Journal of Archaeological Science: Reports 38 (2021) 103061

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Technological knowledge and transfer of Roman pottery production in *Civitas Nerviorum* (northern France, central Belgium) during the 1st–3rd centuries CE

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A R T I C L E I N F O

Keywords:
Roman ceramic technology
Technological transfer
OM
XRF
pottery waste
northern France
central Belgium

A B S T R A C T

Aspects of 1st to 3rd centuries CE Roman production technology and knowledge transfer in northern France and central Belgium (known as *Civitas Nerviorum*) were studied. To this aim, 43 pottery waste fragments from six workshops at Bavay, Pont-sur-Sambre, Blicquy, Cambrai, Les Rues-des-Vignes and Sains-du-Nord were studied macroscopically and analysed in thin section petrography and chemistry with X-ray fluorescence spectrometry. This permitted to reconstruct the production technologies employed at the six workshops, and to infer inter- and intra-site knowledge transfer. More specifically, potters at Bavay transferred their knowledge to craftsmen at Pont-sur-Sambre. The epigraphic evidence on the discarded pottery further suggests that they passed on their technological knowledge through kinship. Craftsmen at Cambrai and Les Rues-des-Vignes also appear to have shared aspects of their technological knowledge. The reconstructed technologies were then used to tentatively indicate the production location of three conspicuous types of pottery, which circulated widely within and beyond the study region but were hitherto not known from production waste contexts. To this aim, seven samples from settlement, burial and sanctuary sites at Famars, Blicquy and Sains-du-Nord were selected and analysed in thin section petrography and chemistry with X-ray fluorescence spectrometry.

1. Introduction

Julius Caesar conquered northern France when he decimated the Nervian tribe in 57 BCE (Arbabe, 2013). Under Octavian's administrative reorganisation between 16 and 13 BCE, the region became integrated in the *Civitas Nerviorum*, with Bavay as the administrative and economic centre (Delmaire, 2011). The capital of Bavay was strategically built on the *via Belgica* from Boulogne-sur-Mer on the western coast to Cologne on the Rhine River in the east (Delmaire et al., 1997; Fig. 1). People and craftsmen moved to the town because of new markets, which started to develop around the turn of the 1st century BCE/CE (Willems and Ledauphin, 2019). Crafts activities, including pottery production and processing of animal products, flourished at several Roman small towns from 70 CE onwards (Clotuche, 2013; Neaud et al., 2017).

In Period 1 (the turn of the 1st century BCE/CE–70 CE), production waste of Gallo-Belgic pottery, storage jars, flagons and grinding bowls was found at Bavay (Labarre and Willems, 2019; Fig. 2a). In Period 2 (70–120 CE), three Roman small towns commenced pottery production, as indicated by numerous discarded vessels: Gallo-Belgic ware, fine ware and Pompeian red plates were found at Les Rues-des-Vignes (Deru, 2005a, 2005b), excavations at Cambrai revealed Gallo-Belgic pottery, coarse ware, grindings bowls and flagons (Gaillard et al., 2001), while waster pits with stamped grinding bowls were discovered during excavations at Pont-sur-Sambre (Delmaire, 1972; Loridant and Ménard, 2002). In Period 3 (120–260 CE), workshops at Les Rues-des-Vignes and Pont-sur-Sambre continued to produce the same pottery wares, as indicated by numerous wasters at the sites (Delmaire, 1972; Deru, 2005a, 2005b; Loridant and Ménard, 2002; Fig. 2b, Fig. 2c), and pottery

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https://doi.org/10.1016/j.jasrep.2021.103061
Received 6 January 2021; Received in revised form 6 May 2021; Accepted 22 May 2021
Available online 5 June 2021
2352-409X/

workshops developed at several other Roman small towns. More specifically, pits with rejected flagons, coarse ware and grinding bowls were found near kilns at Famars (Herbin et al., 2005, Willems et al., 2019), while wasters of coarse ware and flagons were excavated at Blicquy (Deru et al., 2012; Fig. 2e) and Asse (Magerman et al., 2019). Discarded coarse ware, dated to the end of Period 3, was found during excavations at Sains-du-Nord (Loridant, 1997). In period 4 (260–320 CE), waste products of coarse ware have been found at Famars only.

Compositional studies on pottery waste found in the *Civitas Nerviorum*, adopting a multi-analytical method, have focused on the production technology of grinding bowls, flagons and coarse ware from Famars (Batigne-Vallet, 2001; Borgers et al., 2020a), as well as flagons and coarse ware from the workshops at Asse (Magerman et al., 2019) and Blicquy (Deru et al., 2012). These studies have indicated that potters at Asse and Blicquy shared some aspects of their technological knowledge, while potters at Famars adopted a different technology for the manufacture of flagons and grinding bowls. Aside from these studies, however, little is known about potters' technological knowledge at other Roman small towns in the *Civitas Nerviorum*, and its transfer over time.

Not only studies on the numerous excavated workshops indicate that the *Civitas Nerviorum* was an important supplier of Roman pottery to settlements within the region; also, studies of various settlement, burial and sanctuary sites, which were located both within and beyond the province, tentatively suggest that three conspicuous pottery types may have been produced in the study region (Willems, 2005, 2019; Deru and Vachard, 2002; Hendrickx, 2016), even if they have not been documented among the pottery waste found at the various workshops. More specifically, it has been suggested that grinding bowls with stamp 'VXPVRO' may have been produced at Pont-sur-Sambre (Willems, 2019: 223; Fig. 2b). It has further been proposed that Gallo-Belgic fine ware flasks, which were found in a sanctuary at Sains-du-Nord, may have been produced locally (Willems and Neaud, 2012; Fig. 2d). Finally, it is thought that face pots, which were used in a wide range of social practices, may have been produced in the study region (Deru and Vachard, 2002), and more specifically at Famars (Flahaut et al., 2014; Willems: 102, 2013; Fig. 2f).

Following on from this, the present study had two main objectives: first, it aimed to reconstruct pottery production technology in the *Civitas Nerviorum*, by analysing 43 waster sherds from the workshops of Bavay, Les Rues-des-Vignes, Cambrai, Sains-du-Nord, Pont-sur-Sambre and Blicquy. Of importance were the various steps in the production sequence, including raw materials, paste preparation, forming, finishing, firing and discard. Attention was also paid to possible inter- and intra-site knowledge transfer between potters over time. Second, the study aimed to identify the production location of three types of vessels (*e.g.*, stamped grinding bowls, face pots and Gallo-Belgic fine ware flasks), by analysing seven fragments from burial, settlement and sanctuary sites at Blicquy, Famars and Pont-sur-Sambre, and by comparing the data with pottery waste examined in this study and with discarded pottery from Famars (Borgers et al., 2020a). In order to achieve this, all 50 samples were analysed by polarised light optical microscopy and wavelength dispersive X-ray fluorescence spectrometry, in combination with macroscopic evidence on the samples. This allowed to reconstruct the potters' technological signatures that have been employed at the workshops examined. In turn, this permitted to understand whether the three conspicuous pottery types, which circulated beyond the *Civitas* boundaries but were hitherto not known from production waste contexts, were produced in the study region.

2. Archaeological contexts and samples

The *Civitas Nerviorum* was situated east of the Escaut River valley and covers a part of present-day northern France and central Belgium. The *via Belgica* was a major artery for transport in the province, as well as the Escaut and Sambre rivers (Fig. 1). The archaeological sites examined in this study were located in different parts of the study region, with Blicquy in the centre, with Bavay, Famars, Pont-sur-Sambre, Les Rues-des-Vignes and Cambrai in the southwest, and with Sains-du-Nord in the southeast. The pottery workshops were found during several excavation campaigns, which were carried out during the 2000 s (Clotuche, 2013; Deru, 2005b; Deru et al., 2012; Gaillard et al., 2001; Labarre, 2012; Willems et al., 2017). They comprised stone-built structures, numerous circular and square-shaped pits, which served to store clay, ceramic waste or pottery wheels, as well as wells (Deru, 2005b; Neaud et al., 2017; Willems et al., 2017). A mould for the production of face pots (Willems et al., 2017; Flahaut et al., 2014), and a potter's stamp 'NERICCVS FE' (Willems et al., 2017; Willems and Borgers, 2016) were also found, in addition to several tools for the application of surface decoration (Willems et al., 2017; Deru, 2005b), and fragments of pottery wheels (Neaud et al., 2017).

The majority of the kilns are single-flue, double-chambered updraft structures. The combustion chamber and stokehole of this kiln type are

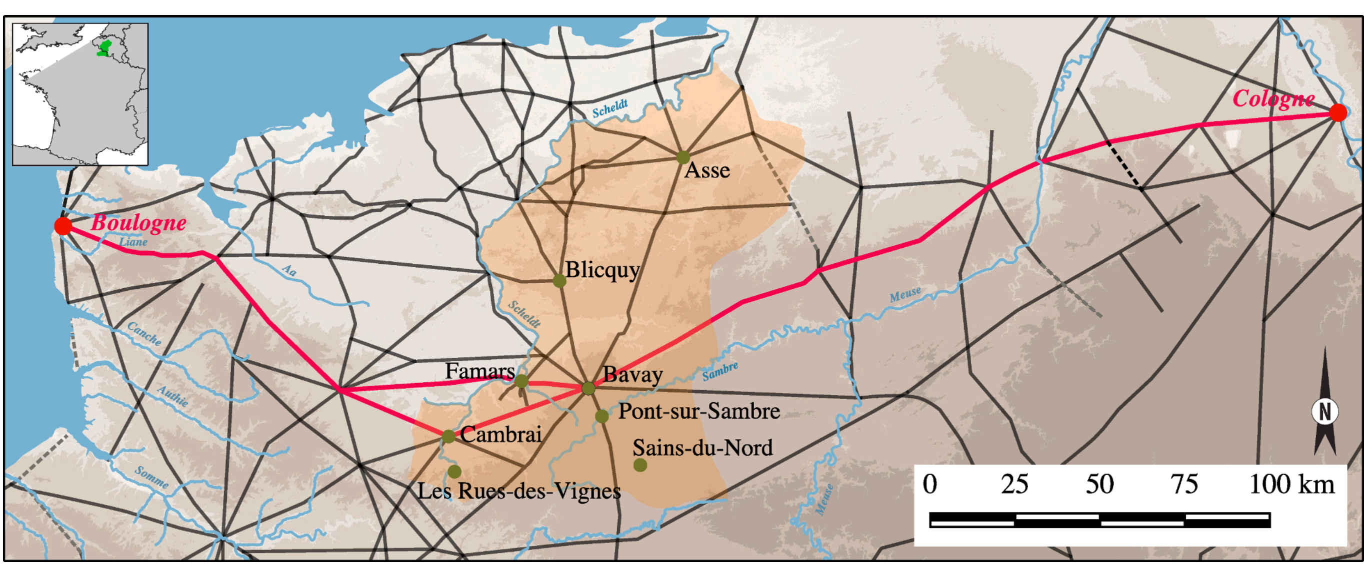

Fig. 1. *Civitas Nerviorum* in present-day northern France and central Belgium with location of the capital at Bavay and Roman small towns, including Blicquy, Asse, Famars, Pont-sur-Sambre, Sains-du-Nord, Les Rues-des-Vignes and Cambrai, as well as the *via Belgica* and the Rhonelle, Escaut and Sambre rivers. Image from © Raphael Clotuche, Inrap.

cut in the natural soil, and a raised (often pierced) oven floor with support is constructed for the placement of pottery (Peacock, 1982; Fig. 3a). This kiln type has been found on five of the six production sites studied, including Les Rues-des-Vignes (Deru, 2005b), Bavay (Labarre and Willems, 2019), Blicquy (Deru et al., 2012), Sains-du-Nord (Neaud et al., 2017) and Cambrai (Gaillard et al., 2001). Several kilns at Les Rues-des-Vignes and Cambrai were used for multiple firings, as witnessed by a change in the direction of the flue (Deru, 2005b; Gaillard et al., 2001). Double-chambered updraft kilns are very common in the *Civitas Nerviorum* and adjacent *Civitas Tungrorum* (Borgers et al., 2020b).

A minority of twin-flue, single-chambered downdraft kilns have been found at one workshop studied, including Cambrai (Gaillard et al., 2001; Herbin et al., 2019). In this structure, air is drawn into the firing chamber from two stoke pits, which are located at opposite ends of the kiln, and there is no compartment that separates the pottery from the fire (Peacock: 68, 1982; Swan, 1984: Fig. 2; Fig. 3b). According to Dufaÿ (1996), this kiln structure is pre-Roman in origin. Whilst it occurs at Cambrai and Famars in the *Civitas Nerviorum*, this kiln structure is common in the *Civitas Viromandorum*, south of the study area (Maréchal et al., 2019). At five of the six production sites studied, kilns appear to have been located in the open air; only at Sains-du-Nord, they appear to have been located inside buildings (Loridant, 1997; Neaud et al., 2017).

There seem to have existed differences in the production organisation in the *Civitas Nerviorum*, based on the number of kiln structures

Fig. 2. Roman Pottery from the *Civitas Nerviorum*: (a) Production waste from Bavay, dated to Period 1 (the turn of the 1st century BCE/CE–70 CE), (b) grinding bowl with stamp 'UXPVRO' from Famars and grinding bowl from the kilns at Pont-sur-Sambre, dated Period 3 (120–260 CE), (c) Gallo-Belgic ware from Cambrai and Les Rues-des-Vignes, dated between Periods 2 and 3 (70–260 CE), (d) Jars and flasks from a sanctuary at Sains-du-Nord, dated to Period 2 (70–120 CE) (e) Coarse ware from the kilns at Blicquy, Period 3 (120–260 CE) (f) Face pot from Famars, dated to Period 4 (260–320 CE) (Images a, b, d, e from © Sonja Willems, CRAN. Images c from © Stephane Dubois and f from © Stéphane Lancelot, Inrap.

Fig. 3. Kiln structures in *Civitas Nerviorum*: (a) single-flue, double-chambered updraft kiln from Famars-Technopôle phase 1, (b) twin-flue, single-chambered downdraft kiln from Famars-Technopôle phase 2 © Inrap and Service Archéologique de Valenciennes.

found at the production sites studied. More specifically, the presence of 50 kilns at Bavay (Labarre, 2012) suggests that local ceramic production was organised at the 'manufactory' level (Peacock, 1982: 9). The workshops at Les Rues-des-Vignes (13 kilns; Deru, 2005b), Blicquy (13 kilns; Deru et al., 2012), and Cambrai (19 kilns; Gaillard et al., 2001; Herbin et al., 2019) can be considered as 'rural nucleated industries' (Peacock 1982: 38-43). In comparison, with only five kilns found at Sains-du-Nord (Loridant, 1997; Neaud et al., 2017), it seems that 'individual' workshops existed at this site.

In Period 1, potters at Bavay manufactured flagons and grinding bowls for export both within and beyond the *Civitas Nerviorum* (Willems, 2005; Willems and Ledauphin, 2019; Fig. 2a). In Period 2, workshops at Pont-sur-Sambre produced stamped grinding bowls (Delmaire, 1972; Loridant and Ménard, 2002; Fig. 2b), at Les Rues-des-Vignes they mainly manufactured Gallo-Belgic fine ware and Pompeian red plates, while workshops at nearby Cambrai produced complementary coarse ware (Gaillard et al., 2001; Fig. 2c). In Period 3, potters at Pont-sur-Sambre continued to manufacture grinding bowls (Delmaire, 1972; Loridant and Ménard, 2002), while those at Blicquy produced mostly coarse ware (Deru et al., 2012; Fig. 2e). At Sains-du-Nord, the bulk of the local pottery comprised coarse ware (Neaud et al., 2017), whereas at Famars, it consisted of grinding bowls, coarse ware and flagons (Willems, 2019). In Period 4, pottery production seems to have ceased at most Roman small towns, with the exception of Famars where manufacture of coarse ware continued (Willems, 2019).

In order to answer the two main research questions in this study, sample selection for detailed compositional analysis focused on: (1) 43 fragments, which were chosen from four pottery wares, including flagons, grinding bowls, coarse ware and Gallo-Belgic fine ware. The samples were selected from pottery waste found at six sites, including Bavay, Cambrai, Les Rues-des-Vignes, Blicquy, Pont-sur-Sambre and Sains-du-Nord, and date to between Periods 1 and 3 (Table 1), in order to gain insight in technological knowledge and transfer over time in the *Civitas Nerviorum*; (2) seven fragments of stamped grinding bowls, face pots and Gallo-Belgic fine ware flasks were chosen from different settlement, burial and sanctuary sites at Famars, Blicquy and Sains-du-Nord (Table 1). The samples date to between Periods 2 and 4, and have not been found among recorded production waste of the workshops studied. The aim of their study was to confirm whether they were produced within the *Civitas*, if not locally at the sites where they have been found.

3. Method

All 50 samples were selected from pottery waste that was not vitrified, in order to avoid chemical and mineralogical alteration (Buxeda I Garrigós et al., 2001), and analysed using a combination of polarised light optical microscopy (OM) and wavelength dispersive X-ray fluorescence spectrometry (XRF). Both methods of compositional analysis were performed independently, and the results were then compared with one another, as well as with macroscopic observation of the sherds. All 50 samples were prepared as standard 30 μm thin sections and studied with an Olympus BX 51 polarized light optical microscope at the Department of Geography and Geology, Paris-Lodron University of Salzburg. The ceramic thin sections were grouped, based upon the size and nature of the inclusions, voids, and clayey matrix (Quinn, 2013: 73–79; Whitbread, 1989). The size limit between inclusions and matrix is 15–20 μm (Ionescu et al., 2011; Maggetti, 1979, 1982). Compositional, shape and structural (*e.g.*, fineness) criteria of inclusions and voids were used to detect the presence of specific paste preparation recipes, such as addition of temper (Quinn, 2013: 156–171; Whitbread, 1986).

XRF analysis was performed on all 50 sherds with a WD-XRF BRUKER S8-Tiger wave-length dispersive spectrometer with Rh excitation source at the Fitch laboratory of the British School at Athens

Table 1
Details of the 50 Roman ceramic samples analysed, including site, period, pottery ware, surface decoration or stamp and surface colour.

Sample	Site	Period	Pottery Ware	Surface Decoration/Stamp	Surface Colour
BA60	Bavay	1	Flagon		Cream
BA61	Bavay	1	Flagon		Cream
BA66	Bavay	1	Flagon		Cream
BA67	Bavay	1	Flagon		Cream
BA72	Bavay	1	Storage jar		Cream
BA73	Bavay	1	Storage jar		Cream
BA179	Bavay	1	Grinding bowl	ULPEFOX	Cream
BA180	Bavay	1	Grinding bowl	BVDE	Cream
BA181	Bavay	1	Grinding bowl	BRARIATVS	Cream
BA182	Bavay	1	Grinding bowl	BRARIATVS	Cream
BA185	Bavay	1	Gallo-Belgic ware	Wavy lines	Black
BLI29	Blicquy	3	Flagon		Red
BLI34	Blicquy	3	Coarse ware		Grey
BLI37	Blicquy	3	Coarse ware		Grey
BLI39	Blicquy	3	Coarse ware		Grey
RDV71	Les Rues-des-Vignes	3	Gallo-Belgic ware		Black
RDV72	Les Rues-des-Vignes	3	Coarse ware		Grey
RDV73	Les Rues-des-Vignes	3	Gallo-Belgic ware		Black
RDV74	Les Rues-des-Vignes	3	Coarse ware		Grey
RDV75	Les Rues-des-Vignes	3	Coarse ware		Grey
RDV76	Les Rues-des-Vignes	3	Coarse ware		Grey
RDV77	Les Rues-des-Vignes	3	Gallo-Belgic ware		Black
RDC8	Cambrai	2	Coarse ware		Grey
RDC11	Cambrai	2	Coarse ware		Grey
RDC12	Cambrai	2	Coarse ware		Grey
RDC13	Cambrai	2	Coarse ware	Wavy/horizontal lines	Grey
RDC14	Cambrai	2	Coarse ware		Grey
RDC17	Cambrai	2	Coarse ware		Grey
RDC18	Cambrai	2	Gallo-Belgic ware	Wavy lines	Black
RDC21	Cambrai	2	Coarse ware		Grey
RDC22	Cambrai	2	Flagon		Light buff
RDC26	Cambrai	2	Grinding bowl	VIIRIVCIVS	Light buff
PSS172	Pont-sur-Sambre	2 and 3	Grinding bowl	VARIATVS	Cream
PSS173	Pont-sur-Sambre	2 and 3	Grinding bowl	VICTOR	Cream
PSS174	Pont-sur-Sambre	2 and 3	Grinding bowl	VARIATVS	Cream
PSS175	Pont-sur-Sambre	2 and 3	Grinding bowl	VARIATVS	Cream
PSS176	Pont-sur-Sambre	2 and 3	Grinding bowl	VARIATVS	Cream
PSS177	Pont-sur-Sambre	2 and 3	Grinding bowl	BRARIATVS	Cream
SDN1	Sains-du-Nord	End of 3	Coarse ware		Grey
SDN2	Sains-du-Nord	End of 3	Coarse ware		Grey
SDN4	Sains-du-Nord	End of 3	Coarse ware		Grey
SDN6	Sains-du-Nord	End of 3	Coarse ware		Grey
SDN7	Sains-du-Nord	End of 3	Coarse ware		Grey
FAM49	Famars	4	Face pot		Cream
FAM170	Famars	3	Grinding bowl	VXPVRO	Cream
FAM171	Famars	4	Grinding bowl		Cream
BLI44	Blicquy	4	Face pot		Light buff
BLI47	Blicquy	4	Face pot		Cream
SDN74	Sains-du-Nord	2	Gallo-Belgic ware		Black
SDN76	Sains-du-Nord	2	Gallo-Belgic ware		Black

(Georgakopoulou et al., 2017). The surface layer was removed with a tungsten carbide drill, in order to avoid possible errors due to burial contamination, and ground to a fine powder with an agate mill. The powdered samples (1 g) were mixed with lithium metaborate + lithium tetraborate + lithium bromide (6 g) and ignited in an automatic fluxer. The pulverised samples were heated in a muffle furnace to 950 °C for four hours. The dried powders were prepared as glass beads for analysis of 20 major, minor and trace elements, including SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, P_2O_5, MnO, V, Cr, Ni, Cu, Zn, Sr, Y, Zr, Ba and La. The equipment was routinely calibrated with 43 certified reference materials, which have been developed for the analysis of soils. In order to monitor the instrument performance, two certified reference materials (GSR-1 and PM-S) were also analysed. Precision was $<$ 1% for major and minor elements and did not exceed 5% for trace elements except for La ($<$10%). Accuracy was $<$ 3% relative error for all elements, except for Cu.

The chemical data obtained by XRF were normalized by log transforming each element to base-10 logarithms, in order to account for the differences in the concentrations of the elements that could have affected the subsequent statistical classification (Baxter and Freestone, 2006). The log-transformed data were analysed via hierarchical cluster analysis (HCA) and principle component analysis (PCA), using the Wards Methods and Squared Euclidean distance, as well as SPSS software, in order to identify existence of chemical groups among the 50 ceramic samples analysed (Glascock et al., 2004). P_2O_5 was left out of the statistical classification, due to its potential post-depositional enrichment (Freestone, 2001; Maritan et al., 2005; Orton and Hughes: 173, 2013). Four elements, including MgO, K_2O, CaO and Ni, were considered to be important, given that studies have demonstrated that variation in their value correlates with differences in the clay mineralogy of the raw materials (*e.g.,* MgO and K_2O, see Borgers et al., 2020b) or technology (*e.g.,* CaO and Ni, see Travé Allepuz et al., 2014).

The macroscopic and microscopic evidence on the 50 pottery sherds was used to interpret aspects of firing technology. More specifically, the surface and core colour of the ceramic fragments was used to interpret the firing atmosphere in the kiln (Rye, 1981: 166), while the optical characteristics of the matrix of the ceramic thin sections were used to interpret the firing temperature (Quinn, 2013).

4. Compositional classification of pottery production waste

Thin section analysis indicated the presence of four main petrographic groups among the 43 pottery waste samples analysed from the sites at Bavay, Pont-sur-Sambre, Blicquy, Les Rues-des-Vignes, Cambrai and Sains-du-Nord. These groups are specific to individual workshops and sites, and include the: 1) 'Microfossil-Glauconite' (MFG), 2) 'Quartz and Glauconite' (QzG), 3) 'Quartz with Argillaceous Rock Fragments' (QzARF), and 4) 'Quartz' (Qz) groups (Table 2). The structure of the samples varies from coarse (*e.g.*, QzARF and Qz groups) and semi-fine (*e.g.*, MFG group) to fine (*e.g.*, QzG group) (Table 2).

1) The **Microfossil-Glauconite** (MFG) group is characterised by microfossils and glauconite pellets and includes 17 sherds (Table 2). The microfossils comprise mainly foraminifera, such as *Globigerina* sp. (Fig. 4a) and ostracods, up to 100 μm. Glauconite pellets and sub-angular mono-crystalline quartz grains (50–150 μm) are well sorted. Rare muscovite and iron aggregates also occur in all samples and fine carbonate grains are dispersed in the clayey matrix. The majority of the samples in this group have an isotropic matrix with low birefringence, while five samples are defined by an anisotropic matrix with moderate or high birefringence (Table 2).

Three samples within the MFG group form the **Microfossil-Glauconite with Quartz** (MFG + Qz) variant (BA179, BA180, PSS178; Table 2). The composition of the three samples is similar to that of the MFG group, and defined by microfossils, glauconite and quartz grains. However, they also contain sub-rounded mono-crystalline quartz grains (200–250 μm; Fig. 4b), and rare angular fragments of chert (250–300 μm). The three samples have a moderate to low birefringent matrix (Table 2). All samples of the MFG group and MFG + Qz variant comprise Gallo-Belgic ware, flagons and grinding bowls from Period 1 at Bavay and from Periods 2 and 3 at Pont-sur-Sambre (Table 1).

2) The **Quartz and Glauconite** (QzG) group consists of 17 samples, and is defined by well sorted fine quartz grains, iron aggregates and mica,

Table 2
Texture, optical characteristics of the clayey matrix (Mx), the OM groups and variants, and the main inclusions in the 50 ceramic sherds analysed. ↑Δ – High birefringence, ≈Δ – Medium birefringence, ↓Δ – Low birefringence, Is – Isotropic, Qz – Quartz, Fsp – Feldspar, Ms – Muscovite, Cal – Calcite, Glt – Glauconite, Fe – iron aggregate, mF – Microfossils, ARF – Argillaceous rock fragments, Chm – Chamotte, Sed – Sedimentary rock fragments, ● – Present.

Crt.No.	SampleNo.	OMGroup/Variant	Structure	Mx	Qz	Fsp	Ms	Cal	Glt	Fe aggregate	mF	Chm	ARF	Chert	Sed.
	BA60	MFG	Semi-Fine	≈Δ to ↓Δ	●	●	●	●	●	●	●				
	BA61	MFG	Semi-Fine	↑Δ	●	●	●	●	●	●	●				
	BA66	MFG	Semi-Fine	↑Δ	●	●	●	●	●		●				
	BA67	MFG	Semi-Fine	↑Δ	●	●	●	●	●		●				
	BA72	MFG	Semi-Fine	↓Δ	●	●	●	●	●		●				
	BA73	MFG	Semi-Fine	≈Δ	●	●	●	●	●		●			●	
	BA179	MFG + Qz	Coarse	≈Δ to ↓Δ	●	●	●	●	●					●	
	BA180	MFG + Qz	Coarse	↓Δ	●	●	●	●	●					●	
	BA181	MFG	Semi-Fine	↓Δ	●	●	●		●	●				●	●
	BA182	MFG	Semi-Fine	↓Δ	●	●	●	●	●	●					
	BA185	MFG	Semi-Fine	≈Δ to ↓Δ	●	●	●	●	●	●					
	BLI29	Qz	Coarse	↓Δ	●	●	●		●	●					
	BLI34	Qz	Coarse	↑Δ	●	●	●		●	●					
	BLI37	Qz	Coarse	↓Δ	●	●	●		●						
	BLI39	Qz	Coarse	↑Δ	●	●	●		●	●				●	
	RDV71	QzG	Fine	↑Δ	●	●	●			●					●
	RDV72	QzG	Fine	↑Δ	●	●	●		●	●					
	RDV73	QzG	Fine	↑Δ	●	●	●			●					
	RDV74	QzG + Qz	Coarse	↑Δ	●	●	●		●	●					
	RDV75	QzG	Fine	↑Δ	●	●	●		●	●					
	RDV76	QzG + Qz	Coarse	↓Δ	●	●	●		●	●					
	RDV77	QzG	Fine	≈Δ	●	●	●			●					
	C8	QzG	Fine	↓Δ	●	●	●								
	C11	QzG	Fine	↑Δ	●	●	●								
	C12	QzG	Fine	↑Δ	●	●	●		●	●					
	C13	QzG	Fine	↑Δ	●	●	●		●	●					
	C14	QzG	Fine	↑Δ	●	●	●		●	●					
	C17	QzG	Fine	↓Δ	●	●	●			●					
	C18	QzG	Fine	↑Δ	●	●	●		●	●					
	C21	QzG	Fine	≈Δ	●	●	●			●					
	C22	QzG	Fine	↓Δ	●	●	●								
	C26	QzG	Fine	≈Δ	●	●	●			●					
	PSS173	MFG	Semi-Fine	↓Δ	●	●	●	●	●						
	PSS174	MFG	Semi-Fine	≈Δ	●	●	●	●	●		●				
	PSS175	MFG	Semi-Fine	↓Δ	●	●	●	●	●		●				
	PSS176	MFG	Semi-Fine	≈Δ to ↓Δ	●	●	●		●	●					
	PSS177	MFG	Semi-Fine	↑Δ	●	●	●	●	●						●
	PSS178	MFG + Qz	Coarse	↓Δ	●	●	●		●	●			●		
	SDN1	QzARF	Coarse	↑Δ	●	●	●			●			●		
	SDN2	QzARF + Chm	Coarse	≈Δ	●	●	●					●	●		
	SDN4	QzARF	Coarse	↑Δ	●	●	●						●		
	SDN6	QzARF + Chm	Coarse	↑Δ	●	●	●			●		●	●		
	SDN7	QzARF + Chm	Coarse	↑Δ	●	●	●			●		●	●		
	FAM49	MFG	Fine	↑Δ	●	●	●	●	●		●				
	FAM170	MFG	Semi-Fine	↓Δ	●	●	●	●	●						●
	FAM171	MFG	Fine	↓Δ	●	●	●	●	●		●				
	BLI44	QzG	Coarse	↑Δ	●	●	●								
	BLI47	MFG	Fine	↑Δ	●	●	●	●	●		●				
	SDN74	QzARF	Coarse	↑Δ	●	●	●			●			●		
	SDN76	QzARF	Coarse	↑Δ	●	●	●			●			●		

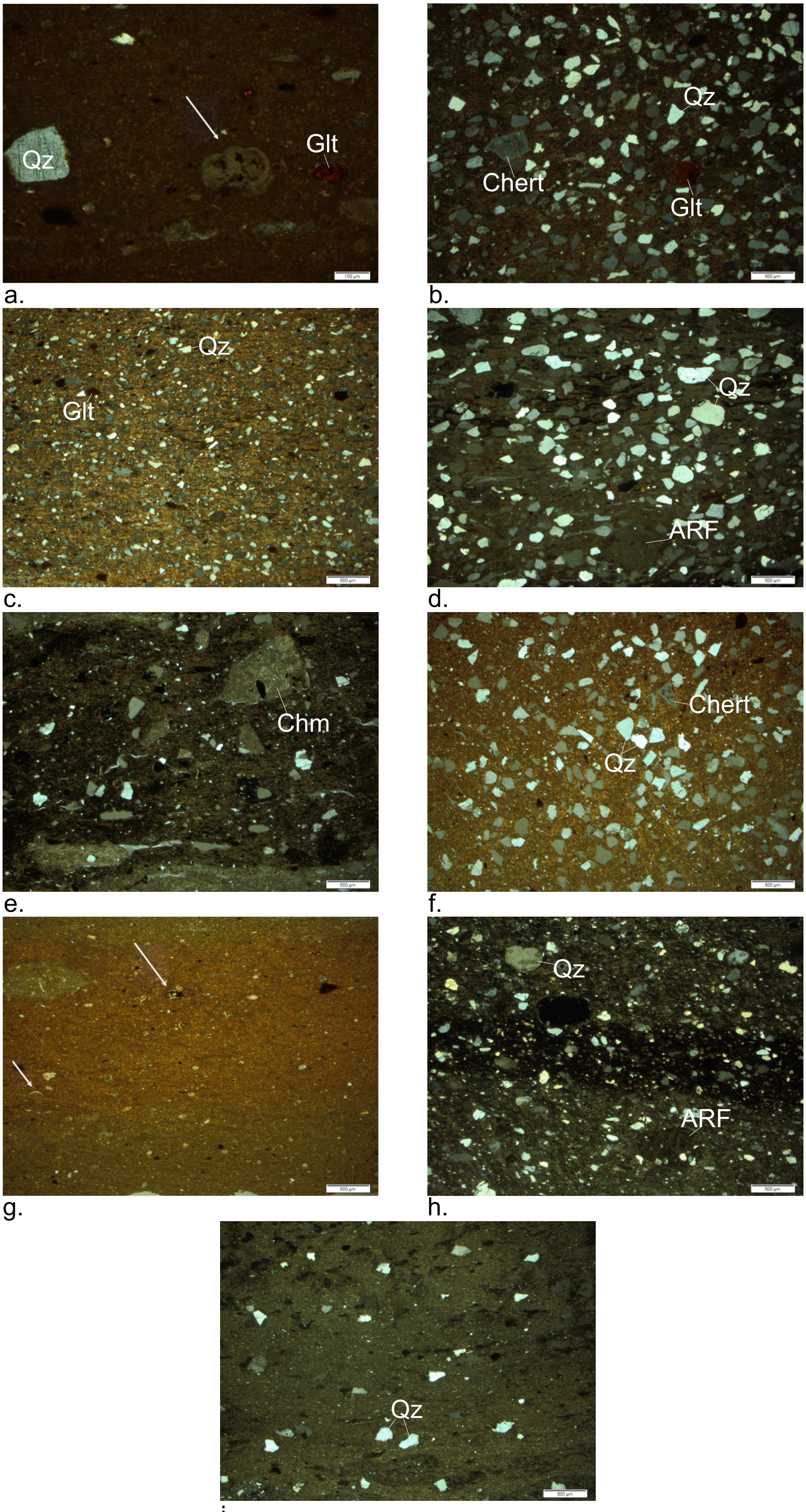

Fig. 4. Ceramic Thin Section Micrographs from the sites at Bavay, Pont-sur-Sambre, Les Rues-des-Vignes, Sains-du-Nord, Famars and Blicquy: (a) MFG group with foraminifera, quartz and glauconite pellets, in PSS174; (b) MFG + Qz variant with microfossils, quartz, chert and glauconite, in BA179; (c) QzG group with well sorted quartz, iron aggregates, mica and glauconite, in RDV75; (d) QzARF group with argillaceous rock fragments (ARF), in SDN1; (e) QzARF + Chm variant with chamotte, in SDN6; (f) Qz group with quartz inclusions, in BLI39; (g) MFG group with foraminifera, quartz and glauconite, in FAM49; (h) QzARF group with ARF, in SDN76; (i) QzG group with well sorted quartz, iron aggregates, mica and glauconite, in BLI44. All images are captured in crossed polarisers. Scale bar is 100 µm (a), and 500 µm (b, c, d, e, f, g, h, i).

as well as rare glauconite pellets (50–100 μm). The majority of the samples in this group have an anisotropic clayey matrix with a moderate to high birefringence, while four samples have an isotropic matrix (Fig. 4c; Table 2).

Two samples within the QzG group (RDV74, RDV76) further contain large sub-rounded mono-crystalline quartz grains (250–300 μm). They form the **Quartz and Glauconite with Quartz** (QzG + Qz) variant. Some of the large quartz grains have a rim of iron oxides. One sample (RDV76) has an isotropic clayey matrix with low birefringence, while the other (RDV74) is defined by an anisotropic matrix with high birefringence (Table 2). All samples of the QzG group and QzG + Qz variant consist of Gallo-Belgic fine ware and coarse ware, and occur in Period 2 at Cambrai and in Periods 2 and 3 at Les Rues-des-Vignes (Table 1).

3) Five samples form the **Quartz and Argillaceous Rock Fragments** (QzARF) group (Table 2). They are defined by quartz grains (200–300 μm), and argillaceous rock fragments (ARF), c. 400 μm in size (Fig. 4d). The ARF are rounded, and their matrix is anisotropic and contains rare fine quartz grains and iron aggregates (10–20 μm). The clayey matrix of the host (or ceramic thin section) includes small fragments of iron aggregates and streaks, and is anisotropic with high birefringence (Table 2).

Three samples within the QzARF group also contain chamotte (SDN2, SDN6, SDN7; Fig. 4e; Table 2). They form the **Quartz and Argillaceous Rock Fragments with Chamotte** (QzARF + Chm) variant. The chamotte fragments have angular rims, their size varies between 250 and 550 μm, and their matrix shows a high birefringence. In the three samples, the clayey matrix is moderately to highly birefringent (Table 2). All the samples of the QzARF group and QzARZ + Chm variant comprise coarse ware from Period 3 at Sains-du-Nord (Table 1).

4) The **Quartz** (Qz) group is defined by quartz grains, and comprises four samples (BLI29, BLI34, BLI37, BLI39; Table 2). The clayey matrix is characterised by fine mica and quartz grains, as well as rare glauconite pellets (<20 μm). The size of the dominant sub-rounded to rounded mono-crystalline quartz grains varies between 200 and 300 μm (Fig. 4f). Rare fragments of chert occur also (Deru et al., 2012). The clayey matrix has a high birefringence in two samples (BLI34, BLI39), while it has a low birefringence in the other two (BLI29, BLI37) (Table 2). The four samples of the Qz group consist of coarse ware and occur in Period 3 at Blicquy (Table 1).

Hierarchical cluster analysis (HCA) of the chemical data reveals the presence of two main chemical groups within the 43 sherds from the six sites at Bavay, Blicquy, Cambrai, Les Rues-des-Vignes, Pont-sur-Sambre and Sains-du-Nord (Fig. 5a). Samples belonging to Group 1 come from Blicquy, Cambrai, Les Rues-des-Vignes and Sains-du-Nord, whereas Group 2 comprises samples from Bavay and Pont-sur-Sambre. The scatterplots of MgO against K_2O (Fig. 5b) and CaO against Ni (Fig. 5c) also reveal the same two groups that are present in the HCA. Sherds belonging to Chemical Group 1 are characterised by low CaO (<2.24 mass%), while Group 2 samples have a comparatively high CaO (5.58–17 mass%; Table 3).

A comparison of the petrographic and chemical classifications of the 43 sherds analysed reveals that they correspond well with one another. As with the petrographic groups, the chemical groups equate to specific sites and workshops. In addition, links are suggested between petrographic groups from more than one site, which might indicate the use of similar raw materials or technology. For instance, the MFG group samples classify within Chemical Group 2 (Fig. 5a). This group is defined by microfossils and glauconite in a CaO-rich matrix and comprises samples from Bavay and Pont-sur-Sambre. This is taken to suggest that the workshops at the two sites used similar raw materials for pottery production.

Also, QzG group samples from Cambrai and Les Rues-des-Vignes, which are defined by well sorted fine quartz grains and glauconite pellets, equate to Chemical Group 1 (Fig. 5a). This suggests that similar raw materials may have been used at the two sites. Whilst samples of the QzARF group and QzARF + Chm variant from Sains-du-Nord also belong to Chemical Group 1 (Fig. 5a), compositional differences are noted in the presence of ARF and chamotte. Their comparatively high Al_2O_3 (20–33 mass%; Table 3) and Ni (63–100 ppm; Table 3; Fig. 5c), and comparatively low MgO (0.25–0.46 mass%) and K_2O (0.4–1.25 mass%; Table 3; Fig. 5b) suggests differences in the production technology and raw materials used at the site.

5. Manufacturing technology of production waste

The results of both petrographic and chemical analysis of the 43 pottery waste samples from the *Civitas Nerviorum* can be used to reconstruct their production sequence, from raw materials, paste preparation, forming, finishing and firing to post-firing handling or discard. This will be combined with the macroscopic evidence on the sherds analysed and interpreted within the broader geological background of the area.

In order to identify the possible raw materials used for Roman pottery production in the *Civitas Nerviorum*, it is necessary to consider the region's bedrock and geology (Fig. 6). Blicquy is located in the centre of the *Civitas*, which is characterised by Pleistocene loess and marine sediments of Paleocene-Eocene age. The soils vary from clayey deposits to sands rich in glauconite. In particular, Lower Eocene clay deposits, such as the Orchies and Roubaix Members of the Ieper Group, are clayey and moderately plastic with illite/smectite interlayer clay minerals (Mango-Itulamya et al., 2019; Spagna et al., 2004), and known to have been used for tile and brick manufacture (Doremus and Hennebert, 1995).

The sites of Bavay and Pont-sur-Sambre are situated on Pleistocene loess deposits, which overlie the sandy or clayey Cretaceous and Paleocene substrata. Several Cretaceous marls (*e.g.*, Marne de la Porquerie) and Paleocene marine deposits (*e.g.*, Louvil Clay) are CaO-rich with microfossils and glauconite (Beugnies and Godfriaux, 1964; Waterlot, 1972; Lacquement et al., 2006).

Cambrai and Les Rues-des-Vignes are located in the alluvial plains of the Escaut River, surrounded by Cretaceous chalk rocks. Pleistocene alluvial clays overlie clayey sediments of Late Paleocene/Lower Eocene age (*e.g.*, continental Landen group) and Lower Eocene age (*e.g.*, Orchies clay of the Ieper group). Continental Landen Group clay deposits are plastic with predominantly illite clay minerals, white sands and some glauconite (Mango-Itulamya et al., 2019; Celet, 1966). Both types of clay deposits are known to have been exploited west of Cambrai (Celet, 1966; Waterlot, 1972).

Sains-du-Nord is situated in the southeast of the study region – an area shaped by the Dinant *Synclinorium*, and characterised by Devonian rocks comprising shaly sandstone, shale and schist. In addition to the plastic kaolinitic Entre-Sambre-et-Meuse clay deposits, which occupy dissolution pockets in the limestone bands of the Dinant *Synclinorum* (Mango-Itulamya et al., 2019; Spagna et al., 2004), there are also small outcrops of Late Paleocene/Lower Eocene clay sediments (*e.g.*, continental Landen group) and Lower Eocene clay (*e.g.*, Ieper group) north of Sains-du-Nord (Delattre et al., 1970; Beugnies and Godfriaux, 1964).

The information on the geological background and dominant clay minerals present in the main deposits, combined with the petrographic and chemical data of the Roman pottery waste might help to indicate probable raw materials used in the *Civitas Nerviorum*. The production waste from Bavay and Pont-sur-Sambre is defined mineralogically by microfossils and glauconite (Fig. 4a, 4b), and chemically by high CaO, K_2O and MgO (Fig. 5b, 5c; Table 4). Following on from this, it seems reasonable to suggest that Roman potters at the two sites may have exploited CaO-rich clay dated to the Cretaceous or Paleocene age for pottery production.

The pottery waste from Blicquy is characterised mineralogically by

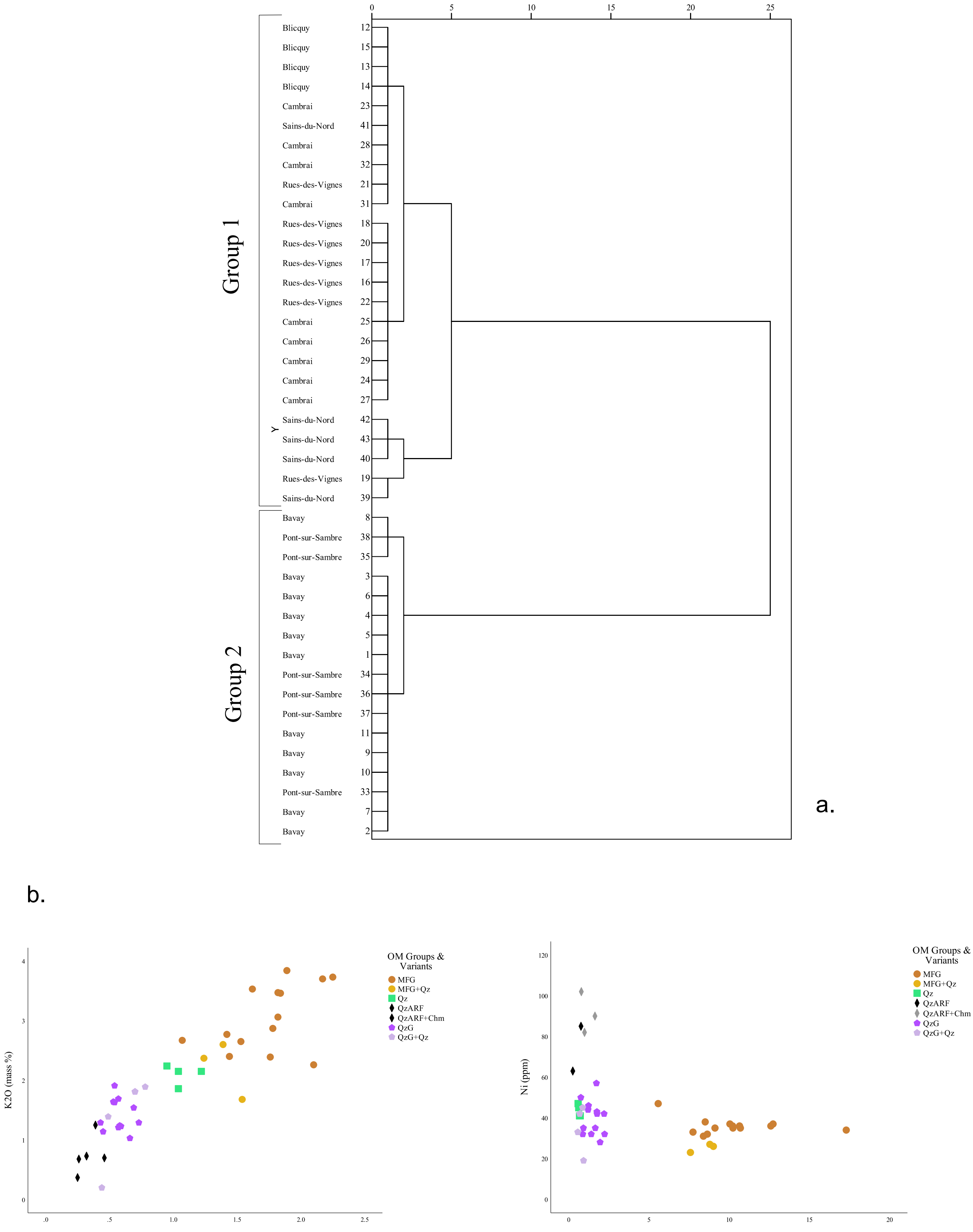

Fig. 5. Chemical classification obtained by XRF of the 43 pottery waste samples from Bavay, Pont-sur-Sambre, Les Rues-des-Vignes, Sains-du-Nord, Cambrai and Blicquy: (a) Hierarchical Cluster Analysis diagram of the 43 ceramic samples; Discrimination diagrams for (b) MgO versus K_2O and (c) CaO versus Ni of the 43 pottery waste sherds labelled according to the OM Groups and Variants as shown in Table 2.

Table 3
Chemical composition of the Roman ceramic samples from the sites at Bavay, Blicquy, Cambrai, Les Rues-des-Vignes, Sains-du-Nord, Famars and Pont-sur-Sambre, as determined by XRF: Major elements are expressed in mass%, minor and trace elements are expressed in ppm.

Sample	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P_2O_5	LOI	Total	V	Cr	Co	Ni	Cu	Zn	Pb	Rb	Sr	Y	Zr	Ba	La	Ce	Nd	Th
BA60	53.26	0.78	17.62	6.08	0.04	1.76	10.24	0.22	2.39	1.34	3.94	97.88	124	126	14	35	14	63	8	101	381	20	127	882	34	63	25	8
BA61	49.2	0.78	17.42	6.02	0.06	1.07	5.58	0.12	2.67	3.70	8.72	95.58	78	95	14	47	22	130	19	111	527	18	135	1182	29	61	37	11
BA66	57.98	0.65	14.55	4.67	0.02	1.53	7.75	0.19	2.65	0.58	8.13	98.89	96	92	11	33	15	65	15	131	230	16	111	926	30	55	21	7
BA67	57.95	0.61	13.3	4.3	0.01	1.44	8.64	0.15	2.4	0.76	9.44	99.19	90	102	8	32	10	61	6	105	249	15	153	844	25	53	20	7
BA72	45.42	0.78	17.44	6.07	0.1	1.42	10.05	0.22	2.77	2.50	9.24	96.26	115	111	12	37	21	83	17	123	460	21	125	887	42	68	23	9
BA73	52.63	0.78	17.06	5.65	0.02	1.78	9.12	0.21	2.87	1.02	6.49	97.82	100	114	13	35	12	67	22	119	268	19	136	846	34	69	30	11
BA179	66.81	0.539	11.92	3.98	0.03	1.24	7.59	0.21	2.37	0.48	4.5	99.77	87	80	9	23	16	45	20	106	196	15	131	299	16	46	18	9
BA180	65.92	0.601	13.43	4.35	0.03	1.54	9.02	0.93	1.68	0.20	1.69	99.53	100	88	12	26	14	44	13	156	254	15	130	301	25	61	31	9
BA181	58.76	0.811	17.56	6.5	0.03	2.25	8.51	0.3	3.73	0.31	0.71	99.62	122	113	12	38	16	73	27	171	222	23	149	388	32	73	27	10
BA182	56.64	0.837	17.1	5.74	0.04	1.82	10.7	0.32	3.06	0.85	2.6	99.88	120	112	14	35	20	67	34	145	311	23	163	478	37	73	30	12
BA185	55.58	0.754	17.49	5.82	0.03	1.84	8.4	0.3	3.46	1.81	4.35	100.01	122	122	16	31	9	76	32	165	306	20	140	543	33	61	26	14
BLI29	71.47	1.13	15.32	5.76	0.01	1.04	0.68	0.27	2.15	0.32	1.59	99.88	174	135	16	41	19	72	32	107	78	34	243	341	41	71	32	13
BLI34	68.01	1.08	13.72	5.64	0	1.04	0.72	0.23	1.86	0.34	6.77	99.56	167	130	14	41	22	74	27	88	66	31	257	362	33	66	34	12
BLI37	72.24	1.14	15.16	5.8	0.01	1.22	0.63	0.3	2.15	0.06	0.79	99.65	169	137	19	45	23	75	34	108	68	35	273	287	44	73	38	11
BLI39	71.04	1.17	16.88	5.41	0.01	0.95	0.59	0.22	2.24	0.12	1.12	99.9	168	140	9	47	24	81	39	112	66	38	202	298	40	75	33	12
RDV71	69.47	0.87	17.44	3.7	0.01	0.66	1.41	0.26	1.03	0.06	5.07	100.11	98	143	6	32	19	40	28	60	84	23	324	380	26	48	20	12
RDV72	71.42	1.19	17.73	2.61	0.01	0.53	1.21	0.25	1.64	0.33	2.92	100.00	108	126	8	44	17	44	28	84	122	38	293	464	40	81	35	20
RDV73	67.37	0.97	17.05	4.00	0.01	0.57	1.77	0.25	1.69	0.55	4.58	98.98	116	126	10	42	24	55	26	90	143	33	308	514	39	76	42	14
RDV74	71.74	1.01	19.5	2.88	0.01	0.44	0.93	0.13	0.2	0.17	2.34	99.43	77	150	2	19	9	15	22	17	63	22	280	141	16	26	17	10
RDV75	67.2	0.8	19.19	3.33	0.01	0.54	1.73	0.24	1.91	0.42	4.09	99.63	130	135	13	57	22	67	29	104	145	35	268	542	35	85	42	16
RDV76	72.14	1.11	19.5	2.67	0.01	0.78	0.69	0.28	1.89	0.039	0.74	100.00	142	141	10	42	18	54	32	101	92	36	271	333	39	76	35	17
RDV77	67.02	0.82	16.97	2.09	0.01	0.43	1.96	0.18	1.29	0.67	7.28	98.87	109	165	7	28	38	31	35	63	149	27	325	479	26	50	29	14
C8	70.21	0.89	20.49	4.52	0.01	0.73	0.88	0.23	1.29	0.03	0.45	99.85	132	124	7	32	26	28	21	75	77	20	201	257	30	45	21	16
C11	69.36	0.71	18.95	3.76	0.02	0.69	1.24	0.35	1.54	0.09	3.07	99.9	121	115	13	46	19	52	22	83	118	22	162	335	28	54	31	15
C12	67.35	0.78	17.35	3.58	0.01	0.59	2.21	0.31	1.23	0.32	5.78	99.65	110	116	7	42	21	36	25	64	199	22	223	531	24	55	23	17
C13	68.64	0.79	17.3	2.69	0.01	0.45	2.24	0.3	1.14	0.26	5.18	99.15	109	120	6	32	21	30	24	64	190	19	232	568	14	34	16	14
C14	69.56	0.64	17.23	3.11	0.01	0.57	1.76	0.25	1.21	0.25	4.78	99.5	103	101	12	43	15	46	25	68	148	19	137	459	31	51	24	11
C17	75.78	0.75	17.03	2.22	0.01	0.7	0.87	0.37	1.81	0.03	0.36	100.06	104	119	7	45	10	44	29	75	106	30	207	323	44	78	41	14
C18	69.88	0.75	18.59	2.34	0.01	0.54	1.66	0.35	1.63	0.13	3.88	99.9	106	117	9	35	16	39	23	80	167	21	177	552	28	50	29	13
C21	70.23	0.8	18.05	5.89	0.01	0.58	0.92	0.23	1.24	0.07	1.60	99.75	123	113	11	35	23	51	24	74	85	28	226	313	37	57	34	16
C22	75.98	0.76	17.00	2.02	0.01	0.49	0.57	0.28	1.39	0.02	0.63	99.26	101	118	7	33	18	33	25	61	79	25	224	290	26	50	26	16
C26	70.93	0.9	21.72	2.56	0.01	0.7	0.76	0.28	1.81	0.03	0.44	100.26	126	134	11	50	14	41	26	91	103	26	208	298	37	64	31	17
PSS173	51.12	0.809	18.14	5.56	0.07	2.17	12.74	0.27	3.7	0.42	4.42	99.59	120	111	14	37	21	65	25	170	332	20	133	503	33	73	24	13
PSS174	47.96	0.76	16.55	5.48	0.03	1.62	17.3	0.24	3.53	0.67	5.39	99.71	115	96	12	34	20	59	26	157	417	21	139	529	29	78	25	12
PSS175	53.29	0.855	18.74	5.97	0.03	2.1	12.6	1.35	2.26	0.32	2.19	99.88	134	115	14	36	16	67	11	280	337	23	144	447	39	75	27	12
PSS176	57.03	0.786	17.07	5.45	0.04	1.82	10.22	0.26	3.47	0.64	2.51	99.47	105	104	14	36	18	64	22	161	306	22	139	524	32	68	23	13
PSS177	54.01	0.844	18.24	5.91	0.03	1.89	10.65	0.25	3.84	0.52	3.27	99.62	134	112	13	36	18	70	27	173	287	22	150	514	35	67	31	11
PSS178	65.48	0.702	14.7	4.58	0.02	1.39	8.8	0.49	2.6	0.18	0.71	99.79	112	101	10	27	16	54	12	149	230	17	150	345	29	52	23	9
SDN1	66.64	1.39	24.09	3.79	0.08	0.25	0.26	0.07	0.37	0.17	1.86	99.07	168	156	21	63	50	59	30	27	77	28	228	138	36	81	36	15
SDN2	54.66	1.6	32.77	4.32	0.08	0.46	0.79	0.15	0.7	0.52	2.85	99.18	199	237	18	102	73	64	60	44	225	141	352	405	160	375	219	29
SDN4	62.16	1.16	20.18	3.6	0.01	0.39	0.77	0.18	1.25	0.32	8.70	98.89	110	142	16	85	24	39	32	63	88	82	213	330	104	215	108	13
SDN6	54.19	1.64	28.84	2.95	0.01	0.26	0.99	0.2	0.68	0.42	8.93	99.29	162	189	11	82	59	32	48	48	132	62	300	367	61	130	69	22
SDN7	51.8	1.21	30.07	2.5	0.02	0.32	1.64	0.29	0.73	0.53	10.11	99.47	128	192	16	90	47	36	56	50	195	146	263	434	171	363	187	26
Sample	**SiO2**	**TiO2**	**Al2O3**	**Fe2O3**	**MnO**	**MgO**	**CaO**	**Na2O**	**K2O**	**P_2O_5**	**LOI**	**Total**	**V**	**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**Pb**	**Rb**	**Sr**	**Y**	**Zr**	**Ba**	**La**	**Ce**	**Nd**	**Th**
BLI44	63.64	1.08	23.49	2.83	0.01	1.31	0.33	0.31	3.47	0.40	1.81	98.85	166	152	14	60	31	71	31	165	138	42	190	543	58	111	56	16
BLI47	44.69	0.95	20.03	6.77	0.02	1.23	9.96	0.16	2.99	2.85	6.06	95.94	114	126	11	43	21	123	36	141	506	27	166	751	38	80	35	16
FAM49	46.33	0.88	18.85	6.32	0.02	1.29	12.63	0.19	3.28	1.14	7.03	98.13	124	123	9	44	17	68	27	152	376	25	146	570	34	80	35	15
FAM170	55.66	0.757	16.21	6.11	0.11	2.22	9.89	0.24	3.1	1.60	3.68	99.73	144	125	13	38	14	85	24	134	278	19	150	457	35	69	26	10
FAM171	52.02	0.843	18.52	6.06	0	1.76	12.27	0.33	3.61	0.46	3.62	99.68	129	121	12	34	19	73	27	171	306	21	143	479	37	77	33	12
SDN74	54.98	1.36	26.86	3.66	0.01	0.18	0.92	0.17	0.33	0.62	9.78	99.00	182	184	10	54	56	23	37	11	122	34	245	249	40	74	27	20
SDN76	65.02	1.19	22.25	1.23	0.01	0.26	1.03	0.18	0.87	0.39	6.71	99.28	142	149	7	38	8	28	35	39	91	39	322	382	52	96	42	13

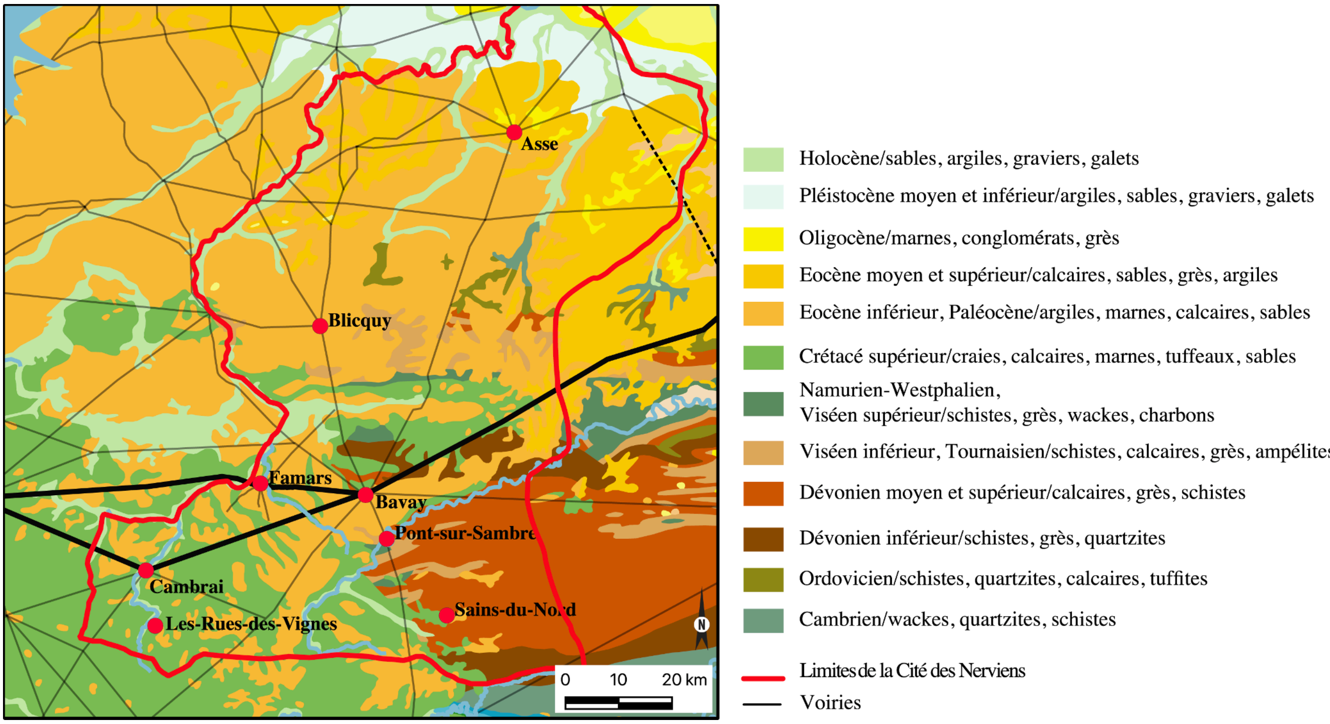

Fig. 6. Simplified geological map of the *Civitas Nerviorum*, modified after BGRM (http://sigesnpc.brgm.fr/ Geologie-en-Nord-Pas-de-Calais.html). © Raphael Clotuche and Laurent Deschodt, Inrap.

large quartz grains (Fig. 4f), and chemically by high SiO_2 and Fe_2O_3 (Fig. 7; Table 4), intermediate K_2O and MgO (Fig. 5b; Table 4) and low Al_2O_3 and CaO (Table 4; Fig. 5c, 7). It has been suggested that Roman potters at the site exploited clay sediments of Lower Eocene age, and in particular the Orchies clay (Deru et al., 2012).

The production waste from Cambrai and Les Rues-des-Vignes appears to have a similar chemical composition to the pottery from Blicquy. More specifically, pottery from Cambrai and Les Rues-des-Vignes is

Table 4
Summary of the main characteristics of the 50 Roman ceramic samples analysed by XRF from the sites of Bavay, Famars, Pont-sur-Sambre, Les Rues-des-Vignes, Cambrai, Blicquy and Sains-du-Nord. (*) the chemical data of the pottery waste samples from Famars have been published in Borgers et al., 2020a, Table 3.

Sample	Site	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5
	Bavay										
Average	(n = 11)	56.64	0.72	15.90	5.38	0.04	1.61	8.69	0.29	2.73	1.23
St. Dev.		6.38	0.10	2.15	0.88	0.02	0.33	1.43	0.22	0.56	1.07
	Blicquy										
Average	(n = 4)	70.69	1.13	15.27	5.65	0.01	1.06	0.66	0.26	2.10	0.21
St. Dev.		1.85	0.04	1.29	0.18	0.00	0.11	0.06	0.04	0.17	0.14
	Les Rues-des-Vignes										
Average	(n = 7)	69.48	0.97	18.20	3.04	0.01	0.56	1.39	0.23	1.38	0.32
St. Dev.		2.30	0.15	1.15	0.67	0.00	0.12	0.47	0.05	0.61	0.24
	Cambrai										
Average	(n = 10)	70.79	0.78	18.37	3.27	0.01	0.60	1.31	0.30	1.43	0.12
St. Dev.		2.85	0.08	1.61	1.21	0.00	0.10	0.61	0.05	0.25	0.11
	Pont-sur-Sambre										
Average	(n = 6)	54.82	0.79	17.24	5.49	0.04	1.83	12.05	0.48	3.23	0.36
St. Dev.		6.04	0.06	1.48	0.50	0.02	0.29	2.97	0.44	0.64	0.21
	Sains-du-Nord										
Average	(n = 5)	57.89	1.40	27.19	3.43	0.04	0.34	0.89	0.18	0.75	0.39
St. Dev.		6.25	0.22	5.02	0.72	0.04	0.09	0.50	0.08	0.32	0.15
	Famars (*)										
Average	(n = 3)	57.54	0.73	14.46	5.23	0.12	1.84	6.39	0.15	2.52	0.96
St. Dev.		4.30	0.10	0.65	0.31	0.03	0.38	1.92	0.05	0.17	0.46
BLI44	Blicquy	63.64	1.08	23.49	2.83	0.01	1.31	0.33	0.31	3.47	0.40
BLI47	Blicquy	44.69	0.95	20.03	6.77	0.02	1.23	9.96	0.16	2.99	2.85
FAM49	Famars	46.33	0.88	18.85	6.32	0.02	1.29	12.63	0.19	3.28	1.14
FAM170	Famars	55.66	0.757	16.21	6.11	0.11	2.22	9.89	0.24	3.1	1.60
FAM171	Famars	52.02	0.843	18.52	6.06	0.02	1.76	12.27	0.33	3.61	0.46
SDN74	Sains-du-Nord	54.98	1.36	26.86	3.66	0.01	0.18	0.92	0.17	0.33	0.62
SDN76	Sains-du-Nord	65.02	1.19	22.25	1.23	0.01	0.26	1.03	0.18	0.87	0.39

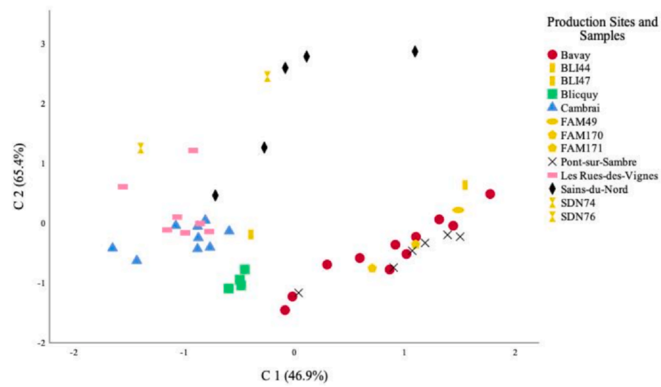

Fig. 7. Chemical classification obtained by XRF of the 50 ceramic samples from Bavay, Pont-sur-Sambre, Les Rues-des-Vignes, Sains-du-Nord, Famars, Cambrai and Blicquy. Principal Component Analysis plot with sample numbers as shown in Table 2.

defined by high SiO_2, intermediate Al_2O_3 and low CaO (Table 4; Fig. 5c, 7). This might be taken to suggest that potters at Cambrai and Les Rues-des-Vignes may have also used the Orchies clay for ceramic manufacture. However, the pottery from Cambrai and Les Rues-des-Vignes also shows important differences. More specifically, it has comparatively high Al_2O_3 (Table 4; Fig. 7) and low MgO and K_2O (Table 4; Fig. 5b), and is defined mineralogically by fine well-sorted quartz and glauconite grains (Fig. 4c). Therefore, it would seem equally possible that potters used continental Landen group clay for Roman ceramic manufacture.

As for the pottery waste from Sains-du-Nord, it is characterised mineralogically by mono-crystalline quartz and ARF (Fig. 4e), and chemically by high Al_2O_3 and low K_2O, CaO and MgO (Table 4; Fig. 5b, 5c, 7). The high value for Al_2O_3 is suggestive of a source with kaolinite clay minerals. Following on from this, Roman potters at Sains-du-Nord may have used one of two raw materials for pottery manufacture, including Entre-Sambre-et-Meuse clay or continental Landen group clay.

Several petrographic variants in this study show evidence of having been tempered with quartz or chamotte. More specifically, two samples from Les Rues-des-Vignes (RDV74, RDV76) are defined by large quartz grains (250–300 μm), and form the QzG + Qz variant. Chemically, they are characterised by comparatively high SiO_2 (Fig. 7). Rounded quartz grains (200–300 μm) may have also been added to coarse ware from Blicquy (Fig. 4f). Furthermore, three samples from Bavay and Pont-sur-Sambre (BA179, BA180, PSS178) have large grains of quartz (200–250 μm) and chert (250–300 μm; Fig. 4b), and form the MFG + Qz variant. This is also reflected in their chemical signature, which is defined by comparatively high SiO_2 (Fig. 7). Crushed fired pottery or chamotte (300–400 μm) seems to have been added to three coarse ware samples from Sains-du-Nord (SDN2, SDN6, SDN7), which form the QzARF + Chm variant (Fig. 4e). These samples are also defined by the highest Al_2O_3 value in the assemblage studied (Fig. 7).

All four pottery wares, including flagons, grinding bowls, Gallo-Belgic fine ware and coarse ware, from the six sites studied appear to have been wheel thrown. This is witnessed by spiral grooves on the interior and cutting marks on the flat base of the vessels (Rye, 1981: 75). This is confirmed in several (vertical) thin sections in this study, by means of parallel alignment of inclusions and voids to the vessel wall (Whitbread, 1996; Quinn: 176-177, 2013; Fig. 4c, d, i).

Macroscopic observation of Gallo-Belgic fine ware from Bavay, Les Rues-des-Vignes and Cambrai reveals a burnished surface layer, which is confirmed in thin section analysis by means of fining of the surface layer of the vessel walls (Fig. 4g). Surface decoration of Gallo-Belgic fine ware and coarse ware consists of continuous wavy or horizontal lines. Several grinding bowls from Bavay, Pont-sur-Sambre and Cambrai exhibit a potter's stamp on the rim (Table 1), which was applied when the vessels were leather-hard.

The firing temperature of the samples in the studied assemblage seems to have varied. The majority of the vessels from Bavay and Pont-sur-Sambre have an isotropic clayey matrix in thin section (Table 2), indicating a high firing temperature. In comparison, half of the analysed sherds from Les Rues-des-Vignes, Cambrai and Sains-du-Nord have an anisotropic matrix under the petrographic microscope (Table 2), suggesting a low firing temperature. This suggests that potters rejected their products for other reasons than overfiring.

Two possible reasons for discard have been identified. First, several grinding bowls from Bavay and Pont-sur-Sambre show considerable variation in the surface colour, a defect known as 'fire clouding' and caused by uneven air distribution in the kiln during firing (Rye, 1981: 120-121). Second, the presence of a substantial number of complete detached handles at Bavay, further indicates that flagons have cooled too quickly at the end of the firing process (Peña, 2007: 33).

Flagons, storage jars and grinding bowls from the studied workshops were tendentially fired in oxidizing atmosphere, while Gallo-Belgic pottery and coarse ware were fired in reducing conditions. Given that the clay source used at Bavay and Pont-sur-Sambre was CaO-rich with a moderate Fe_2O_3 content (Tables 3 and 4), the oxidised ceramics from these sites have a cream colour in hand specimen (Table 1; Molera et al., 1998; Borgers et al., 2020a). In comparison, the light buff colour of flagons and grinding bowls from Cambrai (Table 1) can be explained by the Fe_2O_3-poor and CaO-poor clay source used for their production (Tables 3 and 4; Borgers et al., 2020b). The examined Gallo-Belgic pottery and coarse ware have a black and grey colour respectively (Table 1), as the result of firing in a reducing kiln atmosphere (Maniatis et al., 1983; Maritan et al., 2005).

6. Compositional classification of pottery from burial, settlement and sanctuary sites

Thin section petrographic analysis indicated the presence of three main groups among the seven samples analysed from the sites at Famars, Sains-du-Nord and Blicquy. They are similar to the groups that have been identified at the production sites studied and include samples from the 1) 'MFG', 2) 'QzARF', and 3) 'QzG' groups (Table 2).

1) Four samples are characterised by microfossils and glauconite (FAM 170, FAM49, FAM171, BLI47; Table 2; Fig. 4g) and appear to be similar to the **MFG** group. Sub-angular quartz inclusions and glauconite are well-sorted and measure between 100 and 150 μm. Fine quartz grains, mica and iron aggregates occur in the matrix, as well as dispersed carbonate grains. The clayey matrix of two samples is isotropic with low birefringence (FAM170, FAM171; Table 2), while the matrix of the two other samples is anisotropic with high birefringence (FAM49, BLI47; Table 2). The samples comprise two grinding bowls and a face pot from settlement sites at Famars, which date to Periods 3 and 4, as well as a face pot from a burial site at Blicquy, which dates to Period 4 (Table 1).
2) Two samples are defined by quartz grains and ARF (SDN74, SDN7; Table 2; Fig. 4h). The size of the quartz grains varies between 200 and 300 μm, while the ARF measure between 300 and 400 μm. Their composition resembles the **QzARF** group. The clayey matrix of both samples has a high birefringence (Table 2). Both samples include Gallo-Belgic flasks from a sanctuary at Sains-du-Nord, which dates to Period 2 (Table 1).
3) One sample (BLI44) is characterised by fine well-sorted mono-crystalline quartz grains and mica, as well as some iron aggregates and glauconite pellets, whose size varies between 50 and 100 μm (Table 2). The composition of this sample appears to be similar to the **QzG** group. The clayey matrix of the sample is anisotropic with high birefringence (Table 2; Fig. 4i). The sample comprises a face pot from a burial site at Blicquy, which dates to Period 4 (Table 1).

Principal Component Analysis (PCA) conducted on the log-transformed concentrations of the 19 elements revealed that Components 1 and 2 account for 65.4% of the total variance in the dataset. By plotting these against one another, it is possible to define two chemical groups within the 50 sherds analysed (Fig. 7). Sr, Fe_2O_3, CaO (positive contribution), as well as SiO_2 (negative contribution), strongly affect Component 1, while Al_2O_3 and Cr score heavily for Component 2.

A comparison of the HCA classification of 43 ceramic samples (Fig. 5a) and PCA classification of the 50 samples analysed (Fig. 7) indicates that they correspond well with one another. As with the HCA, samples from Pont-sur-Sambre and Bavay classify within Chemical Group 2, while samples from Blicquy, Cambrai, Les Rues-des-Vignes and Sains-du-Nord equate to Chemical Group 1. Within Chemical Group 1, samples from Sains-du-Nord are defined by a comparatively high Al_2O_3 and Cr. As for the PCA classification of the seven samples from burial, settlement and sanctuary sites, they fall within the two chemical groups identified.

More specifically, three samples from Sains-du-Nord and Blicquy (SDN74, SDN76; BLI44) are defined by high Al_2O_3 (22–26 mass%) and low CaO (0.33–1.03 mass%) and equate to Chemical Group 1. Within Chemical Group 1, which includes samples from Sains-du-Nord, Les Rues-des-Vignes, Cambrai and Blicquy, the two samples from Sains-du-Nord seem compositionally related to the production waste of this site, as suggested by their comparatively high Al_2O_3 and Cr (Table 3; Fig. 7) and presence of ARF (Fig. 4h). As for the sample from Blicquy, it appears more closely related to the production waste of Les Rues-des-Vignes and Cambrai, as suggested by the presence of fine well-sorted quartz grains, mica, iron aggregates and glauconite (Fig. 4i).

Regarding the four remaining samples from Famars and Blicquy (FAM49, FAM170, FAM171, BLI47), they are defined by comparatively high CaO (9.89–12.63 mass%), high Fe_2O_3 (6.06–6.77 mass%) and high Sr (306–506 ppm), and classify within Chemical Group 2 (Fig. 7; Table 3). Their composition is related to the production waste from Bavay and Pont-sur-Sambre. This is confirmed by the presence of microfossils, glauconite and carbonate in the clayey matrix (Fig. 4g).

7. Discussion

Detailed compositional analysis of pottery waste from the six workshops in the *Civitas Nerviorum* has provided insight in their production technologies between the 1st and 3rd centuries CE, and has permitted to shed light on possible knowledge transfer between the workshops studied. This, in turn, has allowed to tentatively infer the production location of three conspicuous pottery types that have been widely distributed within and beyond the study region.

There is a broad split between the workshops of Bavay and Pont-sur-Sambre (in the southwestern part of the *Civitas Nerviorum*) on the one hand, and Blicquy (in the centre), Cambrai and Les Rues-des-Vignes (in the southwest) and Sains-du-Nord (in the southeast) on the other (Fig. 1). These are distinctive in terms of the pottery wares they manufactured as well as the raw materials and production technologies used, permitting to shed light on transferred or shared technological knowledge between the workshops. More specifically, the workshops of Bavay and Pont-sur-Sambre mainly produced grinding bowls and flagons in Period 1 (at Bavay) and Periods 2 and 3 (at Pont-sur-Sambre). They have a cream colour, as they were produced with CaO-rich clay deposits (Tables 3 and 4) and fired in an oxidising atmosphere (Table 1). Given that the data indicate the potters used similar raw materials and technologies at both sites, Loridant's hypothesis (2001) regarding technological transfer from Bavay to Pont-sur-Sambre seems to be confirmed. Moreover, when the epigraphic evidence on the grinding bowls is taken into account, insight into how potters transferred their craft knowledge might be gained. More specifically, potters at Bavay (Period 1) and Pont-sur-Sambre (Periods 2 and 3) stamped their grinding bowls with 'BRARIATVS' (Table 1), suggesting that they transferred their workshop from Bavay to Pont-sur-Sambre. Further to this, grinding bowls with stamp 'VACASATVS BRARIATI F', which have been found at Braives (Brulet, 1981: 178–179 Fig. 73n. 5), further indicate that this craftmanship was passed on through kinship.

Potters at Blicquy, Cambrai, Les Rues-des-Vignes and Sains-du-Nord mainly manufactured Gallo-Belgic fine ware and coarse ware during Periods 2 and 3 (Table 1). Potters at Blicquy used a SiO_2-rich clay with moderate Fe_2O_3 content (Tables 3 and 4), while potters at Les Rues-des-Vignes and Cambrai also employed a SiO_2-rich clay deposit, albeit with comparatively high Al_2O_3 and Fe_2O_3 (Tables 3 and 4). The data in this study indicate that potters at Cambrai and Les Rues-des-Vignes employed similar raw materials and technologies to produce complementary pottery wares during Periods 2 and 3. Therefore, it would seem to follow that potters at these two workshops shared technological knowledge. As for the pottery waste from Sains-du-Nord, it is defined by the highest Al_2O_3 in the studied assemblage (Tables 3 and 4), indicating a distinctive technological knowledge. The coarse ware and Gallo-Belgic pottery produced at the four workshops have a typical grey or black colour from firing in reducing conditions.

The reconstruction of the technological knowledge used at the six workshops of Bavay, Les Rues-des-Vignes, Cambrai, Pont-sur-Sambre, Blicquy and Sains-du-Nord aids to tentatively infer the production location of the three types of grinding bowls, face pots and Gallo-Belgic fine ware flasks, which have been found on settlement, burial and sanctuary sites at Famars, Blicquy and Sains-du-Nord respectively.

Two grinding bowls (FAM170, FAM171) - one of which with stamp 'VXPVRO' (FAM170) - and a face pot (FAM49) from settlement contexts at Famars, in addition to a face pot from a burial site at Blicquy (BLI47), date to Periods 3 and 4 and have a cream colour in hand specimen (Table 1). Compositionally, they are defined by a CaO-rich clay (Tables 3 and 4) with glauconite and microfossils (Table 2; Fig. 4g). These four samples bear compositional similarities to the pottery waste from Bavay and Pont-sur-Sambre (Fig. 7). From a purely compositional point of view then, one could tentatively infer that the four samples were produced at one of these two workshops. However, when the broader archaeological background is taken into account, a more complex picture emerges for at least four reasons.

First, whilst grinding bowls are known to having been manufactured at Bavay, archaeological evidence indicates that pottery production at the site ceased after Period 1. Second, while grinding bowls have also been produced at Pont-sur-Sambre during Periods 2 and 3, no evidence for manufacture of face pots has been found at the site. Third, cream ware grinding bowls were also produced at the site of Famars during Period 3. And finally, three of the four samples analysed are dated to Period 4 (Table 1) – *i.e.*, a period where many settlements in the *Civitas Nerviorum*, including Bavay and Pont-sur-Sambre, seem to have been abandoned or contracted (Kasprzyk and Monteil, 2017), and no evidence for cream ware manufacture has been found within the study region. Only the settlement at Famars appears to have been reorganised during Period 4 (Clotuche et al., 2017), and produced coarse ware at this time (Willems et al., 2017).

Following on from this, the composition of the grinding bowl with stamp 'VXPVRO' (FAM170), which is dated to Period 3 (Table 1), was compared with the composition of the pottery waste from Bavay and Pont-sur-Sambre, as well as with the pottery waste from Famars. Given that the technological signature of grinding bowls from Famars has been determined elsewhere (Borgers et al., 2020a), the average of their chemical data has been used in this study for comparative purposes (Table 4). As can be seen in Table 4, the chemical composition of the grinding bowl with stamp 'VXPVRO' (FAM170) is more closely related to the pottery from Pont-sur-Sambre than to the ceramics from Bavay and Famars. Following on from this, it is tentatively suggested that this particular (stamped) grinding bowl was produced at Pont-sur-Sambre. This hypothesis is supported by the archaeological data, *i.e.,* the production period of stamped grinding bowls at Pont-sur-Sambre coincides with the date of the grinding bowl with stamp 'VXPVRO' (Willems, 2019).

As for the remaining grinding bowl (FAM 171) and two face pots from Famars (FAM49) and Blicquy (BLI47), they have been found in settlement and burial sites, dated to Period 4 (Table 1). The three samples have a cream colour in hand specimen (Table 1), and are characterised by microfossils and glauconite (Table 2; Fig. 4g) in a CaO-rich clay (Fig. 7; Table 3). Following on from this, their compositional signature is closely related to the pottery waste from Pont-sur-Sambre (Table 4). However, during Period 4, the settlement at Pont-sur-Sambre dwindled, and pottery production seems to have ceased. Famars is one of the few sites in the *Civitas Nerviorum* where life continued, albeit reorganised, as suggested by the reconstructed buildings and construction of a military fort (Clotuche et al., 2017), and where coarse ware production has been attested at that time (Willems et al., 2017). Combined with the mould of a face pot, which was found on site (Flahaut et al., 2014), it is tentatively suggested that production of grinding bowls and face pots continued during Period 4 at Famars, even if the argument is one of absence.

The two Gallo-Belgic flasks from the sanctuary at Sains-du-Nord have a black colour in hand specimen and date to Period 2 (SDN74, SDN76; Table 1). Compositionally, the two samples are defined by quartz grains and ARF (Table 2; Fig. 4h) in an Al_2O_3-rich clay (Tables 3 and 4; Fig. 7). Their composition appears to be similar to the pottery waste from the site, which is dated to Period 3. If indeed the flasks have been produced locally, as the compositional data suggest, then it might be tentatively inferred that pottery production at Sains-du-Nord commenced during Period 2, as suggested by Willems and Neaud (2019), even if this is not supported by kilns or pottery waste found.

The last sample (BLI44) is a face pot, which stems from a burial site at Blicquy. It has a light buff colour in hand specimen, and dates to Period 4 (Table 1). Mineralogically, the sample is characterised by fine well-sorted quartz grains, and rare glauconite pellets and iron aggregates (Table 2; Fig. 4i). According to the PCA (Fig. 7), the composition of the face pot is similar to the production waste from Les Rues-des-Vignes and Cambrai, which dates to Periods 2 and 3. However, close inspection of the chemical data (Tables 3 and 4) indicate that the sample is defined by comparatively high Al_2O_3 and K_2O, and low SiO_2. These differences indicate that the face pot was produced in a hitherto unknown workshop.

8. Conclusions

The *Civitas Nerviorum*, which covered present-day northern France and central Belgium, is known for its numerous pottery workshops, dated to between the 1st and 3rd centuries CE. The overarching aim of this paper was to reconstruct the technologies of Roman ceramics produced at six workshops in the study region, including Bavay, Pont-sur-Sambre, Blicquy, Cambrai, Les Rues-des-Vignes and Sains-du-Nord. To this aim, 43 samples of grinding bowls, flagons, coarse ware and Gallo-Belgic fine ware were selected from the six workshops, analysed using OM and XRF, and combined with observation of macroscopic and epigraphic evidence of the fragments. The results were then used to tentatively infer the production location of three conspicuous types of grinding bowls, face pots and Gallo-Belgic fine ware flasks, which were widely distributed within the study region but hitherto not identified in production waste of the various workshops in the *Civitas*. To this aim, seven samples from settlement, burial and sanctuary sites at Famars, Blicquy and Sains-du-Nord were selected and analysed using OM and XRF analysis.

The results have permitted to reconstruct the production technologies used at the six workshops in the *Civitas Nerviorum* and allowed to identify potters' transfer and sharing of technological knowledge. More specifically, potters who used a CaO-rich clay for the production of cream ware flagons and grinding bowls at Bavay (during Period 1) transferred their knowledge to potters, who were active at Pont-sur-Sambre (during Periods 2 and 3). Additional epigraphic evidence on the grinding bowls allowed to infer that potters passed on their craftsmanship trough kinship. Potters at Blicquy used a SiO_2-rich clay with moderate Fe_2O_3 content for the manufacture of grey coarse ware, while potters at Sains-du-Nord sourced an Al_2O_3-rich clay for the production of grey coarse ware. As for the potters at Cambrai and Les Rues-des-Vignes, they used similar raw materials (*e.g.*, clay with low Fe_2O_3 and CaO) and technology for the production of black Gallo-Belgic pottery and coarse ware (during Periods 2 and 3).

Regarding the provenance of the grinding bowls, face pots and Gallo-Belgic flasks, from sanctuary, settlement and burial contexts, the results are encouraging, albeit not conclusive. More specifically, the composition of the two Gallo-Belgic flasks from a sanctuary at Sains-du-Nord (dated to Period 2) is similar to the production waste found at the site (dated to Period 3). This confirms the hypothesis that pottery production at Sains-du-Nord may have commenced earlier than the archaeological evidence (in the form of kilns and pottery waste) suggests. The results further indicate that the grinding bowl with stamp 'VXPVRO', which was found in a settlement context at Famars, may have been produced at Pont-sur-Sambre. As for the two face pots and grinding bowl, which have been found at settlement and burial sites of Famars and Blicquy, their composition is similar to the pottery waste from Pont-sur-Sambre. However, the three objects date to Period 4, and pottery production at the site seems to have ceased by that time. Some indications from the broader archaeological context point to Famars as the (next) possible production location. Finally, the composition of the face pot from a burial site at Blicquy does not match any production technology reconstructed in this study. Therefore, its provenance remains to be determined.

Acknowledgements

The research presented in this study forms part of a doctoral study ('La Céramique gallo-romaine du Haut-Empire produite chez les Ménapiens, Atrébates et Nerviens') undertaken at the Université Paris Nanterre. The authors thank the Institut National de Recherches Archéologiques Préventives (Inrap) and the Service Régional de l'Archéologie (SRA), Nord-Picardie France, for their financial support through the respective projects « Caractérisation des productions céramiques dans le nord du Bassin parisien », and « Fanum Martis: Une agglomération à vocation religieuse, commerciale et militaire à la frontière du territoire nervien. Le pagus Fanomartensis, un terroir spécifique? ». BB also acknowledges financial support of the Austrian Science Fund through the FWF project T -1085G. Several Inrap and museum staff generously provided the ceramic samples analysed: Evelyne Gillet for the pottery from Blicquy, Laurent Bouthor, Véronique Beirnaert-Mary, Laure de Chavagnac and David Labarre for the pottery from Bavay, Patrice Herbin, Denis Gaillard and Frédéric Loridant (†) for the pottery from Cambrai, Les Rues-des-Vignes, Pont-sur-Sambre and Sains-du-Nord, Pascal Neaud for the pottery from Sains-du-Nord, as well as Jennifer Clerget and Géraldine Teysseire for the pottery from Famars. The authors thank Fabienne Vilvorder and Charlotte Kettel for their helpful suggestions, as well as the two anonymous reviewers for their comments, which have improved the manuscript. All scientific preparations analysed are held by the corresponding author, and can be accessed for comparative purposes with prior arrangement.

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