sigma range for the arrival date from 3089 to 2899 cal BCE. We return to this range below.

As yet, aDNA evidence from Dutch Corded Ware burials is scarce due to poor bone preservation (cf. Olalde *et al.* 2018 for exceptions), but the appearance of Corded Ware funerary practices generally coincides with the appearance of individuals with steppe ancestry (Furholt 2020 pp. 9–10).

An arrival around 2975 BCE means migrating communities encountered two indigenous groups in the Netherlands: Vlaardingen and Funnel Beaker West. The distinction between these two is on the basis of differences in subsistence economy, funerary practices, and monumentality (see Section 2.1; 12.2). In reality, potters from these two communities were in the process of exchanging technical knowledge despite these differences, and these interactions led to a convergence on a ceramic production process with sparse decoration and extensive burnishing (see Section 12.2). This standardised production process is the key to understanding interactions with migrating groups. The comparisons of the Corded Ware body of knowledge against this standardised production process results in two conclusions.

Firstly, potters in migrating communities held similar knowledge to indigenous potters in the Netherlands, but may not have obtained that knowledge directly from them. The similarity is evident from the probabilistic comparison, which places the Corded Ware body of knowledge substantially closer to the subsets of Funnel Beaker West than sister group Funnel Beaker North (see Fig. 10.2A-C; Tab. 10.3). This is because potters from both communities use a similar spectrum of techniques according to a similar syntax. Only the greater variation in (combinations of) decorative techniques and surface treatment set Corded Ware apart from the indigenous groups (see Ch. 9; 10).

However, the probabilistic comparison also hints at a more complex scenario. The Corded Ware body of knowledge matches ceramic production in early flat graves, Funnel Beaker North, and megalith inventories better than it does ceramic production in late flat graves (10.2; Tab. 10.3), even though the potters who made Corded Ware had substantially longer to interact with the potters who made the vessels in late flat graves (see Fig. 2.6; 2.9). In addition, there are subtle differences between ceramic production in Funnel Beaker West and Corded Ware (see Ch. 9). For example, the paste recipes of Funnel Beaker West and Corded Ware differ, as well as some modalities of techniques (e.g. fashioning the base by pinching a flattened clay disk), tools (e.g. conical tools), and procedures (e.g. the application of surface treatment to vessels in an upside-down position). These finer nuances matter, because one has to be physically present during the production process to learn them (Gosselain 1992 p. 582, 2000 pp. 192–3; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29). As such, the potters who made Corded Ware vessels and Funnel Beaker West vessels practiced similar ceramic production methods, but this is not due to migrating potters learning all they know from indigenous potters. It is more likely the migrant potters who arrived in the Netherlands around 2975 BCE had already learned a similar production process elsewhere. The next section discusses this point in more detail.

The second conclusion from the comparisons in Chapter 9 and 10 is that the above distinction is not absolute. Whereas the Corded Ware body of knowledge as a whole stands out from late flat graves and Vlaardingen, some Corded Ware specific *chaînes opératoires* bridge this difference. These specific *chaînes opératoires* follow the standardised production process practiced by Funnel Beaker West and Vlaardingen potters (see Ch. 10), or feature the paste recipe seen in Funnel Beaker West vessels (see Ch. 9). Interestingly, the reverse does not apply: there are no Funnel Beaker West vessels with a paste recipe seen in Corded Ware vessels or the more varied (combinations of) decorative and surface treatment techniques. Therefore, knowledge exchange does appear to take place between migrating and indigenous potters, but it is the potters in migrating communities who learn and apply indigenous knowledge, rather than the other way around, as is often suggested (e.g. Furholt 2021; Kristiansen *et al.* 2017).

Interestingly, Bourgeois *et al.* (in press.) reach a similar conclusion for funerary practices in Funnel Beaker West and Corded Ware. Both groups have distinct funerary practices. Funnel Beaker West late flat graves feature large, complex bowls as grave goods, and cremation of the deceased (see Section 2.4; 12.1). By contrast, Corded Ware burials feature inhumations with their own distinct set of practices and grave goods (cf. Bourgeois and Kroon 2017; Wentink 2020). However, there are rare instances where these two distinct funerary practices overlap. Examples are Corded Ware cremation burials, which are extremely rare in the Netherlands (cf. Drenth and Hoogestijn 2014), the deposition of Corded Ware pottery in megaliths according to Funnel Beaker West funerary practices (see Section 2.5), and the integration of Corded Ware funerary sites into Funnel Beaker West alignments (see Section 2.5). These cases show that whereas Funnel Beaker West and Corded Ware funerary practices are largely distinct, migrating communities do on occasion show awareness of, and follow, these deeply meaningful and cosmologically charged funerary practices of indigenous communities.

In addition, Bourgeois *et al.* (in press.) argue these overlaps in funerary practice increased during the subsequent Bell Beaker period. This suggests a gradual build-up of interactions and knowledge exchange between indigenous and migrating communities. Unfortunately, the lack of chronological differentiation within Corded Ware ceramics (see Section 2.3) makes a similar assessment for ceramic technology impossible. Regardless, the appearance of the standardised Funnel Beaker West ceramic production process and paste preparation in Corded Ware vessels show similar knowledge exchange took place among potters.

To conclude, the two defining practices of Corded Ware and Funnel Beaker West, namely funerary ritual and ceramic production, both point towards the same interactions between migrating and indigenous communities 5,000 years ago. Migrating communities arrived in the Netherlands carrying knowledge and practices which already resembled those of indigenous communities, co-existed with these communities, and gradually learned some of their practices. This interpretation is pivotal for our understanding of the third millennium BCE. Not only do indigenous communities continue to exist in the Netherlands several centuries after the arrival of migrating communities (see Ch. 12.1), but it is the migrating communities who learn from the indigenous groups (*contra* Furholt 2021; Heyd 2021; Kristiansen *et al.* 2017).

13.2 …On More than One Occasion

A key observation in Section 13.1 is that migrating communities held technical knowledge which was similar to that of Funnel Beaker West potters, but did not (initially) acquire this knowledge from them. Where did they learn this similar production process? In this section, I argue Funnel Beaker(-affiliated) communities in Central Europe are the probable source for this technical knowledge.

First off, migrating potters are likely to have obtained this knowledge from potters in the European Middle Neolithic. This is because the Corded Ware body of knowledge fits within the broader pattern of Middle and Late Neolithic ceramic technology in Europe (see Ch. 11). Corded Ware specific *chaînes opératoires* follow the same basic structure as ceramics from Funnel Beaker North and West, and Vlaardingen groups: modelling, coiling, continuous pressure, wet smoothing, variable decorative techniques, drying to leather-hard, variable surface treatment, drying to dry, and open firing (see Sections 10.1; 11.1). This indicates that, despite the differences in ancestry, migrating potters probably learned their craft from potters in Middle Neolithic European groups.

Pinpointing which indigenous group is involved is difficult. However, the close match between the Corded Ware body of knowledge and older Funnel Beaker West specific *chaînes opératoires* (see Tab. 10.3; Fig. 10.2) does provide a starting point for this search.

Despite this close match between ceramic production in early flat graves, megalith inventories, and Corded Ware, it is unlikely Corded Ware potters learned their craft from the Funnel Beaker West potters who fashioned these vessels. The Bayesian chronological models (see above, Section 2.3; 2.4) technically leave this possibility open, but subtle differences in the production processes indicate otherwise.

Vessels in megalith inventories and early flat graves exhibit the same subtle differences to Corded Ware in terms of procedures (e.g. the decoration and surface treatment of vessels in an up-side down position), paste recipes, tools, and modalities of techniques, as the vessels in late flat graves (see Ch. 9; 10). In fact, the Funnel Beaker West vessels which pre-date ca. 2925 BCE are closer to those in flat graves in all of these respects (see Ch. 9; 10). As argued above for late flat graves, learning these subtle differences in the production process requires physical presence during the production process. As such, these dissimilarities indicate Corded Ware potters probably did not learn directly from the potters who made Funnel Beaker West vessels prior to the third millennium BCE, regardless of the moment of their arrival.

Instead, the match between the specific *chaînes opératoires* of Corded Ware vessels and those of Funnel Beaker West vessels from megalith inventories and early flat graves points toward a different explanation. Corded Ware potters may have learned ceramic technology from another Funnel Beaker group.

The ceramics of various Funnel Beaker groups are thought to be relatively homogeneous during the first half of the fourth millennium BCE, but to diversify afterward (see Section 2.1; 12.1; Furholt 2014b p. 21). Let us, therefore, assume the vessels in megalith inventories and early flat graves are closer to this initial, more homogeneous phase of Funnel Beaker groups, whereas the vessels in late flat graves were made according to more regionalised practices (see Section 12.2). In this case, the close resemblance between Corded Ware and Funnel Beaker West ceramic production prior to ca. 2925 BCE indicates there is a tie between the knowledge of migrating potters and that of Funnel Beaker potters in general, but not with the specific, regional variant of that knowledge among Funnel Beaker West potters after ca. 3000 BCE. The comparatively short Wasserstein distance between Corded Ware and Funnel Beaker North supports this interpretation (see Fig. 10.2D; Tab. 10.3).

The same conclusion can also be drawn by looking at the combinations of decorative and surface treatment techniques. The choices of potters during these stages are the primary causes of variation in the studied vessels (see Ch. 9; 10). The potters who made vessels in megalith inventories and early flat graves used a broad range of decorative techniques (primarily simple (oblique) impressions, simple incisions, and simple excisions), and surface treatment techniques (burnishing, shining, and smudging, see Ch. 9; 10). The variation in surface treatment and decorative techniques in vessels from Corded Ware and late flat graves can be seen as two different sets of choices within this spectrum. The potters who fashioned the vessels in late flat graves often chose a combination of simple oblique impressions and burnishing, whereas the potters who made Corded Ware vessels chose combinations of simple impressions, simple incisions, burnishing, and shining. Consequently, the specific *chaînes opératoires* from vessels in late flat graves and Corded Ware appear as different sets of choices within the broader spectrum of techniques in Funnel Beaker vessels made prior to ca. 2925 BCE. Given that the vessels in late flat graves form one regionalised production process among Funnel Beaker groups (see Ch. 12.2), the match between megalith inventories, early flat graves and Corded Ware suggests migrating potters may have learned the technical practices from another Funnel Beaker group which did not follow the same trajectory towards standardisation as Funnel Beaker West potters did.

This explanation clarifies the paradoxical close match of the Corded Ware body of knowledge with older, but not younger, Funnel Beaker West ceramic technology (see Ch. 10). In addition, it explains why Corded Ware and Funnel Beaker West specific *chaînes opératoires* appear to be different sets of choices in the same set of (combinations of) techniques (see Ch. 9), and why Corded Ware potters follow Northwest European Middle and Late Neolithic ceramic technology, despite descending from communities on the Eurasian steppe.

The question is: which of the Funnel Beaker groups would be the likely source of this knowledge? It is only possible here to provide an answer by means of elimination. Further studies of specific *chaînes opératoires* in Funnel Beaker groups are needed to provide a definitive answer. However, the fact that a larger Wasserstein distance exists between Funnel Beaker North and Corded Ware than between early flat graves and Corded Ware (see Fig. 10.2D; Tab. 10.3) indicates migrating potters are unlikely to have obtained this knowledge from potters in Funnel Beaker North. Similarly, Funnel Beaker communities in Northwest Germany are not likely to be the source, because the available information on paste recipes and funerary rites indicate these groups exchanged knowledge with Funnel Beaker West (see Section 12.1). This leaves Funnel Beaker(-affiliated) groups in Central Europe (cf. Midgley 2008 Fig. 1.1). Unfortunately, no studies of ceramic technology in these groups are known to me. Various authors do suggest the use of simple impressions (i.a. with cord), simple incisions, and paste recipes with grog are common among Funnel Beaker East and South East (cf. Midgley 1992 pp. 54–5; 58; Nowak 2017 p. 146; Rauba-Bukowska 2019; Rauba-Bukowska *et al.* 2020). Potters among younger Globular Amphora communities are said to have learned some of these same practices (Szmyt 2017 pp. 220–1; 262; Wiślański 1970 p. 221). Therefore, potters among migrating communities may have learned from potters in these Funnel Beaker(-affiliated) groups in Central Europe, causing the resemblance of Corded Ware ceramic production to Funnel Beaker West. Acquiring further data on the specific *chaînes opératoires* from Funnel Beaker(-affiliated) groups in Central Europe could be key to understanding the knowledge of Corded Ware potters, and their interactions with indigenous communities in Europe.

Interestingly, the developments in funerary practices again appear as a close parallel for ceramic technology. The typical Corded Ware burial ritual (cf. Bourgeois and Kroon 2017) differs from that seen among archaeological groups in the Eurasian steppe and forest steppe from which Corded Ware individuals descend (cf. Frînculeasa *et al.* 2015; Heyd 2021 p. 387; Preda-Bălănică *et al.* 2020). Instead, the current consensus is that the Corded Ware burial ritual emerges from interactions between migrating communities and indigenous communities in Central Europe, principally Tripolye, Funnel Beaker, and Globular Amphora (Frînculeasa *et al.* 2015 p. 84; Furholt 2019 p. 123, 2021;

Heyd 2021 p. 390). This interaction would lead to a blend of practices with regard to grave goods, positioning of the corpse in the burial pit, and funerary architecture which is recognisable as Corded Ware.

To conclude, potters in migrating communities brought with them technical knowledge about ceramic production upon arrival in the Netherlands around 2975 BCE. This technical knowledge resembled that of contemporaneous indigenous Funnel Beaker West potters, but subtle differences in the production process indicate migrating potters did not learn this process from these indigenous potters. Instead, the outcomes of the probabilistic and abductive comparison suggest migrating potters obtained this knowledge from potters in Central European Funnel Beaker groups, or affiliated Globular Amphora groups, during earlier encounters. The same encounters may have been formative for the typical Corded Ware burial ritual.

13.3 Concluding Remarks

Ceramics and funerary rituals are the quintessential elements of Corded Ware (cf. Bourgeois and Kroon 2017; Furholt 2019). This study points towards a third, crucial ingredient: the ability of migrating groups to learn from indigenous communities they encountered, and to integrate this learned knowledge into the making of those typical burials and ceramics. Traces of this learning prowess are visible in Corded Ware ceramic technology and funerary ritual.

Migrating communities learned and adopted funerary practices and ceramic technology from indigenous groups they encountered in Central Europe, and carried this knowledge with them upon arrival in the Netherlands (see Section 13.2). Upon their arrival, these migrants again build up contacts with indigenous Funnel Beaker West and Vlaardingen groups, learned from them, and incorporated this information into their own practices. This process is evidenced by the appearance of ceramics which follow the standardised Funnel Beaker West and Vlaardingen ceramic production process, the gradual appearance of cremation burials in Corded Ware and later on Bell Beaker communities, and the manner in which deposition of Corded Ware vessels in megaliths adheres to Funnel Beaker West funerary practices (see Section 13.1). All of these elements indicate that migrating communities regularly, and repeatedly, learned from the indigenous communities they encountered. The fact that these are cosmologically-charged burial practices and in-depth practical knowledge of materials and procedures for which learning probably involved personal participation in these practices, illustrates just how close ties between member of migrating and indigenous communities may have been.

Current archaeological explanations for the outsize impact of migrating communities on European history focus on weapons, diseases, and mobility as success factors for migrating communities (see Section 1.2). Yet, evidence for these success factors remains problematic. The ‘daggers’ and ‘battle axes’ in Corded Ware burials turn out to have mundane functions (cf. Wentink 2020), hard evidence for plagues remains absent (Susat *et al.* 2021), and high mobility appears to be a general feature of this period (Furholt 2021). Instead, this study points towards a different success factor: the willingness of migrating communities to learn from indigenous groups, and their ability to incorporate that learned knowledge into their daily lives without losing sight of where they came from.

In a broader context, the outcomes of this study show a reconsideration of the concept migration is needed in archaeology. In particular with regard to the role of host communities and the identification of characteristic practices for certain groups.

Archaeological studies of migration continue to focus on migrating groups and to treat migration as re-location of groups with characteristic practices or material culture (cf. Burmeister 2000; McSparron *et al.* 2020; Tsuda *et al.* 2015) often followed by the disappearance of indigenous groups (see Section 1.2). Such approaches clash with studies of modern (Castles *et al.* 2014; De Haas 2023) and historical (Geary 2002; Halsall 2013; Oosterhuizen 2019) migrations. These studies systematically point towards more complex, micro-scale processes in which migrants learn and adopt practices from their host societies through daily interactions and balance these with their own practices. Crucially, it is precisely such a scenario of which we find the aggregate effect in ceramic technology for Corded Ware in the third millennium BCE (see above), Funnel Beaker West in the fourth millennium BCE (see Section 12.2), and potentially even early farmers in the sixth millennium BCE (see Ch. 11). All of these once migrating communities learned ceramic production techniques from their host communities and co-existed with them. None of their 'characteristic' material culture would exist without that learned knowledge.

Therefore, this study presents two key take-aways for archaeological studies of migration. The first is to take into account both host and migrating communities instead of one-sidedly focussing on migrating communities. Careful re-examination of the culture-historical definitions and chronologies of these groups is required in this process, for example through Bayesian chronological models (see Ch. 2). The second take-away is to focus on learning processes rather than on isolating characteristic traits of groups. Studies of migration have repeatedly shown learning processes connect migrant and host communities (see above, Section 1.3). The probabilistic toolkit and perspective on aggregate effects developed here for ceramic technology bring these learning processes into focus. Thus, they enable a new perspective on past migrations, and the past in general; a perspective based on the transmission of knowledge.

14

Conclusion

The third millennium BCE is the scene of a migration into Europe from the Eurasian steppe (cf. Allentoft *et al.* 2015; Haak *et al.* 2015; Olalde *et al.* 2018 and further references). This migration set into motion historic changes in ancestry, connectivity, and probably language of which the effects are visible in Europe to this day (Kristiansen *et al.* 2017). Archaeologists long recognised this migration event as the appearance of specific cord-decorated ceramics across Europe. Hence the name attached to these migrating groups: Corded Ware.

Yet these drastic changes should not be taken for granted. These migrants did not arrive in an empty continent. Throughout Europe, they encountered indigenous communities, such as Funnel Beaker West (cf. Furholt 2014a, 2021). Therefore, the crucial question for this period is what interactions between migrating and indigenous communities drove the observed changes. Various answers to this question have been proposed, from slow coalescence of multiple communities under increased interactions (cf. Furholt 2021) to violent destruction of indigenous communities (cf. Heyd 2021; Kristiansen *et al.* 2017).

This pivotal question is approached here through a study of ceramic *chaînes opératoires* (cf. Roux 2019a). Ceramic technology consists of learned, embodied knowledge which potters acquire through working materials as well as direct and indirect interactions with other potters (cf. Gosselain 2018). Therefore, a detailed study of ceramic production processes adds a new dimension to our knowledge about the third millennium BCE: that of knowledge transmission and learning. As such, the following question is at the heart of this dissertation:

> *What can be inferred from developments in ceramic technology about the nature of the interaction between migrating and indigenous communities that shaped the Corded Ware transition?*

This research question is applied to the interactions between indigenous Funnel Beaker West and migrating Corded Ware communities in the Netherlands. Before discussing the answer to this question, the next section sets the stage for these interactions by presenting a revised image of the Middle and Late Neolithic in the Netherlands, based on the findings from this study.

14.1 Setting the Stage

Developments in ceramic technology during the Early Neolithic are crucial for understanding Middle and Late Neolithic ceramic production. Knowledge about vessel production was introduced in Europe independently by farming communities and hunter-gatherers (Gronenborn 2003; Jordan *et al.* 2016; Piezonka 2015). These groups employed different (combinations of) roughing-out and preforming techniques (see Section 11.1, Tab. 11.1; cf. Gomart *et al.* 2017). The developments which followed are unclear, but by the Middle Neolithic, all potters in Northwest Europe learned, used, and taught the production process first seen among hunter-gatherers in Southern Scandinavia (see Ch. 11). As a result, all of the specific *chaînes opératoires* studied here follow a basic structure during roughing out, preforming, finishing, drying, and firing (see Ch. 10, 11). Most variation occurs during the application of decoration and surface treatment, but these operations do generally occur at the same places in the specific *chaîne opératoire* (see Ch. 9, 10), again hinting at a shared knowledge among potters during this period.

During the Middle Neolithic B (3400-2900 cal BCE), two communities co-existed in the Netherlands (see Fig. 14.1). On the one hand, Vlaardingen communities occupied the wetlands, and had roots going back to the Mesolithic. The subsistence economy of Vlaardingen communities combined hunting, gathering, fishing, farming, and fowling. They practiced a burial rite which left few archaeological traces (Amkreutz 2013; Fokkens *et al.* 2016). On the other hand, Funnel Beaker West communities likely migrated into the Netherlands from Southern Scandinavia, and are best known from the upland areas of the Netherlands. These communities practiced a burial rite involving inhumation in megalithic tombs and flat graves, and had a subsistence economy focused on agriculture (Louwe Kooijmans 2018).

It is not possible to substantiate typochronological distinctions within Funnel Beaker West (see Section 2.3). However, the radiocarbon evidence does point towards a chronological distinction between early flat graves which pre-date ca. 2925 BCE, and late flat graves which date between ca. 3000 and 2675 BCE. Materials associated with both early and late flat graves occur in megalith inventories, indicating the accumulation of these assemblages over longer periods of time (see Section 2.4).

There are two developments during the Middle Neolithic B which are crucial for the events during the third millennium BCE. The first development relates to the early and late flat graves which appear from the radiocarbon evidence (see Section 2.3; 2.4). Prior to and during the first century of the third millennium BCE, most flat graves contain inhumations (Bakker 1992 p. 93), but a small number yields traces of wooden structures in the burial pit which were set aflame during the burial (e.g. Bouma and Van der Velde 2022 pp. 50–2). Cremation of the deceased is rare (see Section 2.4). In addition, mourners increasingly selected amphora-like vessels and bowls as grave goods from the larger spectrum of vessel types found in Funnel Beaker West megalith inventories (see Section 2.4). This change in funerary practices is important for understanding later events in the third millennium BCE.

The second crucial development is knowledge exchange between Funnel Beaker West and Vlaardingen communities (see Section 12.2). Funnel Beaker West vessels from megalith inventories follow a production process which is distinct from that found in Vlaardingen vessels, and better resembles specific *chaînes opératoires* from Funnel Beaker North (see Fig. 10.2A, Tab. 10; Section 12.2). This pattern is due to the broad range of techniques applied during decoration and surface treatment of these vessels (see Ch. 9, 10). It points at the existence of shared knowledge among potters in Southern Scandinavia and the Netherlands, and underlines the ties between Funnel Beaker West and North communities (see above). However, Funnel Beaker West vessels do appear on Vlaardingen sites, and vice versa (Amkreutz 2013 p. 342; Beckerman and Raemaekers 2009 p. 79; Drenth 2019).

Crucially, Funnel Beaker West vessels which post-date ca. 3000 BCE show a standardised production process with sparse decoration and intensive burnishing (see Ch. 9, 10). This same production process appears in Vlaardingen vessels (see Appendix F), but contrasts with Funnel Beaker North (see Fig. 10.2C; Tab. 10.3). The start of this standardisation in ceramic production processes already appears in early flat graves (see Ch. 10; Section 12.2), indicating that potters among Funnel Beaker West and Vlaardingen communities were in the process of exchanging knowledge and adopting a similar production process well before the third millennium BCE. This outcome might be part of the increasing regionalisation of Funnel Beaker groups during the fourth millennium BCE (cf. Furholt 2014b).

These two developments, in funerary rites and ceramic technology, bring us to the arrival of migrating communities with steppe ancestry in the Netherlands around 2975 BCE, and the start of the Late Neolithic A (2900-2500 cal BCE). The impact of this event on indigenous and migrating communities, respectively is discussed in the following two sections.

14.2 Business as Usual

Funnel Beaker West communities were unaffected by the arrival of migrating communities around 2975 BCE and co-existed with them for 150-500 years. Moreover, this development is not an exception but part of a broader pattern during the third millennium BCE.

The two defining elements of Funnel Beaker West are practices in funerary rituals and ceramic production (see Section 2.1). This study shows practices in both of these fields continued to be in use until ca. 2675 BCE, meaning people learned them, adhered to them, and passed them on. Changes did occur in these practices, but these changes are rooted in developments which took place prior to the third millennium BCE.

In terms of funerary practices, the archaeological record yields cremation burials dating to ca. 3000-2675 BCE. These cremation burials are a continuation of the practices seen in early flat graves, but cremation has become the norm, rather than the exception (see Section 2.4; 12.1; cf. Bakker 1992 p. 93). In addition, the selection of grave goods has further narrowed to only encompass large, complex bowls (see Section 2.4). These cremation burials also appear in funerary contexts which are associated with Funnel Beaker West burials prior to ca. 3000 BCE, including at flat grave cemeteries with earlier flat graves (e.g. Bouma and Van der Velde 2022 pp. 63–4), and in megaliths (cf. Bakker 1992 p. 93). Therefore, knowledge about Funnel Beaker West funerary rites was still in circulation and being practiced by communities during the first half of the third millennium BCE (see Section 12.1).

The same conclusion applies to the technical knowledge of Funnel Beaker West potters. The potters who made the vessels in late flat graves learned and applied the same paste recipes, techniques, tools, syntax, procedures, and modalities of techniques found in Funnel Beaker West vessels since before the third millennium BCE (see Ch. 9, 10, 12.1). Learning a production method at such a detailed level requires potters to be physically present and to be supervised by knowledgeable individuals them (Gosselain 1992 p. 582, 2000 pp. 192–3, 2018; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29). Therefore, the similarities mentioned above indicate the potters who made the vessels

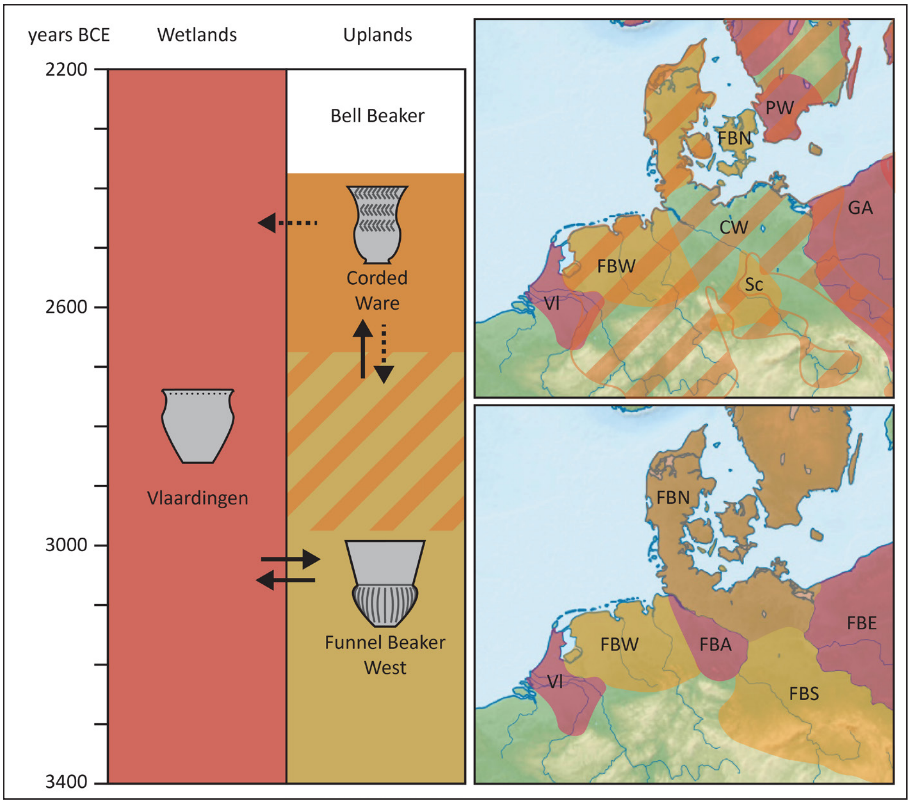


Figure 14.1: Co-existence of migrating and indigenous groups in Northwest Europe. Migrating communities co-existed with various indigenous communities after their arrival around 2975 BCE (top right; those confirmed by other studies), including older Funnel Beaker (-affiliated) groups (bottom right). Solid arrows indicate exchange of knowledge; dotted arrows of vessels alone. Abbreviations: CW = Corded Ware, GA = Globular Amphora, FBA = Funnel Beaker Altmark Group, FBE = Funnel Beaker East, FBN = Funnel Beaker North, FBS = Funnel Beaker South, FBW = Funnel Beaker West, PW = Pitted Ware, Sc = Schönfeld, and Vl = Vlaardingen (after: Iversen 2020 Fig. 3; Midgley 2008 Fig. 1.1; Vanhanen *et al.* 2019 Fig. 1; Von Schnurbein and Hänsel 2009; Wetzel 1979). Not depicted: Bernburg and Salzmünde groups.

in late flat graves were taught by those who made the vessels in early flat graves and megalith inventories (see Section 12.1).

Similar to funerary practices, changes do occur in the specific *chaînes opératoires* of vessels in late flat graves relative to those in megalith inventories and early flat graves. The vessels in late flat graves were made according to a standardised production process which features fewer decorative techniques and intensive burnishing (see Ch. 9; 10; 12). However, these changes again are a continuation of processes visible in Funnel Beaker West vessels since before the third millennium BCE (see above, Section 10.2; 12.1).

Crucially, there is evidence that the same developments in funerary practices and ceramic production also took place among Funnel Beaker groups outside the Netherlands. The same funerary practice involving cremation of the deceased and use of large, complex bowls as grave goods appears in Northwest Germany (Kossian 2000), and Central Germany (Wetzel 1979). There is no data on specific *chaînes opératoires* from these areas, but potters did follow the same, highly standardised paste recipe seen in all Funnel Beaker West vessels (cf. Struckmeyer 2017, 2018, 2019).

Such shared practices emerge out of interactions between mourners and potters across this area. These interactions contributed to their notions about how to conduct burials, or fashion vessels respectively. Potters and mourners then drew on this knowledge when conducting new funerals or fashioning new ceramics (cf. Bourgeois and Kroon 2017). In other words, this system of information exchange is what archaeologists recognise as Funnel Beaker West. The fact that the same system continues to shape burials and ceramic production throughout the first half of the third millennium BCE tells us the indigenous communities continued to thrive after the arrival of migrating groups at the start of the third millennium BCE (see Section 12.1).

Funnel Beaker West is not an exception in this regard. Similar observations have been made for indigenous groups in Denmark (Iversen 2014, 2015, 2020), Sweden (Holmqvist *et al.* 2018; Larsson 2009 pp. 260–1), Germany (Müller 2001), Poland (Włodarczak 2017 pp. 286; 300–1), and other areas of the Netherlands (Beckerman 2015; Kroon *et al.* 2019). Consequently, we mistakenly interpret Corded Ware as the only population during the first half of the third millennium BCE, creating an artificially sharp boundary between migrating and indigenous communities around 2800 BCE (see Section 2.2; 12.1). In fact, migrating communities were never alone in Europe (see Fig. 14.1): they lived side-by-side with indigenous communities who continued to practice the same funerary rites and ceramic production techniques as they had prior to the arrival of migrating communities (see Fig. 14.1). This co-existence of indigenous and migrating communities could explain the resurgence of hunter gatherer and early farmer ancestry in Bronze Age populations (cf. Haak *et al.* 2015; Mittnik *et al.* 2018).

14.3 Serial Learners

How did migrating groups interact with indigenous communities in the Netherlands, and elsewhere in Europe? The pattern evident from Corded Ware ceramic technology is that these migrating groups repeatedly learned from indigenous communities they encountered, and integrated this knowledge into their own technical repertoires without losing sight of their own practices (see Ch. 13).

Migrating potters arrived in the Netherlands with knowledge which was similar to, but also distinct from, that of contemporaneous potters in indigenous communities. Potters in both groups were familiar with the same spectrum of techniques and syntax but made distinct choices within that spectrum. In addition, subtle differences in paste recipes, modalities of techniques, tools, and procedures exist between Funnel Beaker West and Corded Ware vessels. These differences indicate migrating potters did not learn directly from indigenous potters in the Netherlands (see Ch. 13; Gosselain 1992 p. 582, 2000 pp. 192–3, 2018; Roux 2019a p. 311; Thebe and Sadr 2017 pp. 85–6; Wallaert 2012 p. 29), but from another community which shared knowledge with Funnel Beaker West.

This community was probably a Funnel Beaker-affiliated group in Central Europe (see Section 13.2). Funnel Beaker ceramics are more homogeneous during the fourth millennium BCE, but diversified over time (Furholt 2014b). For Funnel Beaker West, this diversification involves the adoption of a standardised production process mentioned above. Therefore, the strong similarities between Corded Ware and Funnel Beaker West ceramics in early flat graves and megaliths, but the weaker resemblance to ceramics from late flat graves with standardised specific *chaînes opératoires* (see Fig. 10.2; Tab. 10.3), suggest a link to Funnel Beaker groups which did not undergo the same standardisation process. The dissimilarity between Corded Ware and Funnel Beaker North (see Fig. 10.2D; Tab. 10.3), and the knowledge exchange between Funnel Beaker communities across the North German plain which is visible in paste recipes (see above), further rule out these communities as potential sources of the technical knowledge in ceramic technology (see Section 13.2). This leaves the Funnel Beaker East and South East group, as well as the affiliated Globular Amphora communities. Studies of ceramics from these groups do show similarities with Corded Ware in paste recipes and tools used during decoration (cf. Midgley 1992 pp. 54–5; 58; Nowak 2017 p. 146; Rauba-Bukowska 2019; Rauba-Bukowska *et al.* 2020). However, further studies of the specific *chaînes opératoires* in these groups are needed to verify this conclusion (see Section 13.2).

After their arrival in the Netherlands, migrating potters again learned from indigenous potters. This is evident from a small number of Corded Ware vessels which follow the Funnel Beaker West paste recipe, as well as Corded Ware vessels which conform the standardised Funnel Beaker West specific *chaîne opératoire* (see Ch. 9; 10; 13.1). Picking up on these specific features of the ceramic production process requires the potters who made these Corded Ware vessels to have witnessed Funnel Beaker West potters in action, to have learned from them, and to have incorporated this knowledge into their production process (see above, Section 13.1). As such, the variability in Corded Ware ceramic technology hints at a process whereby migrating communities repeatedly arrive in an area, learn from the local indigenous groups, and travel on with this knowledge.

This interpretation of Corded Ware ceramic technology is consistent with observations on Corded Ware funerary practices (see Ch. 13). The origins of these distinctive funerary practices lie in the combination of Yamnaya and Central European funerary traditions (cf. Furholt 2021; Heyd 2021). In addition, there is evidence migrating communities in the Netherlands learned and adopted Funnel Beaker West funerary practices. Corded Ware and Funnel Beaker West practices are largely distinct (see above, Ch. 13; Bourgeois and Kroon 2017; Wentink 2020) with a few tell-tale exceptions. The deposition of Corded Ware vessels in megaliths follows Funnel Beaker West funerary practices (see Section 2.5). In addition, cremation burials, otherwise typical for late Funnel Beaker West, appear in Dutch Corded Ware (cf. Drenth and Hoogestijn 2014) and increase in frequency during the subsequent Bell Beaker period (cf. Bourgeois *et al.* in press.). These patterns in Corded Ware funerary practices again indicate the pattern of migrating groups arriving, interacting with and learning from indigenous communities, and then incorporating that knowledge into their own practices before moving on.

Thus, the image of interactions between migrating and indigenous communities which emerges from ceramic technology and funerary ritual is not that of rapacious, war-like bands which terminate indigenous communities (cf. Anthony and Brown 2017; Heyd 2021; Kristiansen *et al.* 2017). Rather, the emergence of Corded Ware appears as a history of migrant communities who interact with, adjust to, and learn from indigenous communities without either losing sight of their own practices. These migrants are not serial killers, but serial learners.

14.4 History of Knowledge: A New Synthesis

Ceramic technology is a powerful tool to explore the European Neolithic and beyond. This power derives from the ability to tap into one of the most fundamental aspects of human nature: our ability to learn. However, this power also comes with a prerequisite, namely an engagement with complexity.

Learning has a complex relation to the commonly used building blocks of Prehistory. It can cut across the historical, linguistic, economic, genetic, and social boundaries which form our culture-historical schemes (see Ch. 3). Moreover, learning may relate to the behaviour of agents, but a complete view of this behaviour is beyond the typical temporal and spatial resolution of archaeology, meaning an understanding based on learning cannot be predicated on agents alone (see Ch. 3). In other words, to fully harness learning and knowledge transmission in archaeology requires a new synthesis of the information at our disposal.

My hope is to have contributed to this new synthesis over the course of this dissertation. The contribution consists of developing and applying new analytical tools, such as the probabilistic comparison of ceramic technology (see Ch. 4). This contribution focuses on understanding the aggregate effects of individual learning trajectories from the available, fragmented, and disparate actualisations of these trajectories in the archaeological record.

Naturally, more work remains to be done. Both to understand developments in ceramic technology (see Ch. 11) and to further enhance the tools at our disposal. Such work will contribute both to understanding the specific events in the third millennium BCE, and to the history of knowledge as a whole.

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Appendices

All Appendices are publicly available in the online repository DANS Data Station Archaeology under: https://doi.org/10.17026/AR/FAXIOW.

This includes the following materials:

- Appendix A: Radiocarbon Dates;
- Appendix B: Site Information;
- Appendix C: Macroscopy Data;
- Appendix D: Photographic Documentation;
- Appendix E: Petrographic Data;
- Appendix F: Simulation;
- High resolution versions of all Figures;
- Code discussed in Ch. 4.

Nederlandstalige Samenvatting

Serieleerlingen: Interacties tussen Westelijke Trechterbeker- en Enkelgrafgemeenschappen in Nederland gedurende het Derde Millennium voor Christus Bezien vanuit Aardewerktechnologie

Inleiding

Het derde millennium voor Christus (3000-2000 v. Chr.) staat in het teken van migraties in Europa. Waar men zich Europa in het vierde millennium voor Christus voorstelt als een lappendeken van lokale groepen met eigen grafgebruiken en aardewerk, verspreidt zich tussen 3050-2900 v. Chr. een pakket van typische grafrituelen en met touwindrukken versierd aardewerk van Rusland tot Nederland. Archeologen hebben deze migrerende groepen naar hun typische aardewerk vernoemd: *Corded Ware*.

Recent onderzoek toont aan dat deze migratie samenhangt met historische veranderingen in genetisch materiaal, taal en interactienetwerken die tot op de dag van vandaag merkbaar zijn in Europa. Welke interacties tussen inheemse en migrerende groepen resulteerden in zulke drastische veranderingen? Was er sprake van een gewelddadige verovering zoals tijdens de Europese kolonisatie van Amerika, of juist van een geleidelijk proces? Dat is het cruciale vraagstuk voor het derde millennium v. Chr. en dit proefschrift. Een vraagstuk dat meer dan ooit relevant is nu migratie en de beeldvorming over migratie hoog op politieke agenda's staan.

Dit onderzoek benadert deze migratie vanuit de maakwijze van het typische *Corded Ware*-aardewerk (ca. 2975-2375 v.Chr.) en het aardewerk van de in Nederland inheemse Trechterbekergroepen (ca. 3700-2675 v. Chr.). Het maakproces van aardewerk is een zgn. *chaîne opératoire*, een sequentie van technische handelingen die een bepaalde syntax volgt. Deze handelingen zijn volledig aangeleerd. Een nauwgezette studie van de *chaîne opératoire* kan dus een perspectief bieden op de interacties tussen migranten en inheemse groepen dat gebaseerd is op kennisoverdracht in het verre verleden. Dit biedt een alternatieve invalshoek die verder gaat dan het problematische hokjesdenken in de gebruikelijke cultuurhistorische aanpak.

Kader

Als we het cultuurhistorische denken in groepen loslaten, ontstaat er een ander beeld van het tijdspad voor de interacties tussen inheemse en migrerende groepen in Nederland. Een Bayesiaanse analyse van de absolute dateringen uit gesloten grafcontexten op Trechterbeker- en *Corded Ware*-vindplaatsen laat zien dat de typische grafriten van inheemse groepen voorkomen tot ca. 2675 v. Chr., meerdere eeuwen na de aankomst van migrerende groepen rond ca. 2975 v. Chr. Er zijn weliswaar veranderingen in Trechterbekergrafritueel, zoals een groeiende voorkeur voor crematie van de dode, maar diezelfde grafgebruiken zijn al zichtbaar voor aankomst van migrerende groepen. Het beeld van een snelle, mogelijk gewelddadige, omslag tussen inheemse en migrerende groepen gaat dus niet op. In plaats daarvan bestaan deze gemeenschappen waarschijnlijk lange tijd naast elkaar in Nederland. Andere studies tonen een soortgelijke overlap aan in Duitsland, Polen en Scandinavië. Migrerende en inheemse groepen leefden dus overal in Europa lange tijd naast elkaar.

Hoe moeten we zo'n lange periode van co-existentie onderzoeken? Zoals gezegd staat in dit onderzoek het leren van aardwerktechnologie centraal. Antropologisch en etnografisch onderzoek tonen aan dat pottenbakkers niet slechts één manier kennen om aardewerk te maken, maar beschikken over een repertoire van technieken dat gedurende hun hele leven verandert. Een pottenbakker kan vele verschillende *chaînes opératoires* maken door deze technieken te combineren. Het leren van deze technieken overschrijdt zelfs etnische, linguïstische en sociaaleconomische grenzen. Daarom stel ik het leerproces en variabiliteit in aardewerktechnologie centraal. Het doel is een corpus van Trechterbeker- en *Corded Ware*-aardewerk samen te stellen dat representatief is voor de variatie uit talloze technische repertoires. De vraag is dan niet of die twee corpora al dan niet verschillen, maar of de variatie in één corpus voort zou kunnen komen uit alternatieve keuzes in het andere.

Het beantwoorden van deze vraag vergt een nieuwe manier om aardewerkproductie te vergelijken. In dit onderzoek wordt daarom een dergelijke vergelijkingsmethode ontwikkeld door de *chaîne opératoire*-aanpak te combineren met netwerkanalyse en kansberekening. De *chaîne opératoire*-aanpak ziet een productieproces als een opeenvolging van technische handelingen die een bepaalde syntax volgt. Netwerkanalyse biedt de mogelijkheid alle mogelijke opeenvolgingen van die technische handelingen in kaart te brengen in een netwerk, de totale *chaîne opératoire*. Dit impliceert dat alle mogelijke productieprocessen voor een specifieke pot bestaan als een pad door dit netwerk, samen met talloze alternatieve paden. We kunnen dit netwerk dus gebruiken om twee sets paden, bijvoorbeeld voor Trechterbeker- en *Corded Ware*-aardewerk, te vergelijken als alternatieve routes door dezelfde ruimte.

Vervolgens wordt een methode uit de kansberekening toegepast voor deze vergelijkingen. Deze methode is de *Wasserstein distance*. Dit algoritme bepaalt hoeveel alternatieve keuzes in combinaties van productietechnieken er minimaal nodig zijn om set één te veranderen in set twee. Het grote voordeel van deze vergelijkingsmethode zijn de kwantitatieve, toetsbare resultaten. Bovendien sluit kansberekening nooit uit dat pottenbakkers in het verleden geheel nieuwe technieken leerden en toepasten. Alleen wordt de kans dat pottenbakkers met vergelijkbare technische repertoires twee verschillende *chaînes opératoires* gemaakt hebben kleiner naarmate er meer verschillende keuzes zijn en meer nieuwe technieken aangeleerd moeten worden.

Resultaten

De centrale opgave in dit proefschrift is het in kaart brengen en vergelijken van de diversiteit in aardewerktechnologie voor Trechterbeker- en *Corded Ware*-aardewerk. Voor dit doel reconstrueer ik de *chaînes opératoires* van 187 stuks Trechterbeker-aardewerk en 89 stuks *Corded Ware*-aardewerk uit grafcontexten verspreid door Nederland. Grafcontexten leveren relatief goed bewaard aardewerk op, hetgeen gunstig is voor de reconstructies en vergelijkingen. Door aardewerk van meerdere vindplaatsen te bekijken, kan voorkomen worden dat een lokaal of regionaal productieproces de uitkomsten van de vergelijkingen vertekent. Het reconstrueren van de *chaînes opératoires* zelf gebeurt door middel van macroscopische en petrografische analyse van het aardewerk.

Naast deze gereconstrueerde *chaînes opératoires* maakt het onderzoek ook gebruik van vier controlegroepen. De eerste controlegroep bestaat uit willekeurig gegenereerde paden. De andere drie controlegroepen zijn gegenereerd in het netwerk op basis van informatie over de maakwijze van aardewerk in twee prehistorische groepen en één moderne groep. Deze controlegroepen maken het mogelijk te evalueren hoe uitzonderlijk eventuele verschillen en overeenkomsten tussen Trechterbeker- en *Corded Ware*-aardewerk zijn.

De eerste prehistorische controlegroep bestaat uit *chaînes opératoires* van de Vlaardingengroepen, die naast Trechterbekergroepen de inheemse bevolking van Nederland vormden tijdens en voor het derde millennium v. Chr. De tweede prehistorische controlegroep bestaat uit *chaînes opératoires* van de aan Nederlandse Trechterbekergroepen verwante Noordelijke Trechterbekergroep. Tot slot is er ook nog een controlegroep met productieprocessen van pottenbakkers in hedendaags India om een vergelijking te kunnen maken met een volledig vreemd productieproces.

De vergelijkingen tussen de gereconstrueerde *chaînes opératoires* en de controlegroepen resulteren in zes cruciale bevindingen.

Ten eerste zien we dat alle pottenbakkers in het Midden en Laat Neolithicum, dus inclusief prehistorische controlegroepen, inheemse Trechterbekergroepen en migrerende *Corded Ware*-groepen, grotendeels hetzelfde productieproces geleerd en beoefend hebben. Dit productieproces begint met de opbouw van de pot door een bodem te modelleren, gevolgd door opbouw van de wand met kleirollen, secundair vormgeven door druk uit te oefenen met de handen, het afmaken van het oppervlak terwijl het nat is, gevolgd door verschillende decoratietechnieken, het drogen van de pot naar een lederharde consistentie, het toepassen van verscheidene vormen van oppervlakteafwerking, drogen naar een droge consistentie en tot slot het bakproces. Opvallend is dat dit maakproces het meest lijkt op de manier waarop jager-verzamelaars in het Vroege Neolithicum aardewerk produceerden en dus niet, zoals nu algemeen wordt aangenomen, op aardewerkproductie van de eerste boerensamenlevingen in Europa. Aardewerkproductie, één van de onderscheidende kenmerken van Neolithische samenlevingen in Noordwest-Europa, heeft mogelijk weinig met het Neolithicum van doen.

Ten tweede wijzen de vergelijkingen uit dat er een standaardisatieproces plaatsheeft in Trechterbekeraardewerkproductie. Het Trechterbekeraardewerk van voor ca. 2925 v. Chr., en met name dat uit hunebedden, vertoont een grote diversiteit aan (combinaties van) versieringstechnieken, werktuigen voor het maken van versiering en oppervlakteafwerking. Er zijn allerlei combinaties van decoratie d.m.v. simpele impressies, simpele incisies, uitsnijdingen en incrustatie en oppervlakteafwerkingen zoals polijsten, gladden en roken. Tijdens het derde millennium v. Chr. kozen pottenbakkers echter stelselmatig voor één specifieke *chaîne opératoire* met weinig versiering, meestal door middel van simpele impressies met één specifiek werktuig, gevolgd door polijsten. Dit proces begint al voor te komen in vlakgraven uit het vierde millennium v. Chr. en de start van het derde millennium v. Chr., maar is alomtegenwoordig daarna. Het lijkt er dus op dat Trechterbekeraardewerkproductie in Nederland een standaardisatie doormaakte.

Ten derde zijn er significante overeenkomsten tussen dit gestandaardiseerde productieproces en aardewerkproductie in inheemse Vlaardingengroepen. Trechterbeker- en Vlaardingengroepen worden doorgaans als aparte bevolkingsgroepen gezien die grotendeels langs elkaar leefden nadat Trechterbekergroepen vanuit Scandinavië naar Nederland migreerden rond 3700 v. Chr. Deze studie wijst uit dat de maakwijze van het Trechterbekeraardewerk van vóór ca. 2925 v. Chr. inderdaad relatief meer lijkt op het productieproces van potten uit Noordelijke Trechterbekergroepen, maar relatief minder op dat van Vlaardingenaardewerk. Het tegenovergestelde is echter waar voor het gestandaardiseerde Trechterbekeraardewerk dat ná ca. 3000 v. Chr. gemaakt is, en deze omslag is al terug te zien in een deel van het Trechterbekeraardewerk van voor die tijd. Deze resultaten wijzen erop dat pottenbakkers in Vlaardingen- en Trechterbekergroepen niet langs elkaar heen leefden maar kennis uitwisselden en dat deze kennisuitwisseling bijdroeg aan het ontstaan van een vergelijkbare *chaînes opératoires* waarbij versiering schaars is en aardewerk intensief gepolijst wordt. Mogelijk droeg deze ontwikkeling zelfs bij aan de toenemende regionalisering van Trechterbekergroepen in Europa.

De vierde uitkomst wijst op de continuïteit van inheemse bevolkingen tijdens het derde millennium v. Chr. De grafgebruiken van inheemse Trechterbekergroepen lopen door tot ca. 2675 v. Chr. (zie boven). De *chaînes opératoires* van het aardewerk in die bovengenoemde crematiegraven tonen sterke gelijkenis met Trechterbekeraardewerk uit eerdere periodes. Deze gelijkenis bestaat onder andere uit dezelfde selecties van en bewerkingen op de klei en magering en het gebruik van vergelijkbare procedures, werktuigen en technieken. Deze pottenbakkers kenden het productieproces van ouder Trechterbekeraardewerk tot in de kleinste details en kozen ervoor hierop voort te borduren. Het is dus zeer waarschijnlijk dat zij in de leer zijn geweest bij de pottenbakkers die het oudere Trechterbekeraardewerk hebben vervaardigd. Daarnaast zien we dat gelijksoortige grondstofkeuzes en grafriten tegelijkertijd in Duitsland verschijnen. Dit spreekt het verdwijnen van inheemse groepen na 2900 v. Chr. in deze regio's tegen. Het is veel waarschijnlijker dat deze gemeenschappen nog steeds in deze gebieden leefden en kennis aan elkaar overdroegen, hetgeen resulteerde in die vergelijkbare productieprocessen en grafriten.

De vijfde uitkomst van dit onderzoek gaat over de maakwijze van Trechterbeker- en *Corded Ware*-aardewerk. Er zijn significante overeenkomsten in de maakwijze van deze twee groepen aardewerk. Zo zijn de verschillen tussen Trechterbeker- en *Corded Ware*-aardewerk kleiner dan die tussen Trechterbekeraardewerk uit Nederland en Scandinavië. Dit wijst erop dat de pottenbakkers in migrerende gemeenschappen een *chaîne opératoire* geleerd hebben die sterk lijkt op die van inheemse groepen. Toch is het onwaarschijnlijk dat ze deze kennis ook daadwerkelijk geleerd hebben van gelijktijdige Trechterbekergroepen in Nederland. Als we kijken naar de *chaînes opératoires*, zien we namelijk subtiele verschillen in de procedures, werktuigen, grondstoffen en voorkeuren voor technieken. Het leren van deze subtiele aspecten vergt fysieke aanwezigheid bij het productieproces. Dit verschil is niet zwart-wit: er is wel degelijk *Corded Ware*-aardewerk dat bijvoorbeeld dezelfde gestandaardiseerde *chaîne opératoire* of keuzes in grondstoffen vertoont als gelijktijdig Trechterbekeraardewerk. Opvallend genoeg geldt het tegenovergestelde niet: de pottenbakkers die Trechterbekeraardewerk maakten bleven vasthouden aan hun eigen gebruiken. Migrerende groepen kwamen dus Nederland binnen met kennis over aardewerkproductie die weliswaar vergelijkbaar was met die van inheemse pottenbakkers, maar ook subtiel verschilde. Daarnaast zien we dat de migrerende groepen het maakproces van inheemse pottenbakkers wel geleerd lijken te hebben, maar niet omgekeerd.

Dat brengt ons bij de laatste bevinding in dit proefschrift. Waar hebben de pottenbakkers in migrerende groepen hun kennis vandaan? De vergelijkingen wijzen uit dat dit waarschijnlijk een andere Trechterbekergroep (of geaffilieerde groep) in Centraal-Europa was die niet dezelfde standaardisatie doormaakte als de Trechterbekergroepen in Nederland. Er zijn geen *chaînes opératoires* bekend van deze groepen, maar studies wijzen wel op overeenkomsten in de cruciale technieken voor versiering en materiaalkeuze. Bovendien lijkt het typische *Corded Ware*-grafritueel eveneens gebaseerd te zijn op een combinatie van de grafgebruiken van de voorouders van migrerende groepen op de Euraziatische steppe en deze zelfde Trechterbekergroepen in Centraal-Europa. Deze studie wijst dus uit dat migrerende groepen op verscheidene momenten leerden van inheemse groepen die ze tegenkwamen en die kennis aanwendden binnen hun eigen typische grafriten en aardewerkproductieproces.

Synthese en Conclusie

Wat zeggen deze patronen in aardewerktechnologie over de interactie tussen migrerende en inheemse groepen tijdens het derde millennium v. Chr.? Er zijn twee belangrijke conclusies op basis van de bovenstaande bevindingen.

De eerste conclusie is dat er geen abrupte onderbreking of verdwijning van inheemse groepen plaatsheeft met de aankomst van migrerende groepen rond 2975 v. Chr. De typische grafrituelen en aardewerkproductie van de Trechterbekergroepen worden tot ca. 2675 v. Chr. geleerd en beoefend. Uiteraard zijn er veranderingen in zowel het aardewerk (de bovengenoemde standaardisatie) als de grafriten (bijvoorbeeld de nadruk op crematies), maar deze veranderingen zijn al zichtbaar voor ca. 2975 v. Chr. Beide elementen zijn relevant omdat het maken van aardewerk en het uitvoeren van een begrafenisritueel gedetailleerde kennis vergt die wordt opgedaan door in de praktijk mee te draaien met ervaren mensen. Het bestaan van deze continuïteit in productietechnieken en grafriten wijst er dus op er in de eerste helft van het derde millennium v. Chr. nog steeds gemeenschappen waren die deze kennis in huis hadden, beoefenden en doorgaven. Het feit dat grafrituelen en materiaalkeuze voor aardewerk in deze periode ook nog steeds sterk op elkaar lijken in Nederland en Duitsland wijst er daarnaast ook op dat dezelfde informatie-uitwisselingsnetwerken die we in het vierde millennium v. Chr. herkennen als Trechterbeker ook in de eerste helft van het derde millennium v. Chr. doorlopen.

Nederland is geen uitzondering wat dit betreft: er zijn gelijksoortige observaties zijn voor inheemse groepen in andere delen van Nederland, Duitsland, Polen, Denemarken en Zweden. Dit betekent dat inheemse en migrerende groepen overal in Europa naast elkaar bestonden. Het scherpe contrast dat we zien tussen inheemse en migrerende groepen in taal, genetica en materiële cultuur ontstaat doordat we deze juxtapositie tot nog toe niet herkenden en deze inheemse groepen als ouder dan migrerende groepen beschouwden.

De tweede conclusie werpt een nieuw licht op de migrerende groepen. Nu wordt veelal een beeld geschetst waarin migrerende groepen een dominante rol hebben: inheemse groepen nemen hun cultuur over of verdwijnen (al dan niet op gewelddadige wijze). Deze studie toont echter aan dat het juist de migrerende groepen zijn die op verscheidene punten in hun geschiedenis aardewerktechnieken aanleerden van de inheemse groepen die ze tegenkwamen, zonder dat de laatste hierbij verdwenen. Hetzelfde lijkt bovendien te gelden voor grafriten. Deze aangeleerde kennis werd door de migranten ingepast om de materiële nalatenis te creëren die wij nu als typisch *Corded Ware* bestempelen. Er is dus geen sprake van een geschiedenis van geweld, maar van een geschiedenis van kennisoverdracht.

English Summary

Serial Learners: Interactions between Funnel Beaker West and Corded Ware Communities in the Netherlands during the Third Millennium BCE from the Perspective of Ceramic Technology

Introduction

The third millennium BCE is a period of migrations in Europe. Europe during the fourth millennium BCE is seen as a patchwork of local groups with their own funerary rites and ceramics. However, these practices rapidly disappear as a single set of burial rites and typical cord-decorated ceramics rapidly spreads in the area from Russia to the Netherlands around 3050-2900 BCE. Archaeologists named these migrating groups after their typical ceramics: Corded Ware.

Recent studies show this migration coincides with historic changes in genomes, languages, and interaction networks; changes which remain visible in Europe to date. What interactions between migrating and indigenous communities resulted in such drastic changes? Was there a violent conquest, similar to the European colonisation of the Americas, or a more gradual process? This is the pivotal question in the debate about the third millennium BCE and in this dissertation. A question which is more relevant than ever now that migration and ideas about migration top political agendas.

This study approaches the above-mentioned migration by comparing the fashioning of those typical Corded Ware vessels (ca. 2975-2375 BCE) to the fashioning of vessels from Funnel Beaker West groups (ca. 3700-2675 BCE) which were indigenous in the Netherlands. The fashioning of vessels is a so-called *chaîne opératoire*: a sequence of technical actions which follows a syntax. These techniques and their ordering are learned knowledge. Therefore, a detailed study of these *chaînes opératoires* can shed light on the interactions between migrating and indigenous communities by tracing learning in the distant past. This perspective also offers an alternative to the problematic categorisations of people by pots in the common culture-historical approach.

Framework

If we let go of the culture-historical classifications, a different image emerges of the duration of the interactions between migrating and indigenous groups in the Netherlands. A Bayesian analysis of the absolute dates from closed Funnel Beaker West and Corded Ware funerary contexts shows the typical burial rites of the indigenous groups continue to be practiced until ca. 2675 BCE, several centuries after the arrival of migrating groups around 2975 BCE. Naturally, changes do occur in Funnel Beaker West burial rites, such as a higher frequency of cremation burials, but these same practices can be seen in burials which predate the arrival of migrating communities. As such, the notion of a fast, possibly violent replacement of indigenous communities by migrating groups does not follow. Instead, migrating and indigenous communities probably lived side-by-side in the Netherlands for several centuries. Similar overlaps are attested in Germany, Poland, and Scandinavia. Therefore, migrating and indigenous groups co-existed throughout Europe.

How to study such a long co-existence? As said, learning of ceramic technology is crucial in this dissertation. Anthropological and ethnographic studies show potters' knowledge is not limited to a single technical tradition, but is a repertoire which encompasses many different techniques learned throughout a lifetime. Potters can produce many different *chaînes opératoires* by combining these techniques. Learning processes can also cut across ethnic, linguistic, and socio-economic boundaries. Therefore, variability in ceramic technology is crucial. The aim of this study is to construct a body of Funnel Beaker West and Corded Ware vessels which is representative of the variation in the countless technical repertoires behind them. The question then is not whether two such bodies differ, but whether the variation seen in one body can be explained as a set of alternative choices in the other.

This approach also requires new methods to compare ceramic technology. As such, a new comparative method is developed in this study by combining the *chaîne opératoire* approach with network analysis and probability theory. The *chaîne opératoire* approach envisions a production process as a sequence of techniques ordered according to a syntax. Network analysis enables one to map all possible sequences of techniques in the form of a network: the total *chaîne opératoire*. This implies all possible production processes for ceramics exist in this network as a specific path, together with countless other alternative paths. Therefore, we can use this network to compare different paths, for example from Corded Ware and Funnel Beaker West ceramics, as alternative routes through the same space.

A metric from probability theory, the Wasserstein distance, is then applied to compare these sets of paths. This measure determines the minimum number of alternative choices in combinations of production techniques needed to transform one set of paths into the other. The advantage of this method lies in the quantitative, verifiable result. Moreover, the Wasserstein distance never excludes the possibility that potters in the past learned and applied a completely new production process. However, the chance of two potters with comparable technical repertoires making two different production processes grows smaller as more different techniques need to be learned or chosen to perform this process.

Results

The central aim in this dissertation is mapping and comparing the diversity in ceramic technology for Funnel Beaker West and Corded Ware ceramics. To this end, 187 *chaînes opératoires* have been reconstructed from Funnel Beaker West vessels and 89 from Corded Ware vessels. All ceramics stem from funerary contexts which were found on multiple sites spread throughout the Netherlands. Funerary contexts yield relatively well-preserved ceramics which is optimal for the reconstructions and comparisons of ceramic technology. By taking ceramics from multiple sites, a potential bias due to regional variations in ceramic technology is avoided. The reconstruction of *chaînes opératoires* is done through macroscopic and petrographic analyses.

Apart from the reconstructed *chaînes opératoires*, four control groups are also used in the comparisons. The first control group consists of paths through the total *chaîne opératoire* which were randomly generated. The other three control groups have been generated on the basis of information about ceramic production in two prehistoric groups and one modern group. These control groups enable an evaluation of how exceptional the differences and similarities between Funnel Beaker West and Corded Ware ceramics are.

The first prehistoric control group consists of *chaînes opératoires* from indigenous Vlaardingen communities, which inhabited the Netherlands together with Funnel Beaker West groups prior to and during the third millennium BCE. The second prehistoric control group consists of *chaînes opératoires* from Funnel Beaker North groups. These groups are thought to be closely related to Funnel Beaker West. The last control group is based on ceramic production processes in contemporary India, so as to have a comparison with a production process which is alien to Europe in the third millennium BCE.

The comparisons between these reconstructed *chaînes opératoires* and control groups resulted in six key observations.

Firstly, all prehistoric potters from the Middle and Late Neolithic, which includes the prehistoric control groups, Funnel Beaker West, and Corded Ware, appear to have learned and used a highly similar production method. This method involves the use of modelling to rough out the vessel bases, followed by the use of coiling for the vessel walls, preforming through pressure with hands, and finishing by smoothing wet clay. Various decorative techniques are then applied, followed by drying the vessel to a leather-hard consistency, applying various surface treatments, drying to dry consistency, and finally firing. Interestingly, this production method best resembles that associated with hunter-gatherer ceramic production prior to and during the Early Neolithic, and not, as is commonly assumed, ceramic production among early farming groups. Ceramic technology, one of the hallmarks of Neolithic societies in Northwest Europe, may have little to do with the Neolithic.

Secondly, the comparisons point to a gradual standardisation process in Funnel Beaker West ceramic production. Ceramics made prior to ca. 2925 BCE, and especially those found in megaliths, exhibit great diversity in (combinations of) decorative techniques, tools to apply these techniques, and surface treatment. Various combinations of decorations with simple impressions, simple incisions, excisions, and incrustation appear as well as surface treatments such as burnishing, shining, and smudging. However, the potters who made Funnel Beaker West vessels during the third millennium BCE systematically opted to use one specific *chaîne opératoire*. This production process featured sparse decoration, usually through simple impressions with one specific tool, and extensive burnishing. This production process already appears in vessels from flat graves from the fourth millennium BCE but is omnipresent after this point. Therefore, Funnel Beaker West ceramic production in the Netherlands appears to have become more standardised over time.

Thirdly, there are significant similarities between this standardised production process and ceramic production in Vlaardingen communities. Vlaardingen and Funnel Beaker West groups are commonly seen as separate populations which interacted little after Funnel Beaker groups migrated to the Netherlands from Scandinavia around 3700 BCE. This study shows the production process of Funnel Beaker West vessels which predate ca. 2925 BCE does indeed better resemble that of Funnel Beaker North vessels than Vlaardingen vessels. However, the opposite is true for the standardised Funnel Beaker West vessels made after ca. 3000 BCE, and this change already appears in those earlier vessels. This means potters in Vlaardingen and Funnel Beaker West communities probably did interact and learn from each other. This exchange of knowledge resulted in the appearance of a shared *chaîne opératoire* with sparse decoration and intensive burnishing. It may also have contributed to the increasing regionalisation of Funnel Beaker groups across Europe.

Furthermore, this study points to continuity of indigenous groups during the third millennium CE. The funerary rites of the indigenous Funnel Beaker West communities continue to be practiced until ca. 2675 BCE (see above). In addition, the *chaînes opératoires* of the vessels used in these funerary rites show strong resemblance to those of Funnel Beaker West ceramics from the fourth millennium BCE. This resemblance encompasses, among others, a similar selection and preparation of clays and tempers, and the use of similar technical procedures, tools, and techniques. These potters knew the ceramic production process from older Funnel Beaker West vessels in minute detail and chose to continue it. Therefore, it is highly likely they learned their craft from the potters who fashioned these older Funnel Beaker West vessels. Moreover, these practices in funerary rites and choices in raw materials are not isolated to the Netherlands but also appear simultaneously in Germany. This outcome contradicts the idea that indigenous groups disappear shortly after the start of the third millennium BCE. It is more likely these communities still inhabited these areas and exchanged knowledge which resulted in those comparable production processes and burial rites.

The fifth outcome of this study is the existence of substantial similarities between Funnel Beaker West and Corded Ware ceramic production processes. These similarities are greater than (f.e.) the similarities between Funnel Beaker ceramics in the Netherlands and Scandinavia. This shows the potters in migrating communities learned a *chaîne opératoire* akin to that used by potters in indigenous groups. However, it is unlikely they learned it from contemporaneous indigenous potters in the Netherlands. This is due to the subtle differences in technical procedures, tools, raw materials, and preferences for techniques. Learning such subtle aspects of ceramic production would result from physical presence during a production process. However, the distinction is not absolute: there are Corded Ware vessels which follow the standardised *chaînes opératoires* and choices in raw materials seen in Funnel Beaker West ceramics. Interestingly, the opposite is not true: the potters who made Funnel Beaker West ceramics continued to apply the standardised production process. Therefore, migrating groups arrived in the Netherlands with knowledge about ceramic production which was comparable to that of indigenous potters but differed in a few subtle respects. In addition, the potters who made Corded Ware vessels appear to have learned from indigenous potters in the Netherlands, but not vice versa.

This brings us to the last result of this study. Where did potters in migrating communities obtain this technical knowledge? The comparisons show Funnel Beaker(-affiliated) groups in Central Europe which did not go through the same standardisation process as Funnel Beaker West are the most probable source for this knowledge. No *chaînes opératoires* of vessels from these groups are known but studies do point to similarities in the crucial decorative techniques and choices for raw materials. Moreover, the typical Corded Ware funerary rites are also thought to be a combination of the funerary rites practiced by the ancestors of migrating groups on the Eurasian steppe and funerary rites in Central European Funnel Beaker groups. Therefore, this study shows migrating groups learned from the indigenous groups they encountered at various points and applied this knowledge within their own burial rites and ceramic production.

Synthesis and Conclusion

What do these patterns in ceramic technology tell us about the interactions between migrating and indigenous communities during the third millennium BCE? Two key conclusions can be drawn from the results presented above.

Firstly, there was no abrupt discontinuity or disappearance of indigenous groups with the arrival of migrating groups around 2975 BCE. The typical funerary rites and ceramic production processes of Funnel Beaker West groups continue to be learned and used until ca. 2675 BCE. Naturally there are changes, both in the ceramic production process (the standardisation mentioned earlier) and the burial rites (such as the increase of cremation burials) but these changes are readily visible before ca. 2975 BCE. Both of these observations are relevant because learning to produce vessels or to bury the dead requires detailed knowledge which is acquired by participating in these practices together with more experienced actors. Therefore, these continuities point at the existence of communities who held, applied, and passed on this knowledge during the first half of the third millennium BCE. Furthermore, the fact that both burial rites and selection of raw materials for ceramics strongly resemble each other in the Netherlands and Germany indicates that the information exchange network which we recognise as Funnel Beaker West in the fourth millennium BCE continued to exist in the first half of the third millennium BCE.

Funnel Beaker West is not an exception in this respect. Similar conclusions have been drawn about indigenous groups in other parts of the Netherlands, Germany, Poland, Denmark, and Sweden. This means that throughout Europe, indigenous and migrating groups co-existed. The sharp contrast between indigenous groups in terms of language, genetics, and material culture seems to be caused by the fact that archaeologists so far did not recognise this juxtaposition and considered indigenous groups as being older than migrating groups.

The second conclusion is about the migrating groups. Currently, these migrants are thought to have a dominant role: indigenous groups would either take up their culture or disappear (possibly meeting a violent end). However, this study shows the exact opposite: migrating groups are the ones who learn and copy from the various indigenous groups they encounter throughout Europe, without the latter disappearing. The material legacy, both ceramics and burials rites, which we consider to be typically Corded Ware results from migrants applying this knowledge they obtained from indigenous communities. Therefore, these migrants are not serial killers, but serial learners.

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Curriculum Vitae

Erik Jasper Kroon was born in Gouda in 1993. He graduated *cum laude* from Coornhert Gymnasium, Gouda in 2011 and went on to study archaeology at the Faculty of Archaeology, Leiden University. He obtained his Bachelor's degree in archaeology *cum laude* in 2014 with specialisations Archaeology of Northwestern Europe, Archaeological Sciences, and Computer Sciences in Archaeology. He was then accepted into the Research Master track Prehistoric Farming Communities in Northwestern Europe which he completed *cum laude* in 2016. His masters' thesis on the Corded Ware transition in the western coastal area of the Netherlands was awarded the University Thesis Award for best MA thesis from Leiden University in 2017 and nominated for the W.A. van Es award. Erik has taught in several courses on ceramic technology and European Prehistory and has worked as a student assistant in several projects during his studies. Between 2016 and 2018, he was employed as data analyst in the NWO project *Economies of Destruction* (Leiden University) and as Finds Advisor Prehistory in the NWO project *Portable Antiquities of the Netherlands* (Free University of Amsterdam). In 2018, he obtained a NWO grant from the PhDs in the Humanities scheme to conduct his PhD research as member of the group European Prehistory at the Faculty of Archaeology, Leiden University. The results of this study are published in this book. Erik is currently employed as a researcher in the NWO project *The Talking Dead* at Leiden University. Some of his long-standing research interests are the *chaîne opératoire* approach, ceramic technology, network analysis, the Late Neolithic in Northwest Europe, and Corded Ware.