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The introduction of Corded Ware Culture at a local level: An exploratory study of cultural change during the Late Neolithic of the Dutch West Coast through ceramic technology

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ABSTRACT

The introduction of the Corded Ware Culture (3000–2500 BCE) is considered a formative event in Europe's past. Ancient DNA analyses demonstrate that migrations played a crucial role in this event. However, these analyses approach the issue at a supra-regional scale, leaving questions about the regional and local impact of this event unresolved. This study pilots an approach to ceramics that brings this small-scale impact into focus by using the transmission of ceramic technology as a proxy for social change. It draws on ethno-archaeological studies of the effects of social changes on the transmission of ceramic production techniques to hypothesise the impact of three idealised scenarios that archaeologists have proposed for the introduction of Corded Ware Culture: migration, diffusion, and network interactions. Subsequently, it verifies these hypotheses by integrating geochemical (WDXRF), mineralogical (petrography), and macromorphological analysis of ceramics with network analysis. This method is applied to 30 Late Neolithic ceramic vessels from three sites in the western coastal area of the Netherlands (Hazerswoude-Rijndijk N11, Zandwerven, and Voorschoten-De Donk). This study concludes that the introduction of Corded Ware material culture is a process that varies from site to site in the western coastal area of the Netherlands. Moreover, the introduction of the Corded Ware Culture is characterised by continuity in technological traditions throughout the study area, indicating a degree of social continuity despite typological changes in ceramics.

1. Introduction

5000 years ago, a lasting change took place in Europe. From the Netherlands to the Baltic, highly similar funerary practices and material culture emerged from a patchwork of regional cultures. Cord-decorated ceramics are the hallmark of this new culture; Hence its name: Corded Ware Culture (CWC) (3000–2500 BCE).

Recent ancient DNA (aDNA) studies tie the spread of the CWC to a 'massive migration' from the Pontic and Caspian steppe and the introduction of Inco-European languages (principally Allentoft et al., 2015; Haak et al., 2015; Olalde et al., 2018). However, the implied discontinuity of a massive migration clashes with mounting evidence for continuity of regional communities (Beckerman, 2015; Furholt, 2014; Larsson, 2009). How do these regional narratives about continuity tie into the supra-regional narrative about migration (Cf. Furholt, 2017; Vander Linden, 2016)? The key to answering this question lies in characterising the interactions between communities that are considered to be migrating or indigenous on the basis of aDNA (Cf. Eisenmann et al., 2018); interactions which resulted in the observed genetic, linguistic and archaeological developments at a regional scale (Kristiansen et al., 2017). This study proposes that ceramic technology can shed new light on this interaction and applies this methodology to study the introduction of CWC in the western coastal area of the Netherlands.

The basis for this study is an ethno-archaeological framework that postulates relations between the transmission of ceramic production techniques and social changes (Gosselain, 2000). This framework proposes that ceramic production techniques spread, are learned, and performed in specific social contexts. Therefore, social changes that affect these contexts leave tell-tale disruptions in the transmission of

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Table 1
idealised scenarios for the introduction of CWC.

Scenario	Migration	Diffusion	Network
Mechanism behind CWC introduction	Substantial groups of people settle an area and replace existing populations, bringing a package of new techniques and practices.	Resident communities adopt a repertoire of objects and ideas from interactions with other communities, but remain otherwise unchanged.	Communities enter into long-lasting interaction networks that facilitate the spread of objects, ideas and humans among various far-flung communities. Changes in material culture result from a mixture of small scale mobility and the dissemination of new practices and objects.
Proponents (international)	(Childe, 1929; Gimbutas, 1994)	(Clarke, 1976; Sherratt, 1981)	(Larsson, 2009)
Proponents (Dutch coastal area)	(De Laet and Glasbergen, 1959)	(Louwe Kooijmans, 1976)	(Beckerman, 2015)
Hypothetical effects on ceramic technology	The ceramic production techniques of indigenous groups are no longer transmitted. This results in: 1. changes in all groups of ceramic techniques.	The spread of ceramic styles and shapes and the import of ceramics made by potters from different communities of practice results in: 1. changes in the salient ceramic production techniques; 2. the presence of objects made with different production techniques in all groups.	The spread of ceramic styles and shapes, the import of ceramics made by potters from different communities of practice as well as the integration of people from different communities of practice into existing ones results in: 1. changes in the salient ceramic production techniques; 2. the presence of objects made with different ceramic production techniques in all groups; 3. the presence of objects made according to pre-existing salient and group-related production techniques, but different resilient production techniques.

ceramic technology. Similar approaches to ceramic technology have yielded new insights regarding the introduction of Corded Ware Culture in the Baltic (Cf. Holmqvist et al., 2018; Larsson, 2009).

This study integrates macromorphological, petrographic and geochemical analysis to detect disruptions and continuities in the transmission of ceramic technology during the introduction of the CWC. The resulting overview of developments in ceramic technology is compared to the hypothesised impact of three idealised scenarios for the introduction of CWC on the transmission of ceramic technology (see Table 1). These scenarios are migration (as proposed by aDNA analysis) and two scenarios that revolve around local continuity: diffusion and network interactions (see upper part of Table 1 for specification). Note that these scenarios are idealised extremes that f.e. strictly separate change in material culture due to population mobility from change due to the spread of ideas and objects. Social processes during the third millennium BCE are likely to have involved more complex combinations of both factors. Similarly, the distinction between groups in these scenarios is a simplification: group membership is likely to have been more fluid (Furholt, 2017; Hofmann, 2015; Van Dommelen, 2014). In sum, the outlined scenarios are best seen as heuristic devices. Each scenario proposes different social processes that leave tell-tale patterns of disruptions and continuities in ceramic technology. As such, these scenarios enable a study of ceramic technology as a proxy for social change.

The target area for this study is the Western coastal area of the Netherlands (see Fig. 1). This area has unique potential for studying the

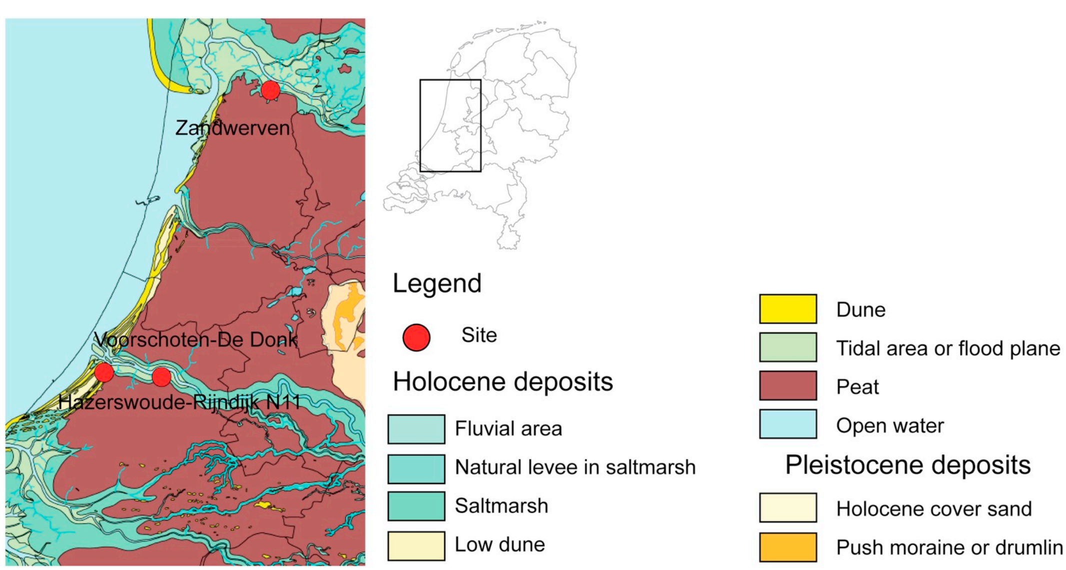

Fig. 1. Study area. Palaeogeographic map of the Netherlands around 2750 BCE (Vos and De Vries, 2013) with the locations of the sampled sites: Hazerswoude-Rijndijk N11, Voorschoten-De Donk, and Zandwerven.

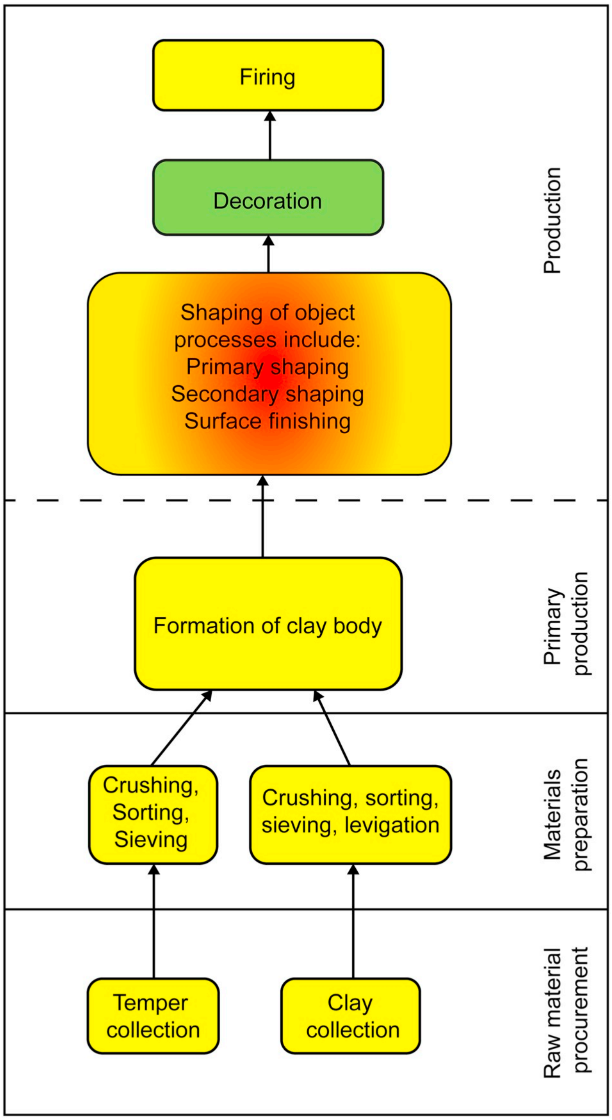

Fig. 2. Simplified *chaîne opératoire*for ceramics that indicates resilient, group-related and salient techniques (based on Gosselain, 2000; Miller, 2009; Larsson, 2009). Green indicates salient techniques, yellow group-related techniques, and red resilient techniques.

introduction of CWC, because the indigenous Vlaardingen Culture (VLC) is thought to co-exist and overlap with the CWC (Beckerman, 2015). The study area is also devoid of CWC burials that could yield material for aDNA-analyses (Fokkens, 2012; Van Gijn and Bakker, 2005), meaning that ceramics, which are ubiquitous at sites from this period, enable studies of the introduction of the CWC in areas where human remains are not preserved.

2. Theoretical framework

Archaeologists have proposed various scenarios for the introduction of the CWC; these scenarios have been abstracted to three archetypes, labelled migration, diffusion and network interactions (see Table 1). A migration scenarios entails that changes in material culture are due to the arrival of new communities in an area. These new groups replace previous communities and bring a package of new techniques and practices. A diffusion scenario holds that the introduction of new material culture results from the adaptation of objects and ideas by communities who remain otherwise unchanged. Lastly, a network interaction scenarios proposes that communities enter into a supra-regional interaction networks that facilitate the spread of humans, objects and ideas between far-flung communities. Changes in material culture result from a combination of the adaptation of new objects and ideas, as well as the impact of small scale human mobility.

Key is that each abstracted scenario for the introduction of the CWC entails a different social process. Upon connecting these different social processes to a theory about the transmission of ceramic technology (Gosselain, 2000), it becomes apparent that these scenarios should have distinct impacts on ceramic technology.

The transmission of ceramic production techniques involves three factors: (1) openness, (2) salience, and (3) technical malleability (Gosselain, 2011, 2008, 2000; Gosselain and Livingstone Smith, 2005). Based on these factors, three groups of ceramic production techniques can be distinguished, each with a different resilience to social change.

The openness of techniques relates to the social context in which techniques are learned and performed. This factor is the primary distinction between two groups of ceramic production techniques: group-related techniques and resilient techniques. Resilient techniques exhibit low openness: they are practiced in isolation and transferred in one-on-one relations. For example, between parent and child or master and apprentice. Resilient techniques include the finer motoric aspects of primary shaping (Gosselain, 2000; Larsson, 2009). Social changes have to disrupt these stable relations in order to disrupt the transmission of resilient techniques. Therefore, such disruptions are associated with migrations (Gosselain, 2000).

Group-related techniques have a high openness. These techniques are practiced, learned and taught in *communities of practice*: groups of potters who share a notion of the proper way to make ceramic vessels (Larsson, 2009). Social changes that affect these groups also disrupt the transmission of these techniques. In addition, these techniques are technically malleable, implying that potters can choose to continue or discontinue their usage of these techniques under the influence of other individuals. Group-related techniques include firing techniques, raw materials selection, extraction and preparation (Gosselain, 2000; Larsson, 2009).

The third factor that impacts the transmission of ceramic production techniques is salience. Salience implies a technique effects a visible property of the final product. Salient techniques principally include decorative techniques, but can in rare cases also pertain to the use of specific raw materials or preforming techniques that visually alter the texture or colour of the final product (Gosselain, 2000). Similar to group-related techniques, these techniques are also technically malleable. Salient techniques can be observed and copied from finished vessels. Consequently, the spread of salient techniques does not necessarily entail social changes and can be due to fashion-like phenomena (Gosselain, 2000).

The connections between changes in ceramic production techniques and social changes (see Fig. 2) allow for the formulation of hypotheses about the technological impact of the scenarios that archaeologists have proposed for the introduction of the CWC (see lower half of Table 1).

If migration (i.e. an influx of new communities that bring new material culture) causes the spread of the CWC, then CWC vessels should differ from the vessels of previous communities in all respects: resilient, group-related, and salient techniques (see Fig. 3). However, if the introduction of the CWC is the result of diffusion of stylistic traits and moving objects, both these imported objects (different raw materials and production sequences) and changes in salient techniques should be observed when comparing CWC vessels to VLC vessels (see Fig. 3). Network interactions should yield the same changes as diffusion, as the combined movement of people, objects and styles within

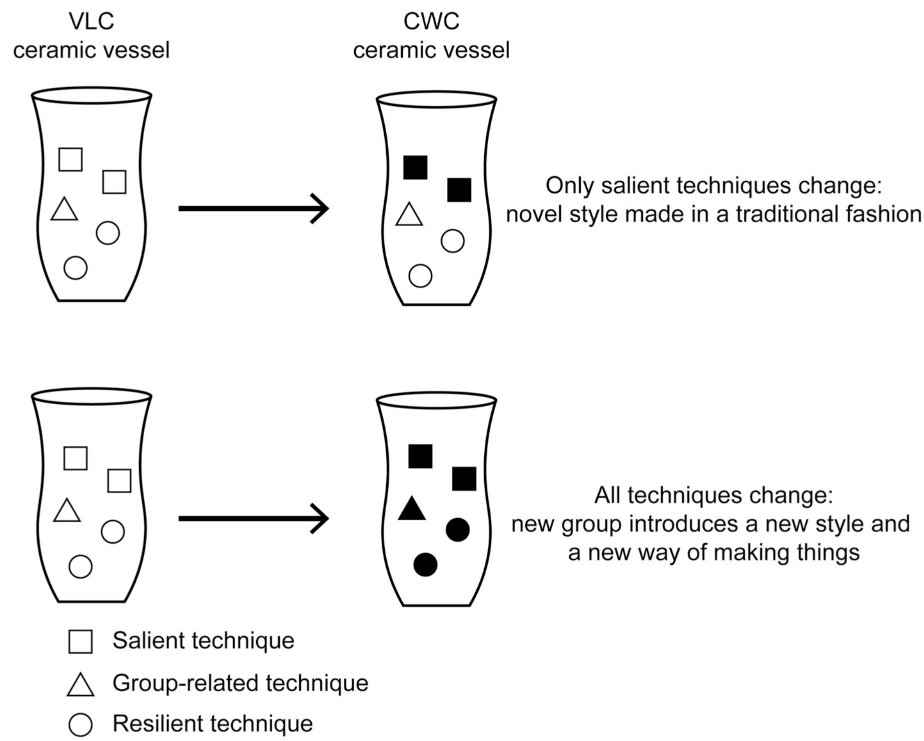

Fig. 3. Schematic representation of the hypothesised changes in ceramic technology for diffusion (above) and migration (below) scenarios for the spread of the CWC.

Table 2
Overview of information for the selected sites.

Site	Hazerswoude-Rijndijk N11	Voorschoten-De Donk	Zandwerven
Environment	Crevasse splay of the Old Rhine	Edge of dune barrier	Basis of a dune in tidal landscape
Excavation year(s)	2005; 2006	1986; 1987	1930; 1957; 1958
Dating (Cf. Beckerman, 2015)	Early VLC to SGC phase 4 (3400–2400 BCE)	Early VLC to Late CWC (3400–2200 BCE)	Middle VLC to late CWC (3100–2200 BCE)
Literature	(Diependaele and Drenth, 2010; Cf. Fokkens et al., 2017)	(van Veen, 1989; Wasmus, 2011)	(Beckerman, 2015; Butter, 1935; Drenth et al., 2008; Van Giffen, 1930; Van Regteren Altena, 1959, 1958; Van Regteren Altena et al., 1962)

existing networks leads to the introduction of CWC. However, network interactions should yield one additional characteristic. Given that new people are integrated into extant communities, the occurrence of vessels with different resilient techniques, but group-related techniques that are stable relative to previous communities, is to be expected.

The hypothesised impacts of migration, diffusion, and network interactions on ceramic technology can be compared to the actual developments in ceramic technology during the introduction of the CWC. To this end, this paper integrates macromorphological, petrographic, and geochemical analysis of VLC and CWC ceramic vessels from the western coastal area of the Netherlands.

3. Materials and methods

In total, 30 vessels from three sites were sampled for analysis. The selected sites are Voorschoten-De Donk, Zandwerven, and Hazerswoude-Rijndijk N11 (see Fig. 1). These sites are settlements that consist of thick anthropogenic deposits, in some cases interspersed by natural deposits. The sites typically yield evidence for various domestic activities, as well as the exploitation of wild and domesticated plants and animals. Moreover, these sites exhibit late VLC and CWC phases, implying they sit around the introduction of CWC (see Table 2 and further references for full information).

Each site contributed five samples from CWC vessels and five samples from VLC vessels to the total number of samples. Existing macromorphological analyses of the ceramics from each site were used to ensure that the samples reflect the variation in ceramics on the sites, and to contextualise the results of this study (Beckerman, 2015; Diependaele and Drenth, 2010; Van Veen, 1989; Wasmus, 2011).

3.1. Analytical methods

The macromorphological analysis follows a widely-used protocol in the Netherlands that is designed to study highly fragmented ceramics from settlements (Van den Broeke, 2012). For the purposes of this study, the description of the ceramics exhibits an additional focus on production techniques.

All 30 vessels were sampled for petrographic analysis. A Leica DM750P polarizing microscope was utilised to perform the analysis. Description and analysis of the thin sections were conducted according to the commonly applied system by Whitbread (Whitbread, 1995, 1989) with slight modifications (Quinn, 2013). Petrography has provided major contributions to the study of ancient ceramics because it provides crucial information on inclusions, technology, and texture (Braekmans and Degryse, 2016; Quinn, 2013). Furthermore, petrographic analysis has seen extensive application in the study of artisanal

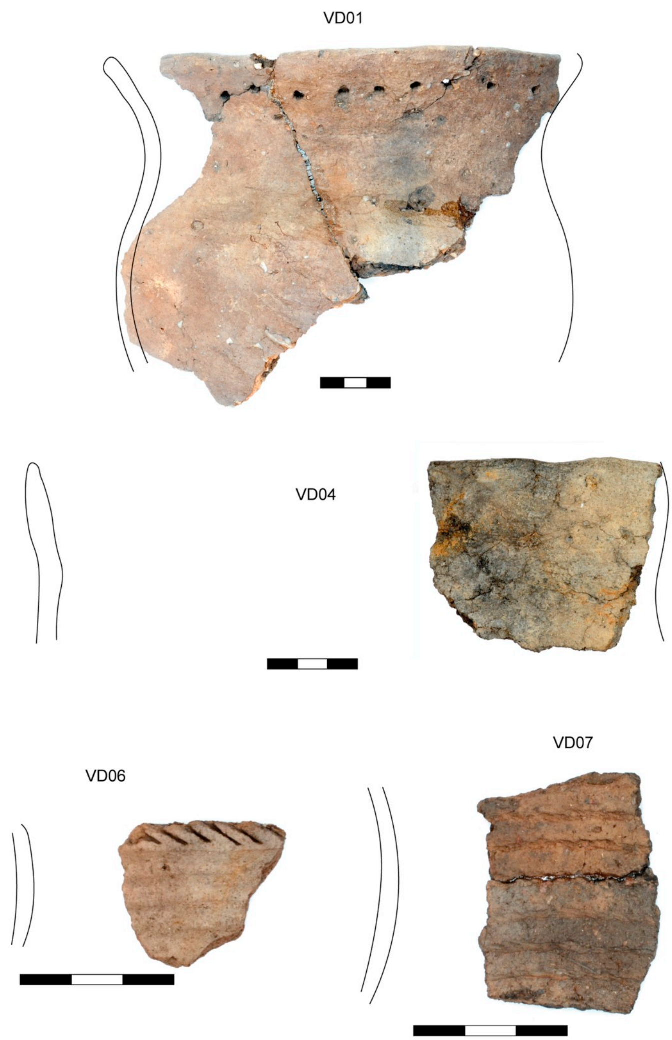

Fig. 4. Four of the sampled vessels from Voorschoten-De Donk. VD01 and VD04 are VLC vessels; VD06 and VD07 fragments of CWC vessels.

activities in the past (Dickinson and Shutler, 2000; Pincé et al., 2018; Quinn et al., 2017; Reedy, 2008; Ting and Humphris, 2017).

Geochemical characterization of the selected ceramics was employed to compare established production groups with raw material resources. A bulk chemical approach, Wavelength Dispersive X-ray Fluorescence (WD-XRF), was selected to achieve a homogeneous compositional signal from the ceramics. WD-XRF offers relative high resolution results and has been successfully employed for provenance analysis in archaeological sciences and a wide range of other fields (Hall, 2016; Janssens, 2003; West et al., 2011). All samples were powdered and oven dried at low temperature (70 °C) for at least 24 h prior to the analysis. Sample preparation involved grinding small fragments of ceramic vessels by hand in an agate mortar (~200–300 mesh), combining 2 g of the resulting powder with a binder (0.5 g H_3BO_3) and pressing the mixture into a pellet with a hydraulic press. Wavelength Dispersive X-Ray Fluorescence (WD-XRF) bulk compositional measurements were conducted at the X-ray facilities of the Materials Science and Engineering (MSE) department of the Delft University of Technology (NL). The WD-XRF instrumentation used was a Panalytical Axios Max sequential wavelength dispersive X-ray fluorescence spectrometer and data evaluation was performed with SuperQ5.0i/Omnian software. The system is equipped with a Rh anode featuring 4.0 kW operating power, 160 mA tube current, 60 kV excitation and vacuum conditions. Data was collected for the following major elements: SiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, TiO_2, CaO, P_2O_5, Na_2O, MnO (expressed as wt%); and minor elements: Ba, Zn, Zr, S, Cr, Rb, Ni, Pb, Sr, Nb, Ce, Y and Cu (expressed as ppm, or parts per million).

Quantification was obtained through a standardless factory-calibrated fundamental parameter approach (SuperQ5 software package), extended with several pure materials as well as NIST standards. For secondary quality control 17 custom in-house ceramic standards were additionally analysed. Accuracy was assessed through high-squared correlation coefficients (R^2) for a selection of major and minor elements: Al (0.93), Ba (0.99), Ca (0.99), Cr (0.99), Fe (0.97), K (0.98), Mg (0.98), Mn (0.99), Na (0.92), Ni (0.99), P (0.99), Rb (0.91), Sr (0.99), Ti (0.98), V (0.99), Zr (0.96). Zn and La provide lower coefficients: Zn (0.808) and La (0.81).

All ceramics presented here are relatively coarse and exhibit various recipes and inclusions (often coarse quartz). The nature and amount of these inclusions might influence the overall bulk geochemistry. However, previous studies of such influences (Munita et al., 2008), and specifically for quartz grains (Sterba et al., 2009), demonstrate they are limited to specific geologies and elements, such as Ba, Na, Zr, and Hf in minerals related to mafic substrates. In these cases, a combination with petrographic analyses is required to firmly address these concerns. To summarise, petrography is essential to validate the grouping based on the chemical analyses due to the coarse nature of the sampled ceramics. Some of the presented chemical values for individual samples might differ, but the differentiation between all samples is considered robust and significant.

The outcomes of the geochemical analyses were compared to earlier WD-XRF analyses of Dutch subsoils from ca. 103 locations throughout the Netherlands (Huisman, 1998). This dataset (along with contextual information) is available in open access www.dinoloket.nl.

3.2. Network analysis

The aim of the study is to look at the transmission of ceramic technology: are technological actions shared or not shared between vessels across the typological boundary between VLC and CWC? This question implies a study of the relations between vessels rather than a study of the properties of individual vessels. As such, technological data is studied from a relational perspective. Network analysis is best suited to explore relational data (Newman, 2010).

Network analysis revolves around graphical and mathematical representation and analysis of relations in a dataset. These relations amount to structures and properties of the dataset that cannot be discerned at the level of individual observations (Newman, 2010). In particular, this study utilises the concept degree centrality to explore shared technological actions. Degree centrality is an analytical tool within network analysis that ranks nodes (observations) by the number of ties (relations) they exhibit to other nodes. The more ties a node has, the more central its role in the network (Newman, 2010). In this case, the more ties a technique has to vessels, the more often this particular technique was utilised in the production process. Therefore, the degree centrality is informative for understanding the extent to which specific techniques are shared.

4. Results

Prior to the presentation of the results, it is worthwhile to outline the typological and technological traits associated with VLC and CWC ceramics (see Fig. 4). Based on these traits, each vessel has been classified as CWC or VLC vessel (see Table 3).

VLC vessels are typically thick-walled and vary in form from barrel-

Table 3
outcomes to the macromorphological analysis.

Sample	Trimming of vessel walls	Rim finishing	Vessel walls smoothed on the inside	Vessel walls smoothed on the outside	Exterior of the vessel is roughened	Decoration with impressions	Perforations in the vessel wall	Firing atmosphere	Typological classification
HA01	No	Indet	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
HA02	No	Indet	No	Yes	No	Indet	Yes	Vessel rapidly cooled while in upside-down position	VLC
HA03	No	Indet	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
HA04	No	Equal pressure on all sides	Yes	Yes	No	Cord impressions	No	Fully oxidising firing atmosphere	CWC beaker
HA05	Yes	Indet	Yes	Yes	No	Cord impressions	No	Fully oxidising firing atmosphere	CWC beaker
HA06	No	Indet	Yes	Yes	No	Cord impressions	No	Vessel rapidly cooled while in upside-down position	CWC beaker
HA07	Yes	Pressure on inside	No	No	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
HA08	Yes	Indet	No	Yes	No	Cord impressions	No	Vessel rapidly cooled while in upside-down position	CWC beaker
HA09	No	Indet	Yes	Yes	No	Grooved lines and incisions	No	Vessel rapidly cooled while in upside-down position	CWC beaker
HA10	No	Equal pressure on all sides	Yes	Yes	No	Finger impressions	Yes	Vessel rapidly cooled while in upright position	VLC
VD01	Yes	Pressure on outside	Yes	Yes	No	Indet	Yes	Vessel rapidly cooled while in upright position	VLC
VD02	No	Indet	No	Yes	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
VD03	Yes	Indet	No	No	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
VD04	Yes	Equal pressure on all sides	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upright position	VLC
VD05	Yes	Indet	No	No	No	Indet	No	Vessel rapidly cooled while in upright position	VLC
VD06	Yes	Indet	Yes	Yes	No	Grooved lines and incisions	No	Vessel rapidly cooled while in upright position	CWC beaker
VD07	Yes	Indet	Yes	Yes	No	Cord impressions	No	Vessel rapidly cooled while in upright position	CWC beaker
VD08	Yes	Indet	No	No	Yes	Indet	No	Vessel rapidly cooled while in upside-down position	CWC short wave-moulded ware
VD09	Yes	Pressure on inside	No	No	No	Indet	No	Firing atmosphere with insufficient oxygen for full oxideing	CWC short wave-moulded ware
VD10	Yes	Pressure on inside	Yes	Yes	No	Finger impressions	No	Fully reducing firing atmosphere	CWC short wave-moulded ware
ZA01	Yes	Equal pressure on all sides	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upside-down position	VLC
ZA02	Yes	Equal pressure on all sides	No	Yes	No	Indet	Yes	Fully reducing firing atmosphere	VLC
ZA03	No	Indet	Yes	Yes	No	Cord and spatula impressions	No	Fully reducing firing atmosphere	CWC beaker
ZA04	Yes	Equal pressure on all sides	Yes	Yes	No	Indet	Yes	Vessel rapidly cooled while in upside-down position	VLC
ZA05	No	Equal pressure on all sides	Yes	Yes	No	Grooved lines and incisions	No	Vessel rapidly cooled while in upright position	CWC beaker
ZA06	No	Pressure on inside	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upright position	VLC

(*continued on next page*)

Table 3 (*continued*)

Sample	Trimming of vessel walls	Rim finishing	Vessel walls smoothed on the inside	Vessel walls smoothed on the outside	Exterior of the vessel is roughened	Decoration with impressions	Perforations in the vessel wall	Firing atmosphere	Typological classification
ZA07	No	Equal pressure on all sides	Yes	Yes	No	Spatula impressions	Yes	Vessel rapidly cooled while in upside-down position	CWC short wave-moulded ware
ZA08	Yes	Pressure on inside	Yes	Yes	No	Indet	No	Vessel rapidly cooled while in upright position	VLC
ZA09	No	Indet	No	Yes	No	Indet	No	Vessel rapidly cooled while in upside-down position	CWC beaker
ZA10	Yes	Indet	Yes	Yes	No	Grooved lines and incisions	No	Vessel rapidly cooled while in upside-down position	CWC beaker

like to S-shaped. Typical elements also include knobs, and rows of perforations or impressions below the rim. Tempers are coarse and commonly consist of crushed rocks, such as quartz and granite, as well as grog (Beckerman and Raemaekers, 2009). CWC vessels are commonly thin-walled with S-shaped profiles. Temper materials may vary. The hallmark of these vessels is geometric decoration with grooves, cord, and spatula impressions that extends from the rim to the widest part of the vessel. Apart from thin-walled CWC beakers, there are also thick-walled CWC vessels, so-called short wave-moulded wares, which may exhibit finger and spatula impressions below the rim (Beckerman, 2015; Drenth, 2005; Van der Waals and Glasbergen, 1955).

The above description does not amount to a description of 'pristine' VLC or CWC ceramics. As shown in following paragraphs, these categories are internally heterogeneous and their mutual boundaries more diffuse.

4.1. Macromorphology

Table 3 presents the characteristics of the sampled vessels that stem from macromorphological analysis.

In general, Table 3 indicates the use of similar production techniques for VLC and CWC ceramics. Only decorative techniques seem exclusive to CWC and VLC vessels, in accordance with typological schemes. Observation of the colours of, and colour differences between, the internal margins, cores and external margins on fresh radial breaks of sherds reveal that most vessels were likely fired in upright, or upside-down, positions in a reducing firing atmosphere, with rapid cooling and oxidisation towards the end of the procedure (Cf. Rye, 1981; see Table 6). All vessels were fired at relatively low temperatures as they exhibit low hardness and optically active matrices in thin section (Cf. Quinn, 2013; see Table 6). Furthermore, CWC and VLC vessels exhibit the same traces of smoothing the inside and outside vessel walls. The pressures exerted during the formation of the rim could not be reconstructed for all vessels, but seems to vary in VLC and CWC wares.

4.2. Petrography

Detailed petrographic descriptions can be evaluated in Table 4. Five sample groups are distinguished through petrographic analysis (see Fig. 5). Most thin sections exhibit abundant temper, but groups exhibit differences in temper materials and coarseness of temper. Grouping also reflects the porosity of the matrix and the alignment of voids.

Group I: quartz rich, compact fabrics exhibit coarse temper with quartz, and rarely granite, against a dark matrix. The fine fraction frequently features angular quartz and more rarely micaceous minerals and granite. The planar voids concentrate around and between larger quartz particles.

Group II: crushed quartz fabrics are primarily characterised by coarsely crushed quartz, grog, and clay pellets. Rounded quartz frequently occurs in the fine fraction. The porosity in this group varies, but pores tend to be oriented parallel to vessel walls.

Group III: fine, grog-tempered fabrics share a compact matrix and are tempered with one or multiple types of grog. Some samples contain organic materials and sedimentary rocks. The fine fractions contain quartz, (minerals associated with) granite and sometimes isotropic minerals.

Group IV: sand-tempered porous fabrics feature temper with quartz-rich sand and less frequently sedimentary and igneous rocks. They are typically porous, giving the fabric a turmoil-like appearance. Fine fractions contain quartz, micaceous materials, and in some cases chert and olivine.

Table 4
summarised outcomes of the petrographic analysis.

Petrographic group			I: Quartz rich, compact fabric	II: Crushed quartz fabric	III: Fine grog-tempered fabric	IV: Sand-tempered porous fabric	V: Coarse grit-tempered fabric
Samples			ZA01, ZA02	HA03, HA06, HA07, HA08, HA09, HA10	HA02, HA04, VD03, VD05, ZA10	HA05, VD02, VD06, VD08, VD09, VD10, ZA05	HA01, VD01, VD04, VD07, ZA03, ZA04, ZA06, ZA07, ZA08, ZA09
Matrix (XP)			Light brown (grey) to dark brown, calcareous	Yellow grey to dark brown, calcareous	Light brown to dark brown, calcareous, rarely ferruginous	Light brown to dark brown, ferruginous and calacareous	Light brown greyish to dark brown, both calcareous and ferruginous
General inclusion size (mm)			4.05–01.5 mm, strong variation	3.1–0.1 mm, strong variation	3.1–0.1 mm, strong variation	2.55–0.1 mm, moderate variation	5.75–0.1 mm, strong variation
Inclusions	Sedimentary rock fragments	Micrite	n/a	One fragment, also secondary in pores	n/a	One fragment	Well-rounded, up to 3.75 mm
		Calcareous mudstone	n/a	n/a	Well-rounded, up to 1.1 mm	n/a	n/a
		Chert	n/a	n/a	One fragment, well-rounded	Well-rounded, up to 0.55 mm	Sub-angular to well-rounded, up to 1.1 mm
		Sandstone	n/a	n/a	n/a	n/a	well-rounded, up to 0.4 mm.
	Igneous rock fragments	Granite	Angular, up to 0.3 mm	n/a	Angular to well-rounded, up to 0,55 mm	Rounded, sometimes angular, up to 2 mm	Angular to well-rounded, up to 4.85 mm
		Plagioclase	n/a	One fragment, angular	Sub-rounded, up to 0.2 mm	Well-rounded, up to 0.25 mm, related to granite	Sub-angular, up to 1.35 mm, related to granite
		Microcline	n/a	n/a	Angular, up to 0.35 mm	Sub-rounded, up to 0.25 mm	Well-rounded, up to 0.3 mm
		Muscovite	n/a	n/a	n/a	Well-rounded, up to 0.1 mm, related to granite	n/a
		Biotite	n/a	n/a	n/a	n/a	Angular, up to 0.45 mm
		Basalt	n/a	n/a	n/a	n/a	One fragment
		Analcite	n/a	n/a	n/a	n/a	Angular to well-rounded, up to 0.55 mm
	Metamorphic rock fragments	Schist	n/a	n/a	n/a	n/a	Angular, up to 5.75
		Chlorite	n/a	n/a	n/a	n/a	Angular, up to 0.45 mm, related to schist
Quartz			Mostly angular, up to 4.05 mm	Mostly angular, up to 3.4 mm	Angular to well-rounded, up to 2.75 mm	Sub-angular to well-rounded, up to 2.5 mm	Angular to well-rounded, up to 2.35 mm
Grog			Few, up to 1 mm	Few, up to 1.75 mm	Common to rare, up to 2.9 mm	Few, up to 1.6 mm	Few to rare, up to 3.95 mm
Tcf (Whitbread, 1989)			Rare, up to 1.65 mm	Few, up to 3.4 mm	Few, up to 1.1 mm	Few, up to 1.25 mm	Few, up to 2.3 mm
Organic Material			n/a	n/a	Charred wood and plant remains	n/a	One fragment
Porosity			Medium. Pores between and around large quartz fragments.	Medium. Pores exhibit orientation parallel to vessel wall.	Frequent. Pores can exhibit moderate orientation parallel to walls.	Frequent. Chaotic patterns, sometimes alignment near surfaces.	Frequent. Alignments to internal features common.
Approx. Paste (%)			40–50	45–65	45–55	35–70	25–65

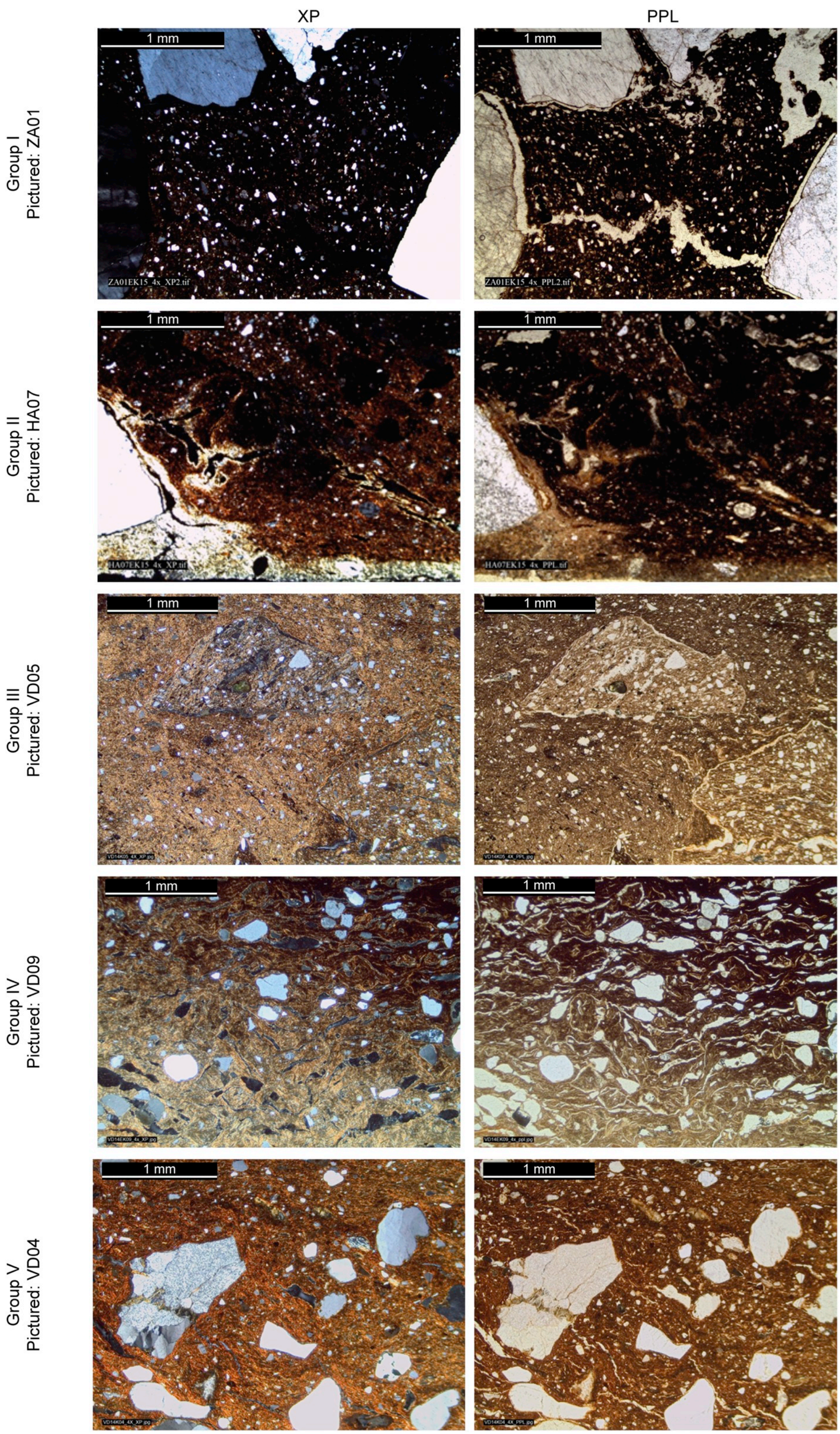

Fig. 5. Micrographs of the fabric groups. Group I: ZA01 (from Zandwerven) features the characteristics of this group: coarse quartz temper, planar voids, quartz in the fine fraction, and a dark matrix in PPL and XP. Group II: HA07 (from Hazerswoude-Rijndijk N11) shows the coarse quartz fragments and clay pellets associated with group II. Group III: VD05 (from Voorschoten-De Donk) exhibits a compact matrix with isotropic inclusions and quartz in the fine fraction, as well as two grog fragments in the coarse fraction. Group IV: VD04 (from Voorschoten-De Donk) is exemplary for the porosity (S-shaped voids) and use of quartz-rich sand in this fabric group. Lastly, VD04 (from Voorschoten-De Donk) features a combination of angular schist and quartz fragments together with rounded quartz grains, typical for group V.

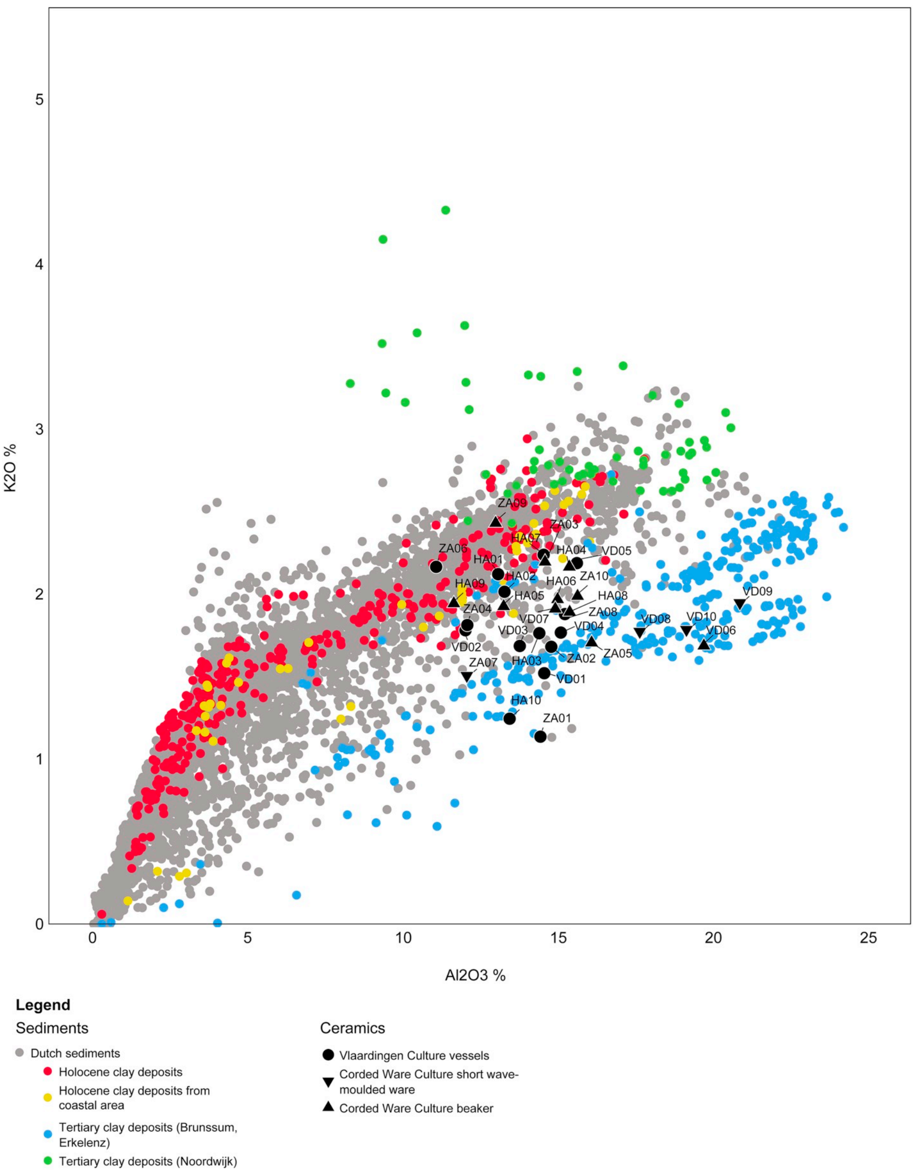

Fig. 6. Biplot of the K_2O:Al_2O_3 signature of sampled vessels and Dutch sediments. Two groups (1&3) containing CWC and VLC vessels exhibit a match with German Tertiary and Dutch Holocene clay deposits respectively. The values for a further group (2), that also consists of CWC and VLC vessels, lie between these groups at the outliers of Tertiary and Holocene clay deposits.

Group V: Coarse, grit-tempered fabrics are tempered with a variety of coarse igneous (granite, basalt), sedimentary (chert, sandstone) and metamorphic (schist) rocks which appear both in rounded and angular shapes. The fine fractions contain a similar variety of minerals. Grog and textural concentration features can also be found.

4.3. Geochemical analysis

The geochemical values of the samples are compared to five groups of clay deposits: (1) Holocene clay deposits from the rivers Rhine and Meuse; (2) Holocene clay deposits in the coastal area; (3) sediments scattered throughout the Netherlands; (4) tertiary clay deposits that surface in German and (5) Belgian areas that are adjacent to the Netherlands. The latter deposits can only be found at great depth (> 100 m) in the Netherlands Together, these deposits provide an accurate overview of the diversity of clay deposits in the Netherlands (Huisman, 1998).

In order to compare the geochemical data of the sampled vessels with Dutch subsoils, four ratios of chemical elements are used: K_2O:AL_2O_3 (Fig. 6), Sr:CaO (Fig. 7), Cr:Al_2O_3 (Fig. 8), and Cr:TiO_2

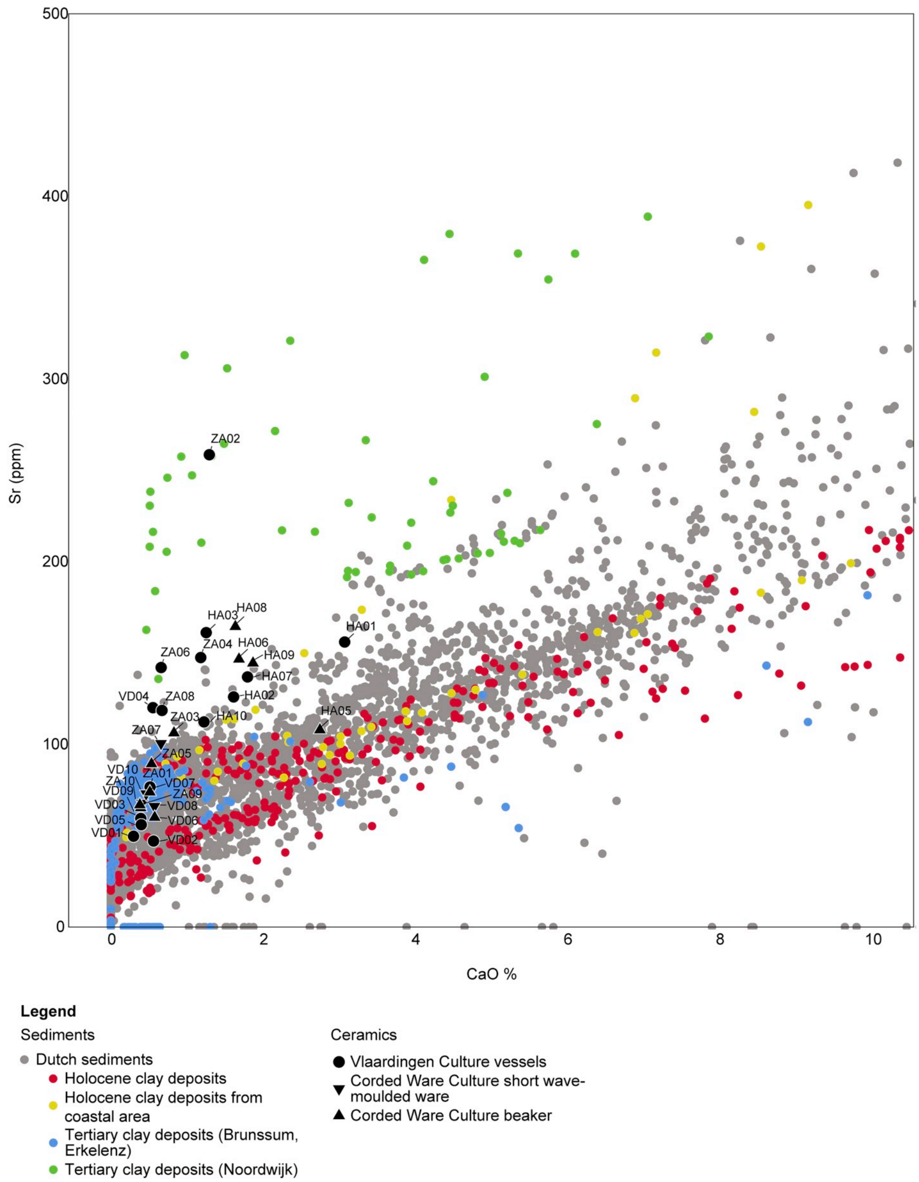

Fig. 7. Biplot of the Sr:CaO values for the sampled vessels and Dutch sediments. Sr values cut off at 500 ppm, CaO values cut off at 10 wt%. HA04 removed due to a non-detection value for Sr. A large number of CWC and VLC vessels (groups 1 and 3) is situated in a cluster at the lower-left part of the graph, where the chemical signatures of various Holocene and Tertiary clay deposits overlap. Several vessels (group 2) exhibit Sr:CaO values outside of the range observed in Dutch clay deposits, but match with values of Tertiary clay deposits found at great depth in the Netherlands.

(Fig. 9). These ratios are particularly suited to distinguish different clays in the Netherlands (Huisman, 1998) and have the potential to yield sub-groups in the sampled ceramics.

The K_2O:Al_2O_3 ratio of clay relates to the environmental and lithological setting in which it was formed. The Sr:CaO ratio indicates whether the calcareous component of the clay has sedimentary or volcanic origins. The Cr:Al_2O_3 indicates whether the clays derive from the weathering of mafic volcanic rocks. Lastly, the Cr:TiO_2 reflects the weathering process of the clay, with Cr being more abundant in fine fractions than in coarse fractions and vice versa for TiO_2 (Deer et al., 1992; Degryse and Braekmans, 2014; Gornitz, 2009; Huisman et al., 2017).

Three consistent clusters of ceramics emerge from the comparisons of the above-mentioned ratios (see Figs. 6–9). The absolute analytical

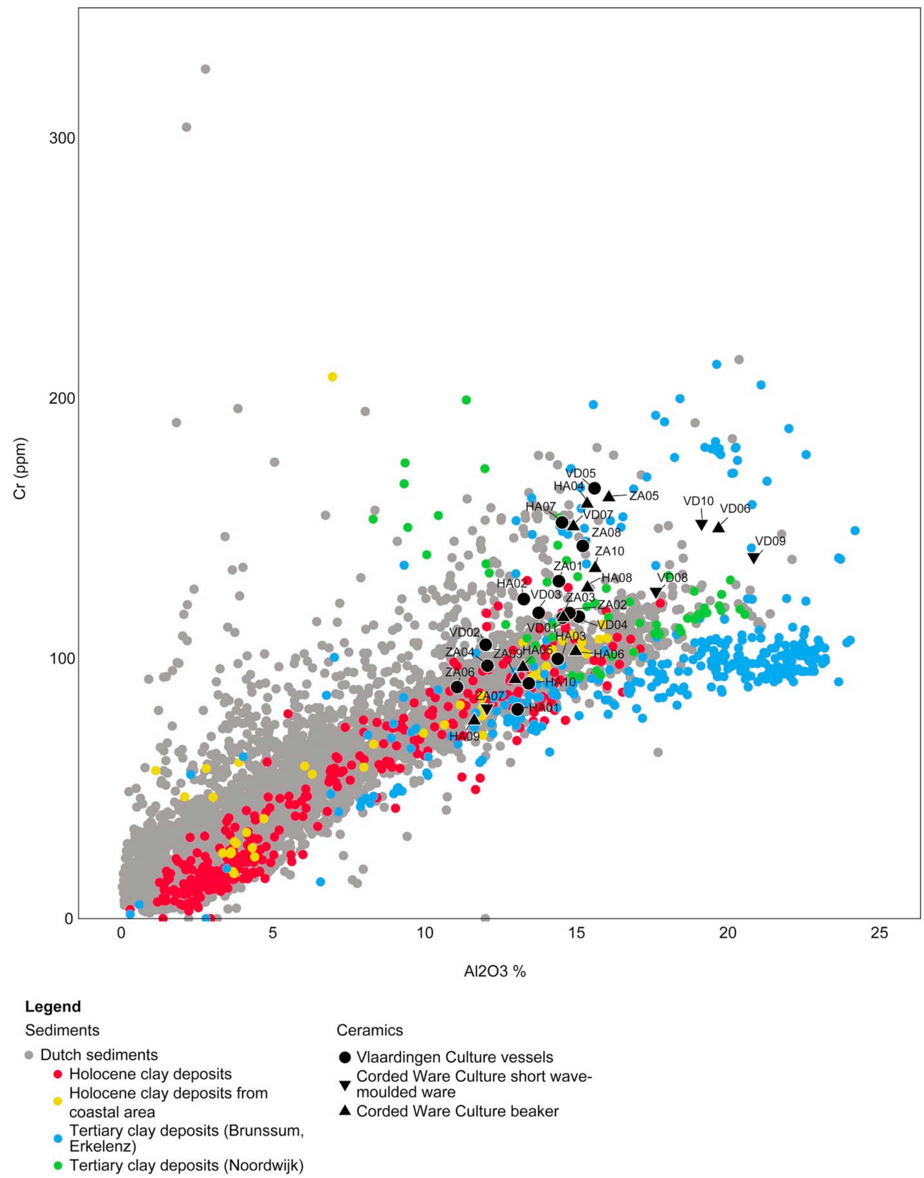

Fig. 8. $Cr:Al_2O_3$ values of sampled vessels and Dutch clay sediments. Similar to Fig. 6, two groups (1 & 3) of CWC and VLC vessels match with Tertiary deposits and Holocene deposits respectively, whereas group 3 lies roughly in between.

values of these clusters can be evaluated with the data in Table 5.

The first cluster of vessels falls outside the range of Holocene sediments in the coastal area and Dutch subsoils in general in terms of $K_2O:Al_2O_3$, $Cr:Al_2O_3$, and $Cr:TiO_2$ ratios. These samples exhibit a provisional match with a tertiary clay deposit found across the Dutch-German border. However, the Sr:CaO ratios of this tertiary deposit and Holocene clays in the Dutch subsoil overlap. This cluster consists of several CWC beakers and short wave-moulded wares from the site Voorschoten-De Donk.

The second cluster of vessels is on the edge of the distribution of Dutch sediments in terms of $K_2O:Al_2O_3$, $Cr:Al_2O_3$, and $Cr:TiO_2$ ratios, but additionally exhibit anomalously high Sr:CaO. As yet, there is no match for these vessels in the background dataset. Furthermore, petrographic analysis of some of these vessels shows the presence of igneous rocks (olivine and basalt) in the fine fraction that are not indigenous to the Netherlands (see Table 4). This cluster consists of CWC and VLC vessels from all sites.

Lastly, vessels from the third cluster match with the Dutch Holocene deposits in the coastal area and fluvial deposits in general in all ratios. Similar to the second cluster this cluster encompasses VLC and CWC vessels from all sites.

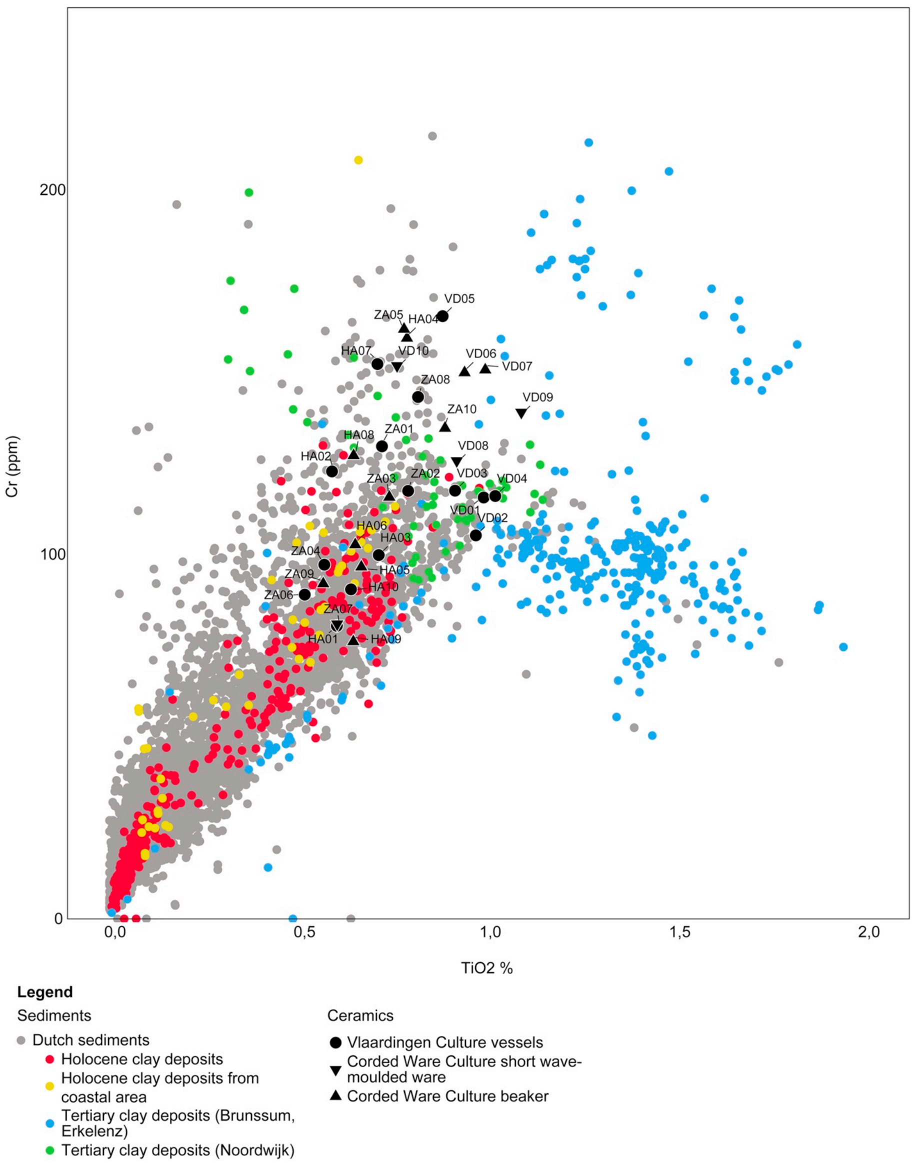

Fig. 9. Biplot showing the geochemical signatures of vessels and Dutch sediments for Cr:TiO_2. Cr values cut off at 250 ppm. A mixed group (3) of vessels (both CWC and VLC) visibly overlaps with Dutch clay deposits, whereas a two further groups (1 & 2) of mixed vessels overlaps with the chemical signatures of Tertiary and the outliers of Holocene and Tertiary clays respectively.

5. Discussion

5.1. Analysis of technical actions

The combination of geochemical, petrographic and macro-morphological analysis allows us to disentangle the technical actions in the creation of various vessels (see Table 6). The data of all three analytical approaches is integrated through network analysis. A two-mode network of the relations between techniques (grey nodes) and vessels (coloured nodes) is presented below (see Fig. 10). A relation between these two types of nodes implies a technique was used in the production of a vessel. The graph is plotted in centrality lay-out: the nodes with the highest degree (i.e. the most commonly utilised techniques) are at the centre of the graph, whereas less common techniques are towards the margins. Based on the values for degree centrality, the techniques form three groups (see Fig. 10).

The first group of techniques has few ties ($n < 10$) and is found towards the margins of the graph. This group encompasses all

Table 5
chemical values from WD-XRF analysis.

Sample name	Main elements											Minor elements															Typology
	SiO2	Al2O3	P2O5	Fe2O3	K2O	TiO2	MgO	CaO	Na2O	MnO	SO3	Ce	Ba	Zr	Cr	Zn	Pb	Rb	Ni	Sr	Y	Nb	Cu	Co	V	Bi	
	wt%	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*wt%*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	
HA01	47.15	13.09	0.91	4.57	2.12	0.6	1.42	3.07	0.54	0.11	0.11	< 5	258	153	80	219	48	122	93	156	< 5	16	47	< 5	< 5	< 5	Vlaardingen Culture vessel
HA02	53.47	13.3	0.5	4.55	2.01	0.59	1.61	1.61	0.48	0.09	0.09	< 5	246	209	123	239	51	115	86	126	< 5	16	56	< 5	< 5	< 5	Vlaardingen Culture vessel
HA03	48.99	14.42	0.7	3.76	1.76	0.71	1.23	1.25	0.28	0.02	0.07	< 5	348	239	100	112	55	101	52	161	< 5	15	47	< 5	114	< 5	Vlaardingen Culture vessel
HA04	55.14	15.39	0.48	4.13	2.17	0.79	1.57	2.89	0.59	0.07	0.17	< 5	435	235	159	128	101	115	79	< 5	< 5	18	60	< 5	< 5	< 5	Corded Ware Culture bBeaker
HA05	45.71	13.27	0.35	4.09	1.93	0.66	1.56	2.75	0.44	0.06	0.04	< 5	223	210	97	103	33	117	61	108	< 5	20	34	< 5	< 5	< 5	Corded Ware Culture bBeaker
HA06	48.86	15.01	0.64	4.85	1.97	0.65	1.09	1.68	0.38	0.07	0.1	< 5	325	207	103	273	84	117	101	147	< 5	16	48	< 5	< 5	< 5	Corded Ware Culture beaker
HA07	50.55	14.56	0.8	4.6	2.24	0.71	1.24	1.8	0.3	0.03	0.16	214	270	206	152	136	65	106	79	137	< 5	22	49	< 5	< 5	< 5	Vlaardingen Culture vessel
HA08	50.86	15.4	0.6	4.88	1.89	0.64	1.11	1.64	0.47	0.07	0.09	336	349	208	127	231	65	121	92	165	< 5	11	44	< 5	< 5	< 5	Corded Ware Culture bBeaker
HA09	43.53	11.66	0.57	3.62	1.94	0.64	1.22	1.87	0.43	0.04	0.08	< 5	336	205	76	169	37	126	98	145	< 5	18	32	< 5	< 5	18	Corded Ware Culture beaker
HA10	61.34	13.46	0.48	3.18	1.24	0.64	1.01	1.22	0.29	0.03	0.03	< 5	231	301	90	120	39	68	39	112	< 5	12	< 5	< 5	< 5	< 5	Vlaardingen Culture vessel
VD01	39.53	14.58	4.09	3.04	1.52	0.99	0.59	0.3	0.11	0.01	0.27	319	334	189	116	110	85	72	46	50	31	14	< 5	< 5	< 5	< 5	Vlaardingen Culture vessel
VD02	39.45	12.04	1.26	4.12	1.78	0.97	1.21	0.56	0.16	0.03	0.12	< 5	410	188	105	209	46	96	97	47	29	< 5	54	< 5	< 5	< 5	Vlaardingen Culture vessel
VD03	41.05	13.79	0.62	3.66	1.69	0.91	< 0.01	0.39	0.17	0.02	0.12	271	224	265	118	164	42	94	75	60	35	22	72	< 5	< 5	< 5	Vlaardingen Culture vessel
VD04	43.35	15.11	0.73	5.12	1.77	1.02	1.71	0.55	0.32	0.02	0.64	< 5	433	247	116	228	119	117	156	120	28	20	79	1402	< 5	< 5	Vlaardingen Culture vessel
VD05	45.8	15.63	1.31	4.3	2.19	0.88	1.74	0.4	0.43	0.01	0.47	< 5	165	262	165	225	34	115	92	56	35	15	118	< 5	< 5	< 5	Vlaardingen Culture vessel
VD06	40.34	19.73	1.36	4.38	1.69	0.94	1.3	0.58	0.18	0.01	0.2	< 5	446	216	150	200	152	111	145	60	39	20	79	< 5	< 5	< 5	Corded Ware Culture bBeaker
VD07	32.59	14.94	1.62	3.64	1.91	0.99	1.11	0.51	0.33	0.02	0.27	242	595	293	151	211	125	171	119	74	46	20	502	< 5	58	< 5	Corded Ware Culture bBeaker
VD08	41	17.66	1.41	5.47	1.77	0.92	1.48	0.57	0.15	0.02	0.17	428	318	200	126	263	106	98	106	66	34	20	57	< 5	< 5	< 5	Corded Ware Culture short wave-moulded ware
VD09	39.57	20.89	3	3.96	1.95	1.09	1.2	0.41	0.16	0.01	0.28	446	516	227	139	240	108	100	177	68	34	20	70	< 5	< 5	< 5	Corded Ware Culture short wave-moulded ware
VD10	41.49	19.16	1.13	4.65	1.78	0.76	1.59	0.46	0.24	0.01	0.46	< 5	406	144	152	185	181	119	73	73	28	25	52	< 5	< 5	< 5	Corded Ware Culture short wave-moulded ware
ZA01	68.68	14.46	1.58	2.28	1.14	0.72	0.68	0.51	0.35	0.01	0.16	170	122	262	130	87	42	58	43	77	< 5	19	< 5	< 5	< 5	< 5	Vlaardingen Culture vessel
ZA02	52.08	14.81	3.17	3.03	1.68	0.79	0.89	1.29	0.29	0.04	0.24	< 5	204	290	117	107	44	72	80	259	< 5	< 5	< 5	< 5	< 5	< 5	Vlaardingen Culture vessel
ZA03	47.12	14.6	1	4.87	2.2	0.74	1.82	0.83	0.31	0.03	0.13	361	212	214	116	202	34	95	87	106	< 5	16	71	< 5	< 5	< 5	Corded Ware Culture bBeaker
ZA04	57.76	12.1	0.41	3.15	1.81	0.57	1.31	1.18	0.63	0.03	0.15	200	164	259	97	96	30	94	50	148	< 5	66	51	< 5	< 5	< 5	Vlaardingen Culture vessel
ZA05	39.33	16.11	0.57	4.99	1.71	0.78	1.16	0.53	0.18	< 0.,01	0.44	< 5	154	181	162	90	92	109	67	89	< 5	18	47	< 5	217	< 5	Corded Ware Culture beaker
ZA06	39.9	11.1	0.82	4.56	2.17	0.52	1.58	0.66	0.55	0.03	0.19	< 5	190	194	89	110	52	< 5	64	142	39	9	50	< 5	< 5	< 5	Vlaardingen Culture vessel
ZA07	43.48	12.08	1.91	4	1.51	0.6	1.1	0.66	0.24	0.02	0.22	< 5	166	186	81	154	49	91	78	101	< 5	14	< 5	< 5	< 5	< 5	Corded Ware Culture short wave-moulded ware
ZA08	50.85	15.25	1.43	4.76	1.88	0.81	1.41	0.67	0.2	0.03	0.4	381	175	190	143	200	36	93	55	119	< 5	22	< 5	< 5	< 5	< 5	Vlaardingen Culture vessel
ZA09	41.63	13.01	0.77	3.14	2.43	0.56	1.49	0.39	0.49	0.02	0.19	241	167	214	92	124	24	130	76	65	< 5	14	41	< 5	< 5	< 5	Corded Ware Culture beaker
ZA10	49.83	15.65	1.51	6.68	1.99	0.89	1.43	0.38	0.22	0.01	0.43	< 5	177	299	135	76	59	123	75	67	< 5	22	63	< 5	< 5	< 5	Corded Ware Culture beaker

Table 6
specification of variables in Fig. 10.

Stage of the *chaîne opératoire*	Input data	Calculation	Output variable(s)
Acquisition of raw materials	Geochemical analyses	See Section 4.3	Raw Material (RM) group 1–3
Choice of temper	Petrographic analysis; Macromorphological analysis	Classified into two categories, based on present materials.	Rock temper Rock and grog temper
Paste preparation	Sorting of inclusions (0 for poor, 1 for moderate) Abundance of TcF's (0 absent or rare; 1 for abundant) Presence and shape of voids	Scores from 0 to 3 for each fabric 1 > coarse paste 2 = medium paste 3 < fine paste	Coarse paste preparation Medium paste preparation Fine paste preparation
Shaping	Macromorphological analysis Macromorphological analysis	Presence of fine, parallel lines on surface Shape of the rim: Lip on the outside Lip on the inside Flattened top	Scraping Rounded outward Rounded inward Rounded 2-way
Surface finish	Macromorphological analysis	Smoothing visible on surface Treatment of surface by roughening with plastic clay	Inside smoothed Outside smoothed Smitten
Decoration	Macromorphological analysis	Technique used to apply decorations	Finger prints Rope Spatula Grooves Incisions Perforations
Firing regime	Macromorphological analysis, petrographic analysis	Firing temperatures from petrographic data all fall between 573 and 850 degrees Centigrade, as shrinkage voids occur around large quartz inclusions, but all matrices are optically active. All fabrics exhibit relatively low hardness. Abbreviations indicate the transition of colours (Ox for reddish hues in a oxidising atmosphere and Red for greyish colours from a reducing atmosphere, with the small letters after the dashes indicating the nature of transitions (s for sharp, v for vague/gradual). Working from outside surface inward.	Ox-sRed Ox-sRed-Ox Red Ox-vRed Ox

techniques for applying decoration, different techniques for rounding of the rims of vessels, surface finish techniques, two raw material groups, fine paste preparations, and a surface finishing technique.

The second group of nodes is directly at the centre of the graph, because these techniques are shared in nearly all vessels (i.e. these techniques exhibit > 20 ties). This group consists of the nodes for the smoothing of internal and external vessel walls.

The last group of nodes takes an intermediate position between the above-mentioned groups (between 12 and 18 ties). They represent techniques such as paste preparation, but also surface finishing and firing methods.

Similar networks are plotted for each individual site in order to understand the CWC transition at the level of sites. At Hazerswoude-Rijndijk N11 (see Fig. 11), techniques do not stick to typological boundaries, with the exception of firing methods and decorative techniques. This network is similar to that in Fig. 10: most notably in the central positioning of smoothing internal and external vessel walls in both graphs. The same pattern can be observed at Zandwerven (see Fig. 11). However, Voorschoten-De Donk features a different pattern (see Fig. 11). The vessels fall into two groups with different raw materials and methods for paste preparation, finishing of the rim, and decoration. Only firing methods and surface finishing techniques are shared across this divide. Strikingly, both groups also exclusively contain VLC or CWC vessels with the notable exception of a CWC beaker that exhibits the raw materials, paste preparation, and the firing technique associated with VLC vessels at the site.

It is possible to contextualise these results by incorporating the data from the published site reports on Zandwerven (Fig. 12) and Hazerswoude-Rijndijk N11 (Fig. 13). These graphs show that at Zandwerven and Hazerswoude-Rijndijk N11, CWC vessels exhibit a narrow set of techniques that fits within the range of techniques observed in VLC vessels at these sites. Changes take the form of shifts in emphasis or as further emphasis of prior patterns in technological choices. Decorative techniques are the only point of divergence between VLC and CWC vessels on both sites.

Unfortunately, extant analyses of the ceramic assemblage of Voorschoten-De Donk lack quantitative data. However, these analyses do hint at changes in decorative patterns against the background of shifts in emphasis within the range of technological patterns visible in VLC ceramics (Cf. Van Veen, 1989; Wasmus, 2011).

5.2. The introduction of the CWC from the perspective of ceramic technology

Each of the three sites exhibits different relations between VLC and CWC vessels in terms of utilised techniques. Upon linking these patterns to the theoretical framework, it becomes possible to falsify a number of scenarios for the introduction of the CWC for each site (see Table 1).

At Voorschoten-De Donk, all but one of the sampled CWC vessels are imports, both in terms of production techniques (different resilient and group-related techniques) and geochemical signature. The CWC vessel that is an exception to this rule matches the VLC vessels from this site in

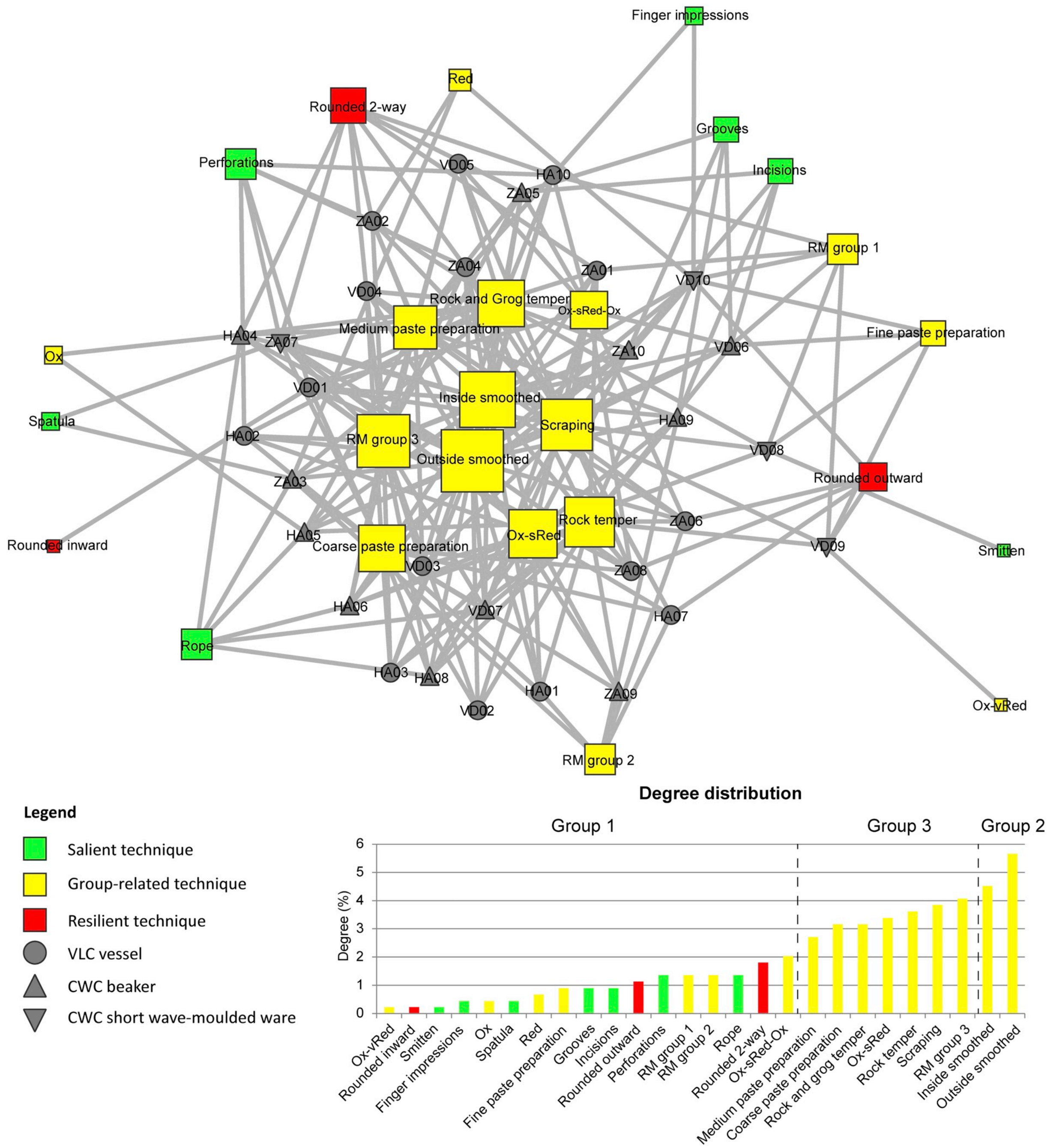

Fig. 10. Network representation of shared techniques in VLC and CWC ceramics. Two-mode network in centrality lay-out showing the techniques used to construct each studied vessel. Ties between the techniques (row mode) and a vessel (column mode) indicate that this specific technique was utilised during the making of the vessel. The degree centrality (%, uniform tie values, values for vessels not plotted) of each technique is shown in the histogram below. Dotted lines indicate the boundaries of groups of techniques based on degree centrality.

terms of resilient and group-related production techniques, but differs from them in salient techniques. These developments match the hypothesised impact of a diffusion scenario, where changes in salient and group-related techniques occur alongside imports.

At Zandwerven, group-related techniques of the VLC appear unchanged after the introduction of CWC, but changes do occur in salient techniques. Furthermore, a select number of vessels yield indications for changes in resilient techniques. The present analysis yields no evidence for the presence or imports. Therefore, this site fits best within a network interaction scenario.

Lastly, a different development occurs at Hazerswoude-Rijndijk N11. Shifts can be observed in the salient production techniques, but not in group-related techniques: the techniques used in CWC vessels fit within the spectrum of VLC techniques. Again, no imports can be attested. Consequently, this site matches the expected patterns for a diffusion scenario.

The over-all patterning in the technological analysis confirms that introduction of CWC in the western coastal area of the Netherlands

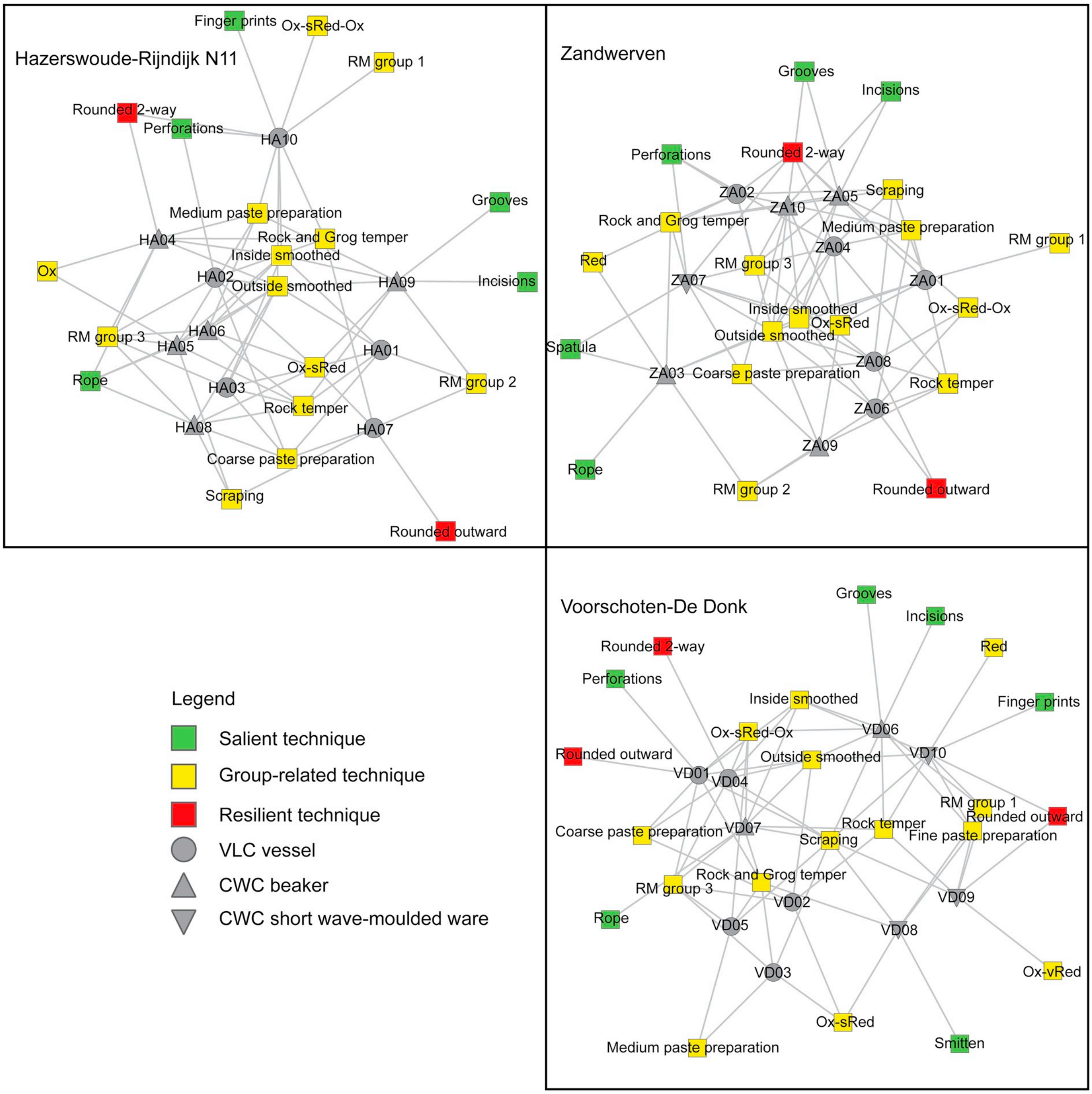

Fig. 11. Network representations of techniques used in vessel production at Hazerswoude-Rijndijk N11, Zandwerven and Voorschoten-De Donk. Two mode network in centrality lay-out. Ties between the techniques (row mode) and a vessel (column mode) indicate that this specific technique was utilised during the making of the respective vessel.

exhibits technological continuity at the level of group-related and resilient techniques. Changes predominantly occur in the salient techniques (see Fig. 10). The CWC vessels in this area differ from VLC vessels in shapes and decoration, but both types of ceramics are essentially made in a similar fashion. To sum up, the appearance of CWC vessels in the western coastal area of the Netherlands indicates a patchwork transition of VLC communities, rather than an introduction of CWC. This conclusion collaborates, but also complicates existing ideas about the relations between VLC and CWC in the western coastal area of the Netherlands, and between the CWC and prior regional groups in general.

A previous study of CWC sites in North Holland indicates continuity between the VLC and the CWC in settlement location and subsistence technology. Furthermore, this study points to a difference in thin- and thick-walled CWC ceramics at these sites. Whereas the characteristic thin-walled CWC beakers are typologically different from the preceding thick-walled VLC ceramics, thick-walled vessels do occur in CWC assemblages and these vessels bear typological resemblance to VLC vessels (Beckerman, 2015). The present study complicates this conclusion, because it demonstrates that the CWC beakers may be typologically different, but are fashioned in a way that is akin to VLC ceramics. Therefore, this study challenges the idea that the appearance of CWC vessels necessarily indicates a break with the past in the coastal area. This raises the question whether there is a CWC 'presence' in the

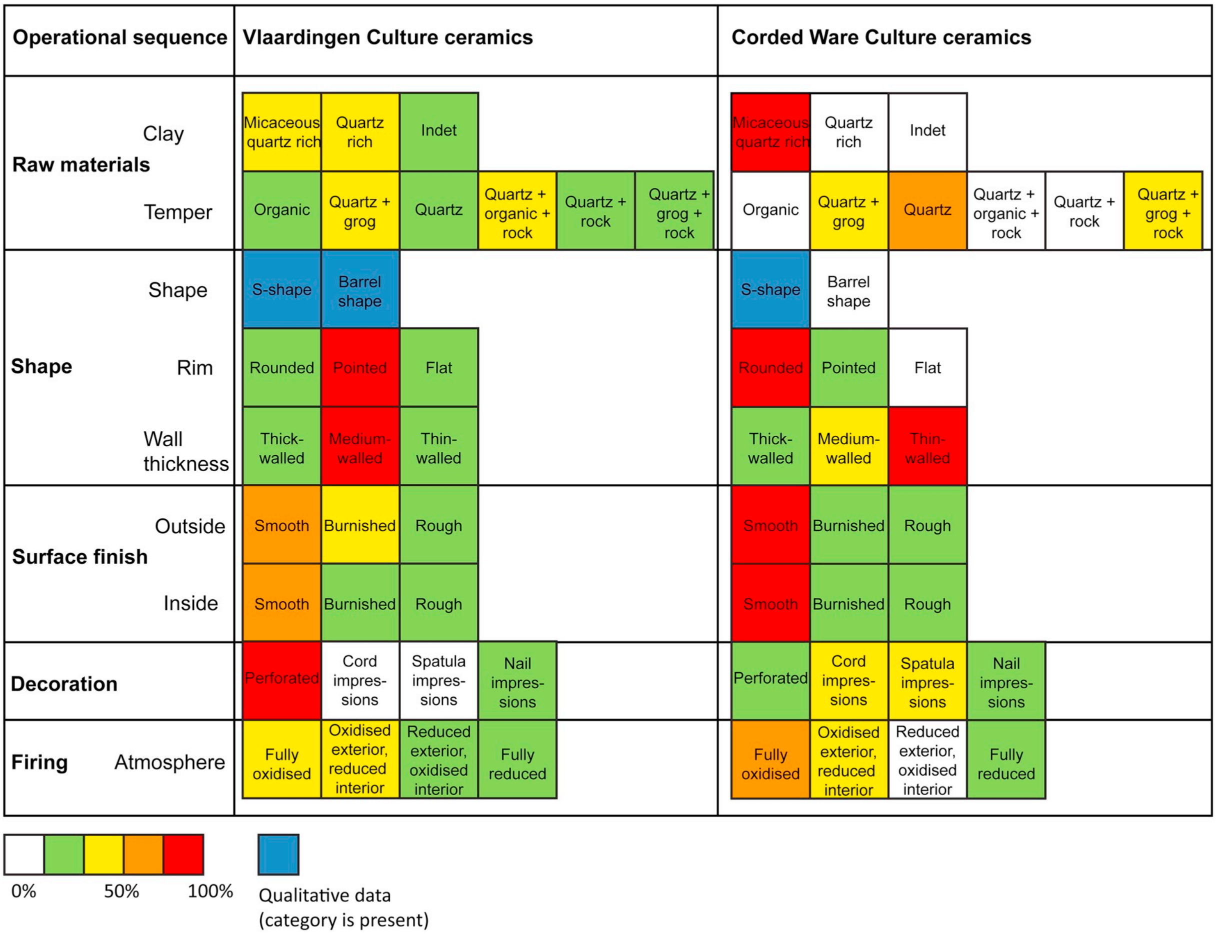

Fig. 12. Synopsis of extant technological studies of the ceramic assemblages from Zandwerven. This figure compares VLC and CWC vessels from Zandwerven in terms of ceramic production techniques (courtesy of Dr. S.M. Beckerman). The colours of the boxes indicate the percentage of vessels that exhibits traces of a specific technical choice. The boundaries for thin-walled ceramics are set to 1–7.5 mm, medium thick ceramics to 7.5–12.5 mm, and thick-walled to > 12.5 mm.

western coastal area of the Netherlands (Cf. Beckerman, 2015).

Rather than looking at the presence of specific material culture to determine whether the CWC is present in a particular area, it is the relation between CWC and previous cultures that should be a key aspect of the understanding of the CWC. As this paper demonstrates for the coastal area of the Western Netherlands, that relation could be a geographical patchwork.

5.3. Persistent long-distance interactions

The geochemical analysis of the sampled ceramics indicates that a substantial number of vessels (17 out of 30) exhibit values that do not match clay deposits in the Netherlands. However, a provisional match can be established with tertiary clay deposits across the border with Germany and Belgium. This is a significant outcome in the light of current discussions about the VLC. It has been argued that the VLC is part of a larger cultural complex that includes the Stein group (Limburg, the Netherlands) and especially the Wartburg Culture (Hessen, Lower Saxony, Thuringia, Germany) and Seine-Oise-Marne Culture in Belgium and Northern France. The basis for this argument are similarities in flint assemblages, dwellings, and ceramics (Fokkens et al., 2017; Louwe Kooijmans, 1983). The provisional match of VLC vessels with clay deposits in these areas could strengthen these arguments. However, further geochemical analysis of ceramics from all three cultures should be undertaken to come to conclusive arguments. Moreover, it seems that these regional networks remained stable, because CWC and VLC vessels have similar geochemical signatures.

The combined geochemical and technological data also attest interactions within regional networks of VLC communities. The production processes of the analysed vessels converge on the practice of smoothing vessel walls despite the geographical range attested by the geochemical analyses. This technique is group-related, but also highly significant because this action seals off, if not obliterates, traces of previous technological steps on the vessel surface. It clears the way for the application of decoration; the step that causes most of the variation within the dataset and links to fashion-like phenomena. In sum, not only does the provenance of the ceramics contribute to the idea of an international orientation among communities in the Western coastal area of the Netherlands, it also shows that these communities were interacting across these distances.

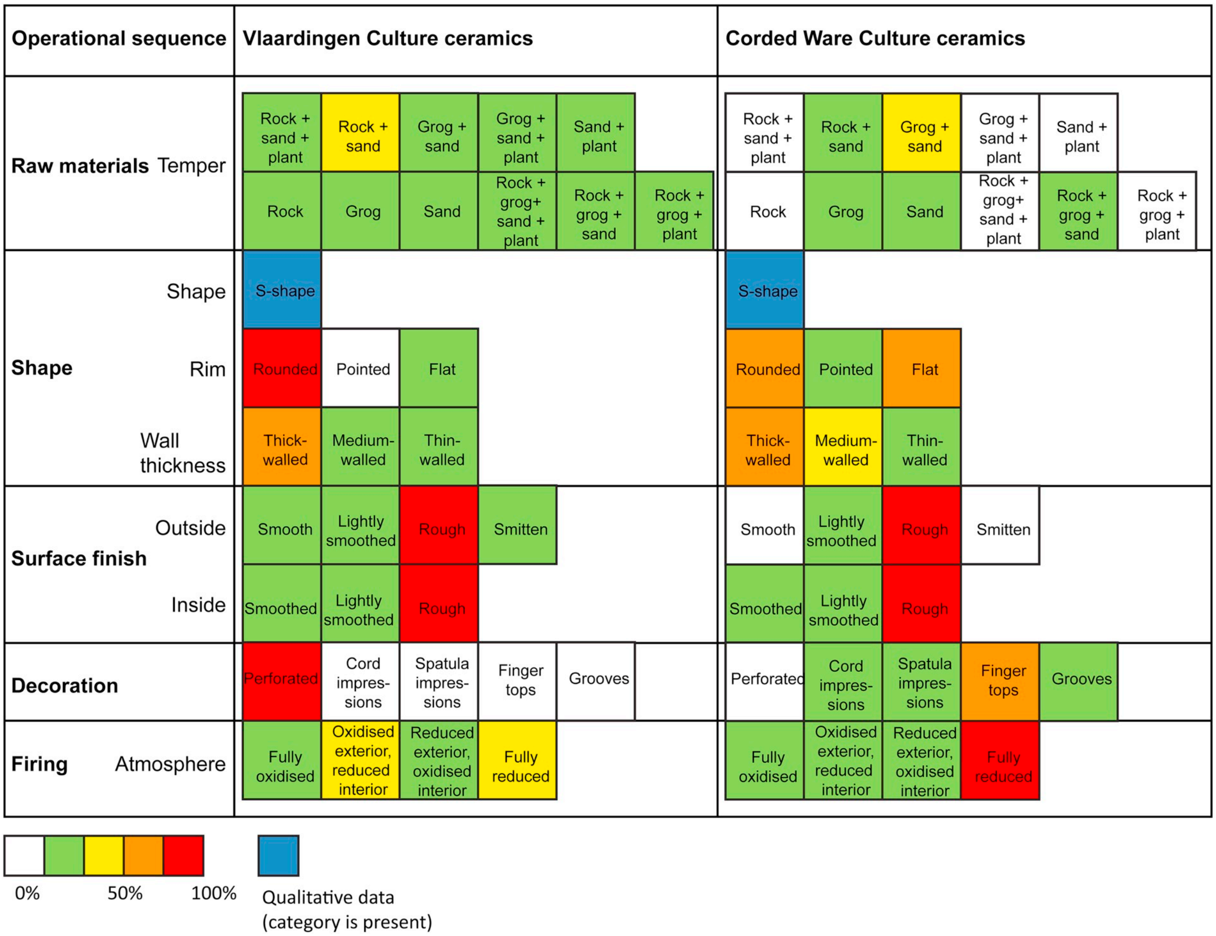

Fig. 13. Synopsis of extant technological studies of the ceramic assemblages from Hazerswoude-Rijndijk N11. This figure shows a comparison of ceramic production techniques in VLC and CWC vessels from Hazerswoude-Rijndijk N11 (courtesy of ArchaeoMedia bv). The colours of the boxes indicate the percentage of vessels from the assemblage that exhibit traces of a specific technique or technological choice. Thin-walled ceramics exhibit a thickness of 1–7.5 mm, medium thick ceramics of 7.5–12.5 mm, and thick-walled ceramics of 12.5 mm or more.

6. Conclusions

The introduction of the CWC is often hailed as a homogeneous process for which explanatory models range from regional to supra-regional scale (Allentoft et al., 2015; Haak et al., 2015). By taking a bottom-up approach, this analysis demonstrates that the introduction of the CWC is better understood as a patchwork process.

The over-arching transitional process in the Western coastal area of the Netherlands is local continuity with diffusion and network interaction traits. Interestingly, the supra-regional networks of the VLC communities in this region, as well as some of the defining technological practices within these networks, remain intact throughout the CWC transition. These results are also a clear argument to integrate geochemical and petrographic analyses into the existing macro-morphological approaches to ceramics from this period. Such an integrated approach can reveal new information regarding the geographic range of past interactions and the nature of cultural transformations.

In the absence of detailed genetic and isotopic data from Late Neolithic individuals from the western coastal areas of the Netherlands, direct conclusions on the relations between the migrations demonstrated by genetic analyses in other regions and the outcomes of this study remain speculative. However, if a similar shift in the late Neolithic gene pool from this area can be detected, this raises questions on the impact of such migrations on knowledge transmission and local traditions. If such a change cannot be attested, questions should be raised about the nature of the CWC in this particular area. Questions that will ultimately boil down to what we define as CWC.

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