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Diverging productions or not? A preliminary exploration of the chemical composition of Neolithic Vlaardingen Pottery

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ARTEFACT BIOGRAPHIES FROM MESOLITHIC AND NEOLITHIC EUROPE AND BEYOND

Papers in honour of Professor Annelou van Gijn

52

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A. VERBAAS, G. LANGEJANS, A. LITTLE
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Diverging productions or not? A preliminary exploration of the chemical composition of Neolithic Vlaardingen Pottery

Dennis Braekmans

Abstract
This paper is an exploratory study into the variability of sherds found at the Neolithic sites of Vlaardingen and Steynhof in the Western part of the Netherlands. Neolithic ceramics can be highly variable and determining discrete fabrics, and especially their use, technology and provenance can often be problematic. In total 44 sherds of these sites were analysed here with porTable X-ray fluorescence in an exploratory fashion in order to assess whether systematic differences occur that need further differentiation. The results obtained in this study highlight the possibility of two different resources for the production of pottery that was employed, with especially Steynhof showing more chemical variation than Vlaardingen in this small-scale study, potentially indicating a more diverging selection and preparation of raw materials for the production of pottery.

X-ray fluorescence (XRF), pottery production, Vlaardingen, Steynhof, Neolithic, the Netherlands

1 Introduction
This paper is written in order to celebrate Professor Annelou van Gijn's distinguished career. Annelou van Gijn always supported and pioneered creative ways to handle, document and research archaeological objects with an unwavering interest in all sorts of materials and technological processes. Over the past few years this also resulted in a research line at Leiden University that encompassed the study of traces on Ceramic materials (BEFIM project) (*e.g.* Van Gijn *et al.* 2020) and subsequently returned to a research interest from the past close to home, the Neolithic Vlaardingen culture or Vlaardingen Group (Glasbergen *et al.* 1967a; 1967b; Van Regteren Altena *et al.* 1962a; 1962b; 1962c; Amkreutz 2010; Amkreutz *et al.* 2016). An assemblage of ceramic artefacts consisting of Neolithic Vlaardingen pottery has been collected for archaeometric research as part of Annelou van Gijn's Archeologie-Telt project in 2021 (https://www.puttinglife.com/). After working together with Annelou for approximately a decade in delivering Material Culture and Materials Science courses across the Bachelor and Master curriculum at the faculty of Archaeology at Leiden University, it is a tremendous opportunity to formally conduct collaborative research as well for the upcoming years.

While the study is geared towards the petrographic and technological study of the selected ceramics, the opportunity occurred to conduct an explorative

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	Find number	Sherd number	Typology	Site/date
1	479	479-24B4	Base	Vlaardingen AK
2	479	479-10B4	Base	Vlaardingen AK
3	459a	64-459-25	Base	Vlaardingen AK
4	459a	64-459-24	Rim	Vlaardingen AK
5	349a	64-349-06	Body	Vlaardingen AK
6	449a	64-449-01	Rim	Vlaardingen AK
7	355b	64-355-04	Rim	Vlaardingen AK
8	522a	64/522-03	Rim	Vlaardingen AK
9	522a	64/522-01	Rim	Vlaardingen AK
10	520a	64-520-01	Rim	Vlaardingen AK
11	458b	64-458-25	Rim	Vlaardingen AK
12	450a	64-450-37	Base	Vlaardingen AK
13	458a	64-458-26	Rim	Vlaardingen AK
14	-	32-02	Rim	Vlaardingen AK
15	65	65-01/’64	Rim	Vlaardingen AK
16	382	64-383-05	Rim	Vlaardingen AK
17	523a	64-523-03	Rim	Vlaardingen AK
18	531a	64-531-06	Rim	Vlaardingen AK
19	392a	64-392-04	Rim	Vlaardingen AK
20	172a	64-172a-01	Rim	Vlaardingen AK
21	1220	STY170-001220.2	Body	Steynhof
22	560	STY170-000560.4	Rim	Steynhof
23	591	STY170-000591	Rim	Steynhof
24	1455	STY170-001455	Rim	Steynhof
25	1165	STY170-001165	Base	Steynhof
26	986	STY170-000986	Base	Steynhof
27	341	STY170-000341	Rim	Steynhof
28	1364	STY170-001364.3	Rim	Steynhof
29	1226	STY170-001226	Body	Steynhof
30	887	STY170-000887	Rim	Steynhof
31	1364	STY170-001364.4	Body	Steynhof
32	327	STY170-000327.2	Rim	Steynhof
33	1249	STY170-001249	Rim	Steynhof
34	1236	STY170-001236.2	Rim	Steynhof
35	583	STY170-000583	Rim	Steynhof
36	420	STY170-000420	Rim	Steynhof
37	314	STY170-000314	Rim	Steynhof
38	526	STY170-000526.4	Rim	Steynhof
39	1563	STY170-001563	Base	Steynhof
40	1549	STY170-001549	Rim	Steynhof
41	415	STY170-000415	Rim	Steynhof
42	1159	STY170-001159.2	Rim	Steynhof
43	503	STY170-000503.1	Rim	Steynhof
44	503	STY170-000503.2	Rim	Steynhof

Table 1 List of all analysed sherds.

chemical study as well, of which the first outcomes are presented here and can be a stepping stone for further data collection, geochemical analysis and contributes to reconstruct the raw material selection and manufacturing processes.

Defining and classifying clay and ancient ceramic provenance groups in the Netherlands is often very difficult due to the similar sediments, especially in the coastal areas of the Netherlands. This preliminary study wishes to explore if and how these types of ceramics can be characterised through non-destructive X-ray fluorescence analysis (XRF). The primary goal here is to assess the consistency of the compositional features in the studied pottery assemblages.
This information can subsequently contribute to understand exchange mechanisms between these two sites and can act as a baseline for variability in the comparison with local and regional communities. Additionally, it aims to assess the validity of portable XRF spectrometry for this type of materials and its provenance resolution in the Netherlands.

2 Materials and methods

The material studied here consists of sherds selected for residue and petrographic analyses (cf. forthcoming publications of the Archeologie-Telt project) and are derived from two (Vlaardingen) sites, respectively Vlaardingen AK (Arij Koplaan) (n=20) and Den Haag Steynhof (n=24) (table 1). The dataset consists mostly of diagnostic rim and base pieces, which will be further studied as part of the ongoing ArcheologieTelt project.

As an explorative method to assess the chemical composition of these ceramics next to petrographic and other analytical studies, portable (or handheld) X-ray fluorescence (hXRF/pXRF) was selected (Tykot 2018). The use of this technique received considerable criticism but developed operating procedures provided successful applications over the past decade (Young *et al.* 2016; Speakman and Shackley 2013; Holmqvist 2016). The main advantage being the good range of elements, portability and non-destructive nature of the analysis. This debate pushed towards a shared set of standard operating procedures, which are currently applied in archaeological science in general for various types of materials (*e.g.* Rowe *et al.* 2012; Shugar and Mass 2012; Heginbotham and Solé 2017; Hunt and Speakman 2015; De Winter *et al.* 2017; Frahm *et al.* 2022).

Handheld equipment (Bruker Tracer III-SD) was utilised out to define the chemical composition of the selected ceramics in order to identify (in)consistencies. The instrument is equipped with an Rh anode X-ray tube and a Peltier-cooled Silicon Drift Detector (~145 eV at MnKa). Spot size is approximately in the range of 10 mm^2. Because of homogeneity considerations and the spot size of a pXRF device, analysis was concentrated on flat surfaces of both fabric and surface areas to achieve the most consistent bulk chemical data.

In general, the ceramics themselves do show a macroscopically heterogeneous texture and occasional visible larger grains were avoided as much as possible. Measurements were taken in air for 120 seconds, using a 150 μm Cu, 25 μm Ti, and 300 μm Al filter, with beam conditions of 40 keV and 14 μA. In this study net intensities (obtained through a Bayesian approach in proprietary Bruker Artax software) were used to differentiate the assemblage of ceramics on a relative scale.
In future studies, if variation is systematic and validated, a custom empirical calibration developed at Ceramics Laboratory at Leiden will be employed for semi-quantitative results, that will be ready for comparative studies with both clay and other contemporary ceramic materials from the region and period under study. Elements considered here are: Ca, Cr, Cu, Fe, K, Mn, Nb, Ni, Rb, Sr, Ti, Y, Zn and Zr.

The measurements were evaluated by an assessment of net intensities through bivariate diagrams, as well as by means of commonly applied multivariate statistical procedures such as principal component analysis (PCA). Prior to statistical processing the data were normalised at the Compton peak. Principal Component Analysis is widely applied as a pattern-recognition technique, by means of identifying subgroups in the compositional data and ideally suited for archaeological case-studies as well (Baxter 2001; Michelaki and Hancock 2011). After PCA a visual output is often displayed in the form of a biplot. These represent reference axes as calculated by the statistical procedure arranged by a decreasing order of variance. It is important to note the contribution of specific elements to validate the obtained groupings/separations.

3 Results and Discussion

A first step in the exploration of the chemical data is to establish if any correlations are present between the elements analysed. These correlation matrices are, under normal conditions, computations of Pearson product-moment correlations. Because of the generally, not normal distributed nature of our chemical data, a

	Ca	Cr	Cu	Fe	K	Mn	Nb	Ni	Rb	Sr	Ti	Y	Zn	Zr
Ca	1.000	-0.202	0.134	0.109	0.184	0.446	-0.034	-0.162	0.117	0.443	-0.335	0.023	-0.288	-0.134
Cr	-0.202	1.000	0.076	0.028	-0.045	-0.135	0.189	0.283	0.005	-0.148	0.321	-0.018	0.136	0.131
Cu	0.134	0.076	1.000	0.162	0.276	0.063	0.300	0.167	0.453	0.356	0.152	0.360	0.139	0.165
Fe	0.109	0.028	0.162	1.000	0.314	0.287	0.214	-0.119	0.457	0.292	0.006	-0.058	0.251	-0.255
K	0.184	-0.045	0.276	0.314	1.000	0.416	0.118	-0.096	0.709	0.222	-0.043	-0.230	-0.031	-0.169
Mn	0.446	-0.135	0.063	0.287	0.416	1.000	-0.209	-0.074	0.382	0.087	-0.240	-0.299	-0.183	-0.301
Nb	-0.034	0.189	0.300	0.214	0.118	-0.209	1.000	0.177	0.179	0.244	0.616	0.513	0.007	0.451
Ni	-0.162	0.283	0.167	-0.119	-0.096	-0.074	0.177	1.000	-0.035	-0.076	0.220	0.308	0.160	0.051
Rb	0.117	0.005	0.453	0.457	0.709	0.382	0.179	-0.035	1.000	0.226	-0.003	-0.231	0.110	-0.233
Sr	0.443	-0.148	0.356	0.292	0.222	0.087	0.244	-0.076	0.226	1.000	0.232	0.106	0.033	-0.073
Ti	-0.335	0.321	0.152	0.006	-0.043	-0.240	0.616	0.220	-0.003	0.232	1.000	0.267	-0.007	0.385
Y	0.023	-0.018	0.360	-0.058	-0.230	-0.299	0.513	0.308	-0.231	0.106	0.267	1.000	0.175	0.490
Zn	-0.288	0.136	0.139	0.251	-0.031	-0.183	0.007	0.160	0.110	0.033	-0.007	0.175	1.000	-0.041
Zr	-0.134	0.131	0.165	-0.255	-0.169	-0.301	0.451	0.051	-0.233	-0.073	0.385	0.490	-0.041	1.000

Table 2 Spearman Correlation matrix of analysed elements. Data in red is significant at $p<0.05$.

correlation matrix based on non-parametric statistics was constructed using Spearman Ranked Order correlations (table 2).

Positive or negative correlations frequently occur between elements as some elements are commonly geologically associated in mineral or rock fragments. Unexpectedly here, there is no clear and significant correlation that can be identified. A relative strong positive correlation exists between K and Rb and between Nb and Ti to a lesser extent, the latter probably relating to a heavy mineral presence. K is a common element present in K-feldspars and various alteration products, also K^+ can furthermore be absorbed by clays. High K values usually relate with the clay material content in argillaceous sediments. In coarser fractions the K value is mainly correlated with K-feldspars and K-mica (*e.g.* muscovite). It was noted K content usually rises when the granularity of the sediment decreases. Moreover, K has very similar atomic and ionic properties as Rb, and are thus likely to have positive correlation factors. A differentiation relative to K is expected in the felsic fraction as the K/Rb ratio will decrease. Furthermore, in weathering processes Rb is closely related to K, especially in the formation of clays from weathered micas and feldspars. This result however would implicate that contributions of these different elements might not have a single origin, *e.g.* from the presence of certain minerals or rocks, but are rather facilitated by different sources, both clay and inclusion based, yielding these non-consistent values (Degryse and Braekmans 2014).

To establish the variability in chemical composition within the location of the finds as well as between them, several bivariate diagrams are shown (figs. 1-4) which provides a graphical output of the relative chemical differences. From these results it can be established that a wider variation exists within the Steynhof assemblage than the samples from Vlaardingen. In fig. 1 the consistency of the Vlaardingen group (VL) is clear considering the Zr content, and by extent has a similar heavy mineral related content. Sherds at Steynhof show both a higher Zn containing as well as Zr containing group.

In a subsequent bivariate diagram (fig. 2), the Vlaardingen group show a higher Rb and Fe content, although the latter might also be subdivided. While these Vlaardingen results are corresponding in part to Steynhof, also a low Fe and Rb composition, diverging from the Vlaardingen samples can be identified.

It can be noted that the ceramic materials from Vlaardingen have a higher variability in their Ca composition opposed to the sherds from Steynhof which show a more restricted range in Ca composition. However, when combined with Fe, clearly two different groups (low and high Fe) seem to occur (fig. 3).

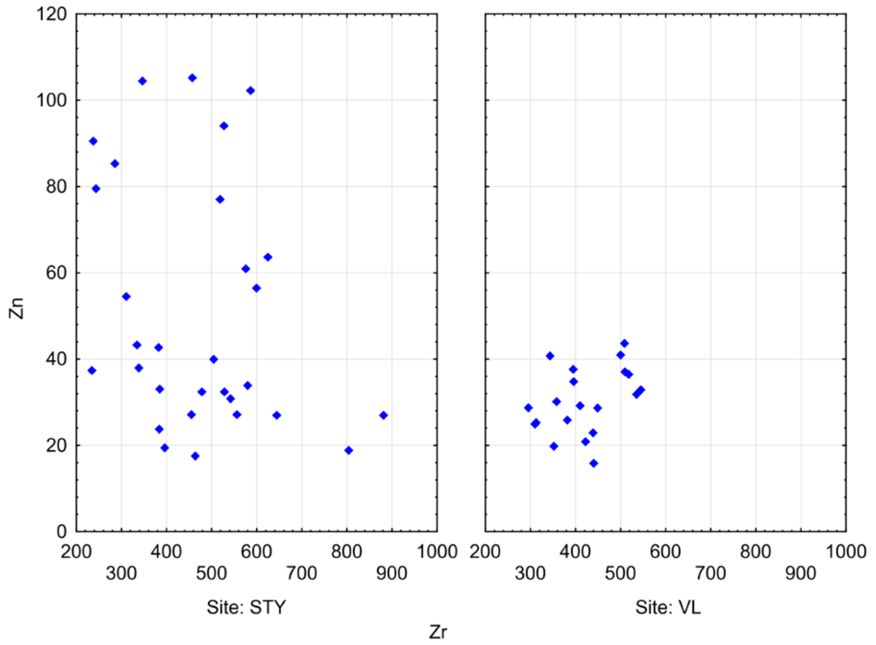

Figure 1 A bivariate plot of normalised net intensities of Zn versus Zr.

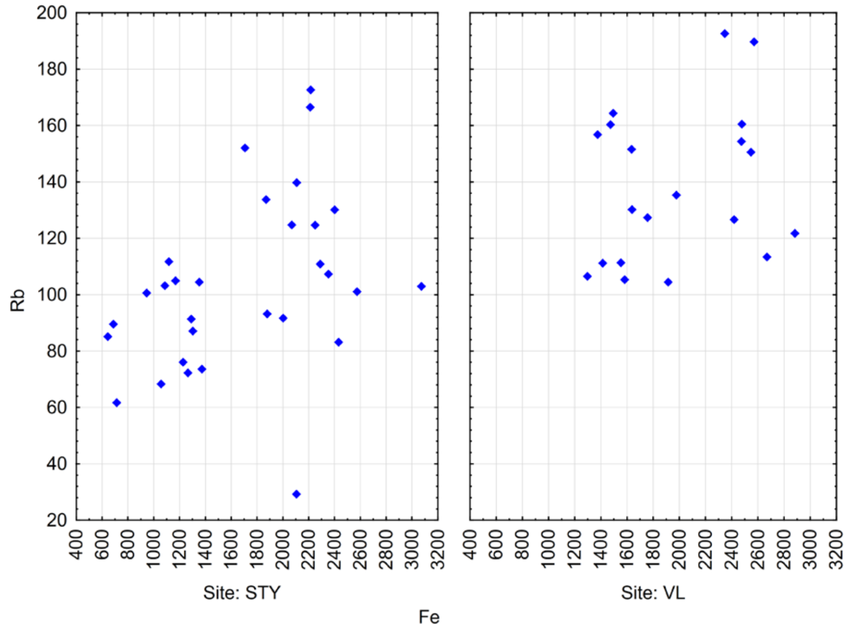

Figure 2 A bivariate plot of normalised net intensities of Fe versus Rb.

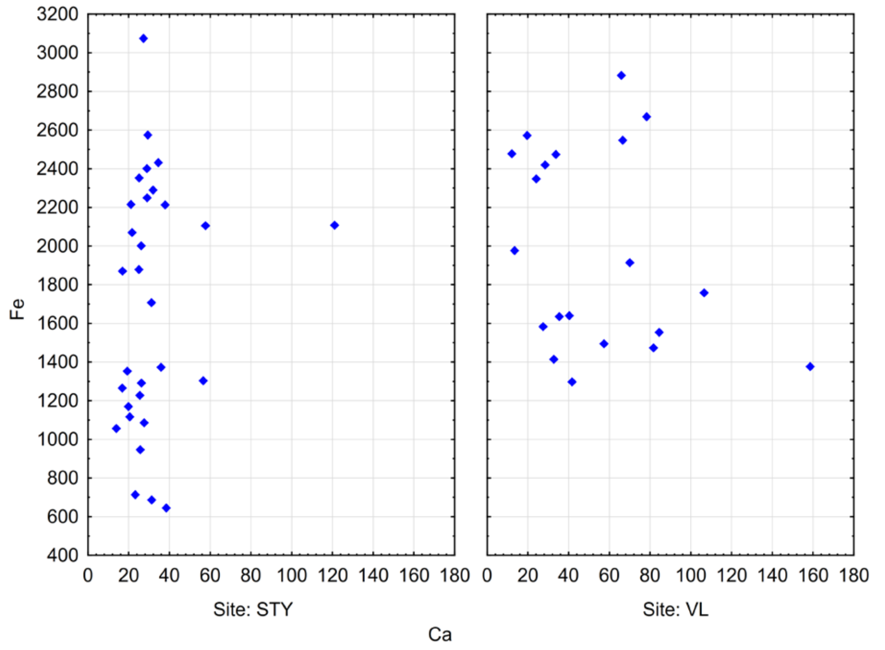

Figure 3 A bivariate plot of normalised net intensities of Ca versus Fe.

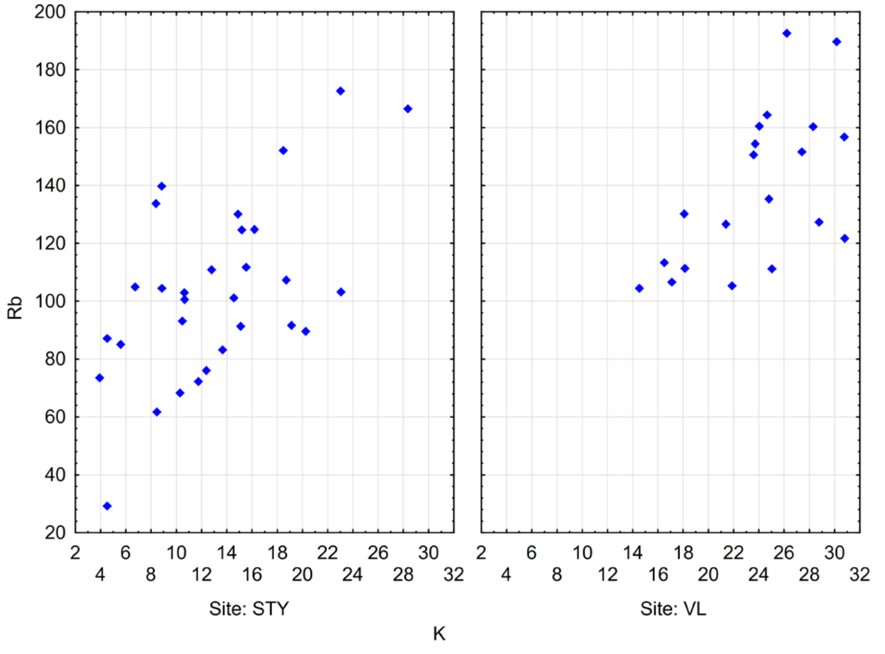

Figure 4 A bivariate plot of normalised net intensities of K versus Rb.

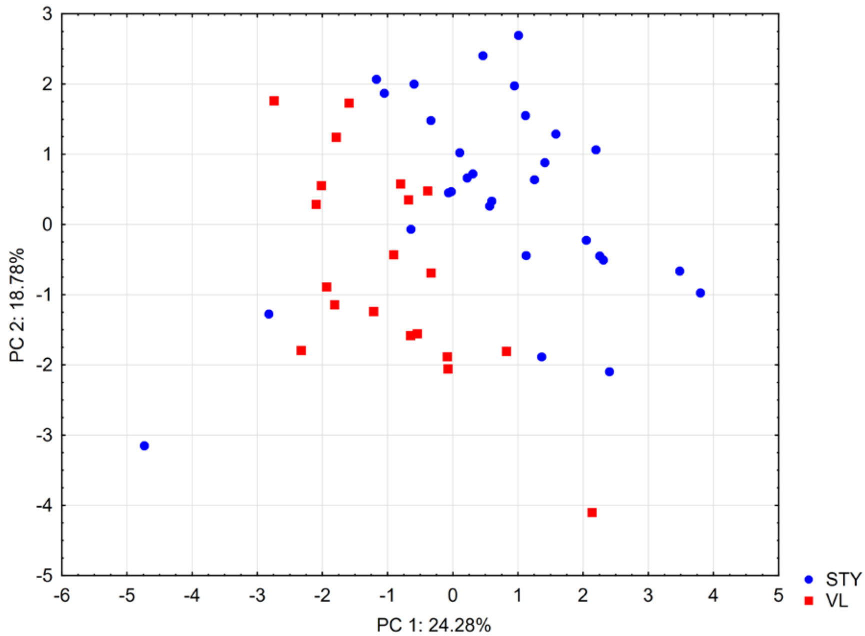

Figure 5 Principal Component Analysis showing the first two components.

In a K versus Rb plot (fig. 4), the general dissimilarity interestingly becomes apparent where relative high Rb and high K is a feature of nearly all Vlaardingen sherds. That likely implies a higher felsic component, related to, for example, feldspar or granite inclusions. Steynhof does overlap slightly, but the majority of the samples fall clearly within a low Rb and low K group.

Higher K values might point in the direction of a higher abundance of K-feldspars and micas, which would directly relate to a more significant presence of granite (or felsic in general) inclusions (or temper), an inclusion that has been identified before in this type of ceramics (Beckerman and Raemaekers 2009; Kroon *et al.* 2017). In fig. 4a trend can be observed that the assemblage from Vlaardingen is slightly enriched in these elements opposed to Steynhof. Interestingly, at Steynhof both low K/Rb and higher K and Rb intensities were found, which suggests ceramics at the site had a more variable composition.

These bivariate diagrams provide important information to identify potential elements that are representative for different groups and to confront them with (dis)similar elements. However, to firmly assess whether the bulk chemical component of these ceramics are consistently different, as much elements as possible should be evaluated. A fundamental statistical technique commonly employed in ceramic provenance studies is Principal Component analysis.

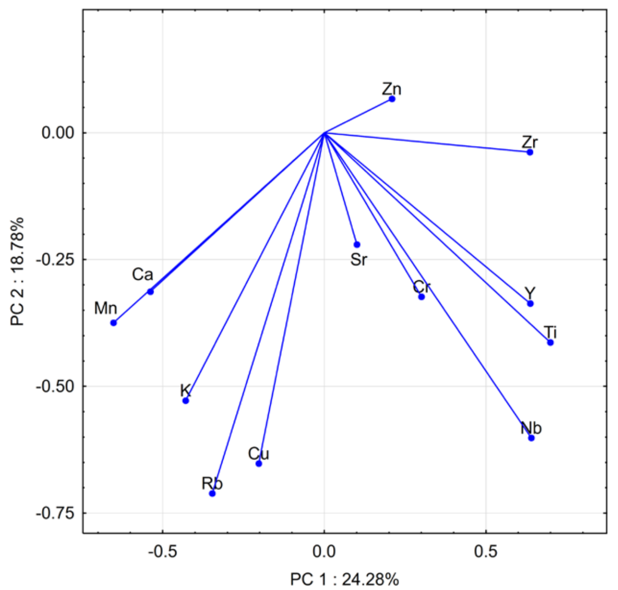

Figure 6 Extracted principal component 1 and 2 loadings of the contributing elements in the Principal Component Analysis.

In fig. 5 the graphical representation can be seen for the first two components while fig. 6 depicts the factors that are responsible for this two-dimensional output. In this case, the first two components respectively explain ca. 42 % of the total variability, which is relatively low. While in general the dataset can be considered as quite variable with at least two different raw materials as derived from the bivariate diagrams, especially K-Rb, the PCA-plot of PC1 versus PC2 suggests a different compositional trend in Vlaardingen opposed to Steynhof (fig. 5), while some overlap still remains. While a larger dataset is certainly advised, it is remarkable that it seems that these sites within the same region and timeframe seem to largely produce – or use – different products. The dataset at this point might be too small to robustly sustain this, but the pattern is clear and can certainly be adopted as an hypothesis for the next phases of the project.

Elements contributing to this differentiation are plotted in fig. 6. The differences between the ceramics, and by extent seemingly part of Vlaardingen assemblage opposed to Steynhof is mainly governed by the amount of K-Rb-Ca, likely connected to the presence of granitic inclusions. Less evidently, elements connected to heavy minerals and sand deposits are slightly more enriched in the Steynhof materials.

This differentiation documented here seems to follow a model not unlike what Fokkens *et al.* 2017 and Kroon *et al.* 2019 described regarding the acting of the Vlaardingen culture in a relative wide network, also continuing in light of the introduction of Corded Ware material culture. Differences exist in raw material selection for pottery from site to site in the Dutch coastal areas. Based on the tentative observations in this study it suggests various patterns are present in the Vlaardingen culture itself, given the relative clear differentiation in composition at Steynhof opposed to Vlaardingen (and Steynhof as well) material, and by extent the choice of raw materials at two Vlaardingen sites in relative close proximity.

4 Conclusion

The data presented here offers a first insight into the chemical compositions of these two Vlaardingen sites. Considerable variability exits between the different ceramics, but a pattern emerged based mainly on the contents of K-Rb-Fe-Ca that suggests two observations: (1) The ceramics at Steynhof are more quartz orientated (based also on levels of Zr and associated elements) and more variable while maintaining some overlap with Vlaardingen, and by extent the use of similar resources; (2) Higher K and Rb values indicate an association with more felsic associated rich fabrics and are internally fairly consistent. This profile connects especially to the ceramics from Vlaardingen itself.

These observations suggest that likely different or diverging raw material resource strategies were being conducted, in which Steynhof is more variable than Vlaardingen itself, but partly incorporating similar resources. Steynhof and Vlaardingen could share or exchange these similar products but in addition to Vlaardingen material, the Steynhof data suggest the presence of an additional resource use based on different compositions, but this needs to be validated on a larger sample scale. Some sherds are consistent and overlap, which suggests that these sites are participating in a wider network of interaction and movement between sites. This data shows there is no singular production or resource use for this type of pottery. The mechanisms behind the selection of resources is however a goal for the continuing project.

In good tradition of van Gijn's legacy this interesting observation can draw scholarly attention for the upcoming time within the research group, providing us with more pieces to an ever-growing Vlaardingen puzzle.

5 Acknowledgements

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References

Amkreutz, L., Verhart, L. and Van Gijn, A.L., 2016. Vlaardingen-cultuur en Stein-groep. In: L. Amkreutz, Brounen, F., Deeben, J., Machiels, R., Van Oorsauw, M.F. and Smit, B. (eds), *Vuursteen verzameld. Over het zoeken en onderzoken van steentijdvondsten en – vindplaatsen*. Amersfoort, (Nederlandse Archeologische Rapporten 60), 169-175.

Amkreutz, L. 2010. De laatsten der Mohikanen? Enige gedachten over de positie van de Vlaardingencultuur in het neolithisatieproces. In: Ridder, T. De and Verhart L. (eds), *Vlaardingen Special. Westerheem* 2, 12-25.

Baxter, M. J., 2001. Statistical modelling of artefact compositional data, *Archaeometry*, 43, 131-147.

Beckerman, S.M. and D.C.M. Raemaekers, 2009. Vormvariatie van Vlaardingen-aardewerk: een nieuwe typochronologie van het aardewerk van de Vlaardingengroep (ca. 3400-2500 v. Chr.). *Archeologie* 13, 63-82.

Degryse, P. and D. Braekmans, 2014. Elemental and isotopic analysis of ancient ceramics and glass. In: T. Cerling (ed.), Oxford (*Treatise on Geochemistry 4: Second Edition*),191-207.

De Winter, N.J., M. Sinnesael, C. Makarona, S. Vansteenberge and P. Claeys, 2017. Trace element analyses of carbonates using PorTable and micro-X-Ray Fluorescence: performance and optimization of measurement parameters and strategies. *Journal of Analytical Atomic Spectrometry* 32 (6): 1211-23.

Fokkens, H., S.F.M. Van As and B.J.W. Steffens, 2017. *Farmers, Fishers, Fowlers, Hunters. Knowledge Generated by Development-Led Archaeology about the Late Neolithic, the Early Bronze Age and the Start of the Middle Bronze Age (2850-1500 Cal BC)*, Amersfoort (Nederlandse Archeologische Rapporten 053).

Frahm, E., C.M. Carolus, A. Cameron, J. Berner, H. Brown, J. Cheng, J. Kalodner, J.L. Legget Jr., A. Natale, S. Seibert, D. Sparks-Stokes and E. Wuellner ,2022. Introducing the BRICC (Bricks and Rocks for Instruments' Ceramic Calibration) sets: pen-source calibration materials for quantitative X-Ray fluorescence analysis. *Journal of Archaeological Science: Reports* 43, 103443.

Glasbergen, W., W. Groenman-van Waateringe and G.M. Hardenberg-Mulder, 1967a. Settlements of the Vlaardingen Culture at Voorschoten and Leidschendam (I), *Helinium* VII. 3-31.

Glasbergen, W., W.Groenman-van Waateringe and G.M. Hardenberg-Mulder, 1967b. Settlements of the Vlaardingen Culture at Voorschoten and Leidschendam (II). *Helinium* VII. 97-120.

Heginbotham, A., and V. A. Solé, 2017. CHARMed PyMca, Part I: a protocol for improved inter-laboratory reproducibility in the quantitative ED-XRF analysis of copper alloys. *Archaeometry 59*, 714-730.

Holmqvist, E., 2016. Handheld PorTable Energy-Dispersive X-Ray Fluorescence Spectrometry (pXRF). In: A. Hunt (ed), *The Oxford Handbook of Archaeological Ceramic Analysis*, Oxford (Oxford University Press), 363-381.

Hunt, A.M.W. and R.J. Speakman, 2015. PorTable XRF analysis of archaeological sediments and ceramics. *Journal of Archaeological Science* 53, 626-38.

Kroon, E.J., D.J. Huisman, Q.P.J. Bourgeois, D.J.G. Braekmans and H. Fokkens, 2019. 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. *Journal of Archaeological Science: Reports* 26, 101873.

Michelaki, K. and R.G.V. Hancock, 2011. Chemistry versus data dispersion: is there a better way to assess and interpret archaeometric data?. *Archaeometry* 53 (6), 1259-79.

Rowe, H., N. Hughes, and K. Robinson, 2012. The quantification and application of handheld energy-dispersive x-ray fluorescence (ED-XRF) in Mudrock chemostratigraphy and geochemistry. *Chemical Geology* 324-325, 122-31.

Shugar, A.N. and J.L. Mass, 2012. *Handheld XRF for Art and Archaeology*. Leuven (Leuven University Press).

Speakman, R.J. and M.S. Shackley, 2013. Silo science and PorTable XRF in archaeology: a response to Frahm. *Journal of Archaeological Science* 40 (2), 1435-43.

Tykot, R.H., 2018. PorTable X-Ray Fluorescence Spectrometry (pXRF). In: S.L. López Varela (ed.), Hoboken (*The Encyclopedia of Archaeological Sciences*), 1-5.

Young, K. E., C. A. Evans, K. V. Hodges, J. E. Bleacher and T. G. Graff, 2016. A review of the handheld X-Ray Fluorescence Spectrometer as a tool for field geologic investigations on earth and in planetary surface exploration. *Applied Geochemistry: Journal of the International Association of Geochemistry and Cosmochemistry* 72, 77-87.

Van Gijn A.L., J. Fries-Knoblach and P. Stockhammer (eds), 2020. *Pots and practices: an experimental and microwear approach to Early Iron Age vessel biographies,* Leiden (Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa (BEFIM) No. 3).

Van Regteren Altena, J.F., J.A. Bakker, A.T. Clason, W. Glasbergen, W. Groenman-van Waateringe and L.J. Pons, 1962a. The Vlaardingen Culture (I). *Helinium* II, 3-35.

Van Regteren Altena, J.F., J.A. Bakker, A.T. Clason, W. Glasbergen, W. Groenman-van Waateringe and L.J. Pons, 1962b. The Vlaardingen Culture (II). *Helinium* II, 97-103.

Van Regteren Altena, J.F., J.A. Bakker, A.T. Clason, W. Glasbergen, W. Groenman-van Waateringe and L.J. Pons, 1962c. The Vlaardingen Culture (III). *Helinium* II, 215-243.