POTS AND PRACTICES

An experimental and microwear approach to Early Iron Age vessel biographies

ANNELOU VAN GIJN, JANINE FRIES-KNOBLACH
& PHILIPP W. STOCKHAMMER (EDS)

BEFIM
VOLUME 3

POTS AND PRACTICES

Sidestone Press

POTS AND PRACTICES

An experimental and microwear approach to Early Iron Age vessel biographies

ANNELOU VAN GIJN, JANINE FRIES-KNOBLACH
& PHILIPP W. STOCKHAMMER (EDS)

BEFIM
VOLUME 3

Gefördert vom

Bundesministerium
für Bildung
und Forschung

Verbundpartner:

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Baden-Württemberg
LANDESDENKMALPFLEGE

Landesmuseum Württemberg

EBERHARD KARLS
UNIVERSITÄT
TÜBINGEN

Kooperationspartner:

Universität Basel

Universiteit Leiden

uB UNIVERSITÉ DE BOURGOGNE

The authors are responsible for the content of the papers (incl. image credits).
Quotation style and abbreviations according to: Bericht der Römisch-Germanischen Kommission 71, 1990, 973-998; 73, 1992, 477-540.

BEFIM 3: Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa
https://www.befim.gwi.uni-muenchen.de

Published by Sidestone Press, Leiden
www.sidestone.com
Lay-out & cover design: Sidestone Press
Editing & formatting: J. Fries-Knoblach
Illustration cover front: Use-wear analysis carried out in the Laboratory for Material Culture Studies Leiden University, © Laboratory for Material Culture Studies Leiden University
Illustration cover reverse: Experimentally broken pottery replica of a vessel from the Heuneburg, © V. Brigola

ISBN 978-90-8890-774-6 (softcover)
ISBN 978-90-8890-775-3 (hardcover)
ISBN 978-90-8890-776-0 (PDF e-book)

Contents

Foreword

Philipp W. Stockhammer & Annelou van Gijn

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 7-8.

The meanings and functions of Early Iron Age ceramics of the so-called early Celts are the focus of the BEFIM research project. From the very beginning, our goal was to achieve better insights into the dynamics of the constitution and the change in functions and meanings of Early Iron Age pottery and its accompanying Mediterranean imported ceramics found at outstanding sites of the 7th to 5th cent. BC in South-West Germany and Eastern France by integrating archaeological and scientific methods of analysis (cf. BEFIM 1 and BEFIM 2). BEFIM's starting premise is that meanings and functions of things do not exist *per se*, but rather are constantly re-constituted when these objects are used in social practices (Stockhammer in BEFIM 1). Meanings and functions are therefore not stable but highly dynamic, and human practices play a central role here. Particularly in intercultural contact situations, when foreign objects are creatively appropriated and associated information is translated into local environments in the context of transformative processes, quite surprising new attributions of function and meaning are always possible. It is precisely those human practices with things, the so-called human-thing entanglements, that play a central role for BEFIM - either because they leave organic residues in the pottery (cf. Mötsch et al.-Vix and Mötsch et al.-Heuneburg in BEFIM 2), or because handling things produces traces on them - scratches, abrasion and much more, which needs to be closely examined. Up to now, use-wear analyses have concentrated mainly on objects made from stone, bone, shell and recently metal and there have been few use-wear analyses on pottery (van Gijn, this volume). Use-wear analysis on pottery was therefore not only a special challenge, but also a special chance to gain fundamental methodological knowledge and completely new insights into the actual handling of Early Iron Age pottery. However, due to the lack of relevant preliminary work, the scope of the study was much larger than originally thought. It became clear that we would have to take a highly experimental approach and, first of all, would have to reproduce many of the pots in question. Dennis Braekmans (Braekmans/Jacobs, this volume) provided the necessary information on the composition of the clay and its inclusions. Loe Jacobs (Jacobs, this volume) took over the pottery work, and with the vessels he recreated it became possible to carry out practical experiments. Afterwards, the emerging microwear traces were observed with the naked eye and under a microscope and described (van Gijn et al., this volume). It was only in a third step that the prehistoric sherds from the Heuneburg and the Mont Lassois could be analyzed under the microscope for comparable traces and interpreted by analogy (van Gijn/Verbaas, this volume; Verbaas/van Gijn-Vix, this volume). Despite all efforts of preliminary work and transport of the original finds to Leiden, as well as a rather ambitious time schedule, it was possible for almost one third of the vessels analyzed (62 of 231) to jointly interpret the results of organic residue analysis (ORA) and a wide range of use-wear traces on one and the same vessel (cf. concordance list, this volume; BEFIM database: https://www.befim.gwi.

uni-muenchen.de). Special studies on vessel sealing (Verbaas/van Gijn-Permeability, this volume) and on traces of alcohol production (Groat, this volume) complete the research spectrum and specify possible explanations for detected residues. Thus, our experimental and microscopic analyses of Early Iron Age pottery provide a whole range of new insights into the production and use of these vessels.

(Translated from German by Janine Fries-Knoblach)

Bibliography

BEFIM 1: Ph. W. Stockhammer/J. Fries-Knoblach (Hrsg.), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019). https://www.sidestone.com/books/was-tranken-die-fruehen-kelten

BEFIM 2: Ph. W. Stockhammer/J. Fries-Knoblach (Hrsg.), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019). https://www.sidestone.com/books/in-die-toepfe-geschaut

Author information

Philipp W. Stockhammer
Institut für Vor- und Frühgeschichtliche Archäologie und Provinzialrömische Archäologie
Ludwig-Maximilians-Universität München
Geschwister-Scholl-Platz 1
D-80539 München
philipp.stockhammer@lmu.de

Annelou van Gijn
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.l.van.gijn@arch.leidenuniv.nl

Vorwort

Philipp W. Stockhammer & Annelou van Gijn

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 9-10.

Bedeutungen und Funktionen früheisenzeitlicher Keramik der sogenannten frühen Kelten stehen im Zentrum des Forschungsinteresses von BEFIM. Von Anfang an war es der Gedanke, durch die Integration archäologischer und naturwissenschaftliche Analyseverfahren nähere Einblicke in die Dynamik der Konstitution und des Wandels von Funktionen und Bedeutungen dieser früheisenzeitlichen Keramik sowie der begleitend gefundenen mediterranen Importkeramik an herausragenden Fundorten Südwestdeutschlands und Ostfrankreichs im 7. bis 5. Jahrhundert v. Chr. zu gewinnen (vgl. BEFIM 1 und 2). BEFIM geht davon aus, dass Bedeutungen und Funktionen von Dingen eben nicht an sich existieren, sondern sich immer wieder neu im Rahmen sozialer Praktiken mit diesen Dingen konstituieren (Stockhammer in BEFIM 1). Bedeutungen und Funktionen sind demnach nicht stabil, sondern höchst dynamisch, und menschliche Praktiken spielen hier eine zentrale Rolle. Insbesondere in interkulturellen Kontaktsituationen, wenn fremde Objekte kreativ angeeignet und damit verbundene Informationen im Rahmen transformativer Prozesse in eigene Lebenswelten übersetzt werden, sind immer wieder ganz überraschende neuartige Funktions- und Bedeutungszuschreibungen möglich. Eben jene menschlichen Praktiken mit den Dingen, die sogenannten Mensch-Ding-Verflechtungen, spielen für BEFIM eine zentrale Rolle - entweder, weil sie organische Rückständen in der Keramik hinterlassen (vgl. Mötsch u. a.-Vix und Mötsch u. a.-Heuneburg in BEFIM 2), oder weil das Handeln mit den Dingen Spuren daran hinterlässt - Kratzer, Abrieb und vieles mehr, was es näher zu beleuchten gilt. Bislang konzentrierten sich Gebrauchsspurenanalysen vor allem auf Gegenstände aus Stein, Knochen, Muschel und neuerdings auch Metall, aber es liegen noch wenige Gebrauchsspurenanalysen an Keramik vor (van Gijn in diesem Band). Use-wear Analysis an Keramik war also nicht nur eine besondere Herausforderung, sondern auch eine besondere Chance, grundlegende methodische Erkenntnisse zu erzielen wie auch ganz neuartige Einblicke in die tatsächlichen Handlungen mit der früheisenzeitlichen Keramik zu gewinnen. Aufgrund eben jenes Mangels an relevanten Vorarbeiten stellte sich jedoch der Arbeitsumfang sehr viel größer dar als ursprünglich gedacht. Es wurde klar, dass wir einen stark experimentellen Ansatz verfolgen und zunächst einmal viele der entsprechenden Gefäße nachtöpfern mussten. Dafür lieferte Dennis Braekmans (Braekmans/Jacobs in diesem Band) die nötigen Erkenntnisse zur Zusammensetzung des Tons und seiner Einschlüsse. Loe Jacobs (Jacobs in diesem Band) übernahm das Töpfern, und mit den von ihm nachgebildeten Gefäßen wurde es möglich, entsprechende praktische Experimente durchzuführen. Im Anschluss wurden mit bloßem Auge bzw. unter dem Mikroskop die entstandenen Gebrauchsspuren untersucht und beschrieben (van Gijn u. a. in diesem Band). Erst in einem dritten Schritt konnten dann die prähistorischen Scherben von der Heuneburg und dem Mont Lassois unter dem Mikroskop auf vergleichbare Spuren hin analysiert und analog interpretiert werden (van Gijn/Verbaas in diesem Band; Verbaas/van

Gijn-Vix in diesem Band). Trotz aller Mühen der Vorarbeiten und des Transports der Originalfunde nach Leiden sowie der dortigen Untersuchung in einem sehr knappen Zeitfenster gelang es für ein knappes Drittel der analysierten Gefäße (62 von 231), organische Rückstände und ein breites Spektrum unterschiedlicher Gebrauchsspuren an ein und demselben Gefäß interpretativ zusammenzubringen (vgl. Konkordanzliste in diesem Band und BEFIM-Datenbank: https://www.befim.gwi.uni-muenchen.de). Spezialstudien zur Abdichtung von Gefäßen (Verbaas/van Gijn-Permeability in diesem Band) und zu Spuren der Alkoholerzeugung (Groat in diesem Band) ergänzen das Forschungsspektrum und präzisieren mögliche Erklärungen für nachgewiesene Rückstände. Damit ermöglichen unsere experimentellen und mikroskopischen Analysen der früheisenzeitlichen Keramik ein ganzes Spektrum neuer Einblicke in die Herstellung und Verwendung dieser Gefäße.

Literatur

BEFIM 1: Ph. W. Stockhammer/J. Fries-Knoblach (Hrsg.), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019). https://www.sidestone.com/books/was-tranken-die-fruehen-kelten

BEFIM 2: Ph. W. Stockhammer/J. Fries-Knoblach (Hrsg.), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019). https://www.sidestone.com/books/in-die-toepfe-geschaut

Kontaktdaten

Philipp W. Stockhammer
Institut für Vor- und Frühgeschichtliche Archäologie und Provinzialrömische Archäologie
Ludwig-Maximilians-Universität München
Geschwister-Scholl-Platz 1
D-80539 München
philipp.stockhammer@lmu.de

Annelou van Gijn
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.l.van.gijn@arch.leidenuniv.nl

Introduction

Annelou van Gijn

Summary

This introduction to the last volume of the BEFIM series briefly highlights the biographical study of Celtic pottery from the Early Iron Age sites of the Heuneburg and Vix-Mont Lassois by staff and students of the Laboratory for Material Culture Studies at the Leiden University Faculty of Archaeology. The possibilities and limitations for a biographical analysis of pottery, as shown by experiments and the archaeological analysis, are discussed and perspectives for microwear studies on ceramic vessels are outlined.

Keywords: *ceramic technology, microwear analysis, vessel function, vessel biography, Early Celtic pottery*

Zusammenfassung

Diese Einleitung zum letzten Band der BEFIM-Reihe stellt die Studie zu Objektbiographien keltischer Keramikgefäße der früheisenzeitlichen Fundstellen Heuneburg und Vix-Mont Lassois kurz vor, die Mitarbeiter und Studenten des Laboratory for Material Culture Studies an der Faculty of Archaeology der Universität Leiden durchgeführt haben. Potenzial und Grenzen von Keramikbiographien, wie Experimente und archäologische Analysen sie aufzeigen, werden diskutiert und die Perspektiven von Gebrauchsspurenanalysen an Keramikgefäßen umrissen.

Schlüsselwörter: *Keramiktechnologie, Gebrauchsspurenanalyse, Gefäßfunktion, Gefäßbiographie, frühkeltische Keramik*

The BEFIM project

When Philipp Stockhammer asked me whether I would like to join the BEFIM project (*Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa*) on the "Meanings and Functions of Imported Mediterranean Vessels in Early Iron Age Central Europe", in order to do microwear analysis on Early Celtic pottery, I was a little hesitant. We met in 2011 at a conference titled "Itineraries of the Material: shifting contexts of value and things in time and space" (Hahn/Weiss 2013) and shared an interest in "things on the move", i. e. how objects change their role and meaning when moving from one cultural context to another (van Gijn 2010; 2015; van Gijn/Wentink 2013). However, with virtually no experience in matters

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 11-24.

Figure 1: (a) Part of the BEFIM team in front of a Late Neolithic house reconstruction at Vlaardingen near the city of Rotterdam (NL), where we did the experiments with breaking vessels (cf. van Gijn et al., this volume). (b) Inspecting and photographing a broken vessel (© V. Brigola).

of pottery technology and function, I knew it was going to be a huge challenge, and a risky one at that. It would require setting up an extensive experimental reference collection, producing replicas of the Celtic vessels, familiarizing ourselves with pottery technology, and learning to understand and interpret microwear traces on ceramic vessels. On the other hand, it offered the enticing prospect of collaborating with a new interdisciplinary team of colleagues on an exciting research theme (Fig. 1).

Together with experienced potter Loe Jacobs and experimental archaeologist and microwear specialist Annemieke Verbaas, we accepted the challenge.

The BEFIM project addressed, among others, the question of drinking habits of the Celtic inhabitants of the Early Iron Age hillforts the Heuneburg (Herbertingen-Hundersingen, Baden-Württemberg, Germany) and Mont Lassois (Vix, Côte-d'Or, France). These sites are interpreted as the "princely seats" of the local Celtic elite (Fernández-Götz 2014; 2018; Krausse et al. 2016). Mediterranean vessels, mostly Attic ware imported especially via Italy, were found at these sites, as well as locally produced tableware that nearly matched the quality and craftsmanship of the imported vessels (Mötsch et al. in BEFIM 1 and BEFIM 2a/b). The import of these Attic vessels has long been interpreted as evidence that the local elite emulated Mediterranean artefacts, practices and ideas, among them lavish feasts during which wine was consumed (*symposion*). However, were these import vessels used in the same way as in their area of origin or were perhaps other beverages consumed from them? Formulated differently, were the Attic vessels appropriated along with their original function or were they used differently in the recipient Celtic communities, indicating a transformation when changing cultural context? And what was the role of the highly crafted local pottery, some of which seems to have been inspired by the imported ware considering their firing technique, fineness and beauty?

In order to answer these questions the BEFIM project was designed to go beyond typology to study the function of these supposed drinking vessels. In addition to a detailed contextual and typo-morphological re-analysis of these vessels (Mötsch et al. in BEFIM 1 and BEFIM 2a/b; Schorer et al. in BEFIM 1), the BEFIM project also included organic residue analysis (ORA) of the, often quite porous, pottery surfaces (Rageot et al. 2019a; 2019b; Spiteri et al. in BEFIM 2). ORA gives direct information about the contents of the vessels, but the gestures involved in e. g. food and drink preparation or the way these were consumed cannot be ascertained by residue studies. Towards this end microwear research is a potentially fruitful approach as it is focused on the actual traces of wear and tear that occur as a result of handling and use. As alcohol was assumed to have played such an important role in Celtic festivities, we also explored the kind of traces of wear associated with alcohol production, storage and consumption.

This volume is the third and final part of the BEFIM series (Stockhammer/Fries-Knoblach 2019a; 2019b) and reports on the research done at the Leiden University Laboratory for Material Culture Studies.

Use-wear studies on pottery

Pottery is one of the most frequently and intensively studied find categories in archaeology. The culture-historical approach, predominant until the 1960s, relied on pottery shape and decoration to define archaeological cultures, such as the Globular Amphora Culture, the Funnelbeaker Culture and so forth, all with a specific spatial distribution and chronological timespan. The function of pottery vessels was generally implied from the classifications made on the basis of shape: cup, bowl, and so forth are handy classificatory terms but also have a functional implication. These functions were assumed on the basis of the role such vessel shapes have in our present-day households, but they were rarely tested.

In the 2nd half of the 20th cent. ethnoarchaeological research on traditional potters led to a series of publications that instead focused on vessel manufacture and the social context of its production (Longacre et al. 1991; van der Leeuw 1993; Skibo 1992). This was also the time when the Leiden Center for Pottery Studies was established, focused on studying pottery manufacturing from a technological

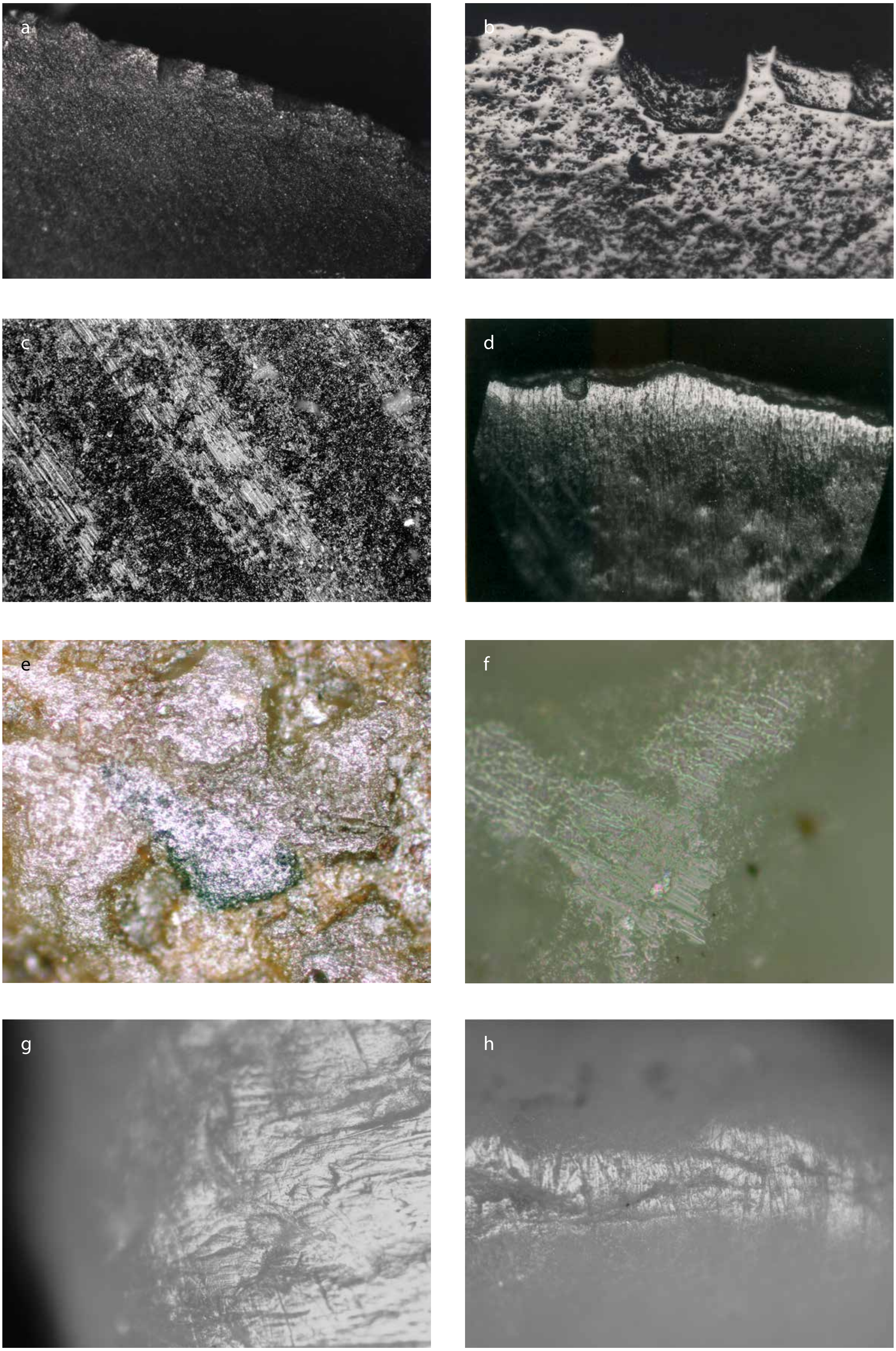
a
b
c
d
e
f
g
h

Figure 2: (a-d) Wear traces on experimental flint tools seen and documented by means of a metallographic microscope: (a) Edge removals on an experimental tool used to cut fish (taken at 100x original magnification (OM)). (b) Polish seen on a tool used for cutting reed (Phragmites) (100x OM) (c) Striations on a transverse arrowhead (100x OM). (d) Edge rounding seen on a flake used to scrape the inside of a ceramic vessel (100x OM). (e-h) Wear traces observed on experimental tools made from other raw materials. (e) Flattened grains and polish seen on a sandstone quern used for milling cereals for 3 h (100x OM). (f) Scraper of coral (Porites sp.) used to sand down the lip of a shell of a large sea snail (Libatus gigas) for 30 min (400x OM) (after Kelly/van Gijn 2008, fig. 9.4b). (g) Bone chisel used to debark soft wood for 105 min (100x OM). (h) Shell of saltwater clam Codakia used to peel the bark of the root of hard wood for 20 min (100x OM) (© Laboratory for Material Culture Studies Leiden University).

perspective while relying extensively on ethnographic sources as well (van As 2004; van As et al. 2010; Jacobs, this volume). Up until today ethnoarchaeological research is of pivotal importance for a better understanding of ceramic production and use as well as the social contexts of pottery (e. g. Gosselain 2000; 2002; Arthur 2014). Longacre's long-term work with the Kalinga in the Philippines (Longacre et al. 1991) also led to the first real use-wear study of pottery by James Skibo who based much of his study of wear traces on his observations of Kalinga pottery (Skibo 1992). In collaboration with Schiffer he carried out a wide array of experiments, often focused on post-depositional traces (Schiffer/Skibo 1989; Skibo et al. 1997; Skibo/Schiffer 1987). Skibo's extensive experience with pottery function led to two influential manuals on the study of pottery function (Skibo 1992; 2013).

However, Skibo's lead was initially followed by only a few (e. g. Arthur 2002; Beck et al. 2002; Beck 2010). While microwear studies of objects made of all sorts of materials took flight (for some recent overviews see e. g. Evans et al. 2014; Marreiros et al. 2015), wear trace analysis of pottery was largely focused on traces that were obvious to the naked eye such as soot from cooking (Forte et al. 2018). Microwear analysis, alternatively termed traceology or use-wear analysis, was initially developed by Semenov (Semenov 1964). He found that the stone, bone and antler tools used by indigenous people in Siberia, developed traces of wear. By doing replicative experiments with "fresh" tools, he found that these traces could be distinguished by microscope and be linked to specific activities. Scraping bone e. g. left different traces than scraping skin. Such traces encompassed edge removals, rounding of the edge, striations and polish (Fig. 2a-d).

Semenov's methodology, involving ethnographic observations, experimentation and microscopy, was followed in the west by the pioneers of microwear research there (Keeley 1980; Odell 1977). At the outset most such studies were directed at the ubiquitous flint assemblages, albeit with varying success. Although initially the expectations were high, blind tests made very clear that there were various limits to the method (e. g. Unrath et al. 1986; Newcomer et al. 1986). Traces from different contact materials showed similar wear features, post-depositional traces turned out to be a frequent occurrence and not always easy to distinguish, and briefly used tools hardly displayed any wear traces at all. Moreover, from a methodological point of view, functional inferences relied on an analogy with experimental counterparts and therefore had to be considered interpretations (Knutsson et al. 1990; van Gijn 2014). These limitations have been shown to be pertinent to objects of all sort of raw materials, from flint to coral, to metal and also pottery. Nevertheless, bearing these limitations in mind, microwear analysis has delivered numerous exciting results, contributing substantially to our knowledge of the active role material objects play in all aspects of past human life.

From the mid-1990s onwards more and more researchers started applying microwear analysis to a range of materials from bone and antler (e. g. van Gijn 2006; Maigrot 2005), shell (e. g. Cuenca Solana et al. 2011; Lammers 2007), to hard stone objects such as querns (e. g. Adams 2013; Tsoraki 2011; Dubreuil/Savage 2014; Verbaas/van Gijn 2007) and even coral (Kelly/van Gijn 2008) (Fig. 2e-h). Pottery sherds were identified as tools on the basis of their morphological characteristics and subjected to the same methodology, showing that indeed, these pottery fragments were, in a later stage of the vessels' biographical trajectory, used as actual tools (López Varela et al. 2002; van Gijn/Hofman 2008; Vieugué 2015). Studying objects made of a variety of raw materials in conjunction, also led to a better understanding of the toolkits involved in different (craft) activities such as pottery making (Martineau/Maigrot 2004; van Gijn/Lammers-Keijsers 2010).

Recent publications show an increased interest in a more detailed functional study of complete vessels or parts thereof in order to reconstruct their former function (Vieugué 2014; Forte et al. 2018; Fanti et al. 2018; Vuković 2009). Several ethnoarchaeological studies discuss the traces that develop on pottery surfaces due to fermentation processes (Hayashida 2008; Arthur 2002; 2003), a topic that is of special relevance in the context of the BEFIM project (Stockhammer in BEFIM 1, 23 f.).

The studies in this book

Loe Jacobs, an expert potter with decades of experience with ceramic technology, explored how the vessels from Heuneburg and Mont Lassois were made, using a combined analytical and experimental approach (Jacobs, this volume) (Fig. 3a). A limited sample of the prehistoric pottery from the Heuneburg was subjected to petrographic analysis (Braekmans/Jacobs, this volume). The replicas of original vessels made by Jacobs formed the departure point for the experiments performed for the actual microwear research of the archaeological samples from the Heuneburg and Mont Lassois. A total of 62 experiments were carried out, covering the range of activities and gestures that were assumed to be relevant for a better understanding of the archaeological finds. These experiments were carried out by students and staff of the Material Culture Studies Group at Leiden University's Faculty of Archaeology (van Gijn et al., this volume). Groat experimentally explored the effects of fermentation, especially of making honey-wine, on the ceramic surfaces (Groat, this volume). We also performed a pilot study on the permeability of different types of surface treatments, including beeswax as a sealant, in storing fluids (Verbaas/van Gijn-Permeability, this volume). Last, we studied the archaeological pottery from the Heuneburg (van Gijn/Verbaas, this volume) and from Mont Lassois (Verbaas/van Gijn-Vix, this volume) for surviving use-wear marks.

Methodological issues

In the literature a range of different terms can be found related to the analysis of function: microwear analysis, traceology, use-wear studies and functional analysis. In this volume we predominantly use the terms microwear and use-wear analysis. In the literature on ceramic functional studies the term "use alterations" is also frequently employed, following Skibo's terminology (Skibo 1992; Skibo 2015, 190-193). This term is occasionally used in the various articles of this volume. For the study of both our experimental vessels and the archaeological specimens from the Heuneburg and Mont Lassois, we predominantly made use of stereomicroscopes with magnifications between 10x and 100x in order to observe traces of production and macroscopic traces of use like the more pronounced scratches, spalling and attrition as well as the spatial distribution of these features. Additionally we used an incident light or metallographic microscope (magnifications ranging between 100x and 200x) to examine the fine striations, pitting and polish (see van Gijn/Verbaas, this volume; Verbaas/van Gijn-Vix, this volume; van Gijn et al., this volume) (Fig. 3b).

Loe Jacobs conducted a thorough analysis of the fabric as well as of the manufacturing marks on the Heuneburg pottery, using a stereomicroscope (Jacobs, this volume,

Figure 3: The Leiden Laboratory for Material Culture Studies. (a) Loe Jacobs at work producing Early Celtic pottery. (b) Annelou van Gijn examining the traces on experimental vessels under the stereomicroscope (© V. Brigola).

fig. 3). His work not only produced some beautiful replicas of Early Celtic pottery, but also revealed aspects of the *chaîne opératoire* that would otherwise have lain hidden. The vessel reproductions were as close as possible to the archaeological specimens from, especially, the Heuneburg, not only in terms of their shape but also with respect to fabric, temper, shaping techniques and ways of firing (Jacobs, this volume).

The experiments we conducted were related to food and drink preparation, storage, consumption, cleaning and handling, all activities that were related to the possible culinary practices of the Celtic inhabitants of the Heuneburg and Mont Lassois. In addition we also did some experiments with possible accidents that could cause the vessels to break, as well as with post-depositional and post-excavation processes.

The experimental program was extensive, but not extensive enough: few experiments could be repeated as is required for a scientifically sound experimental program (Reynolds 1999; Mathieu 2002; Lammers-Keijsers 2005; Outram 2008). The number of experiments was limited by the number of vessels that could be made: it is easy enough to produce 50 flint scrapers for an experiment, but it is an altogether different story to make 50 ceramic vessels. This is an important limitation for establishing a reference collection for microwear analysis on pottery vessels. We also felt that one of our ambitions - to establish a standardized description of the wear traces observed - could not be achieved due to the limited number of observations. More experiments, performed by different researchers, are needed, as well as having a round-table session with all involved in the use-wear analysis of pottery in order to arrive at a consensus about the descriptive system.

Another limitation lies in the enormous variability of fabrics, tempers and firing temperatures of pottery. We found that this variation to a large extent determined the development and character of the wear traces that developed as a result of different activities (van Gijn et al. in BEFIM 1). The bad news is therefore that microwear analysis of each new ceramic assemblage requires new experiments with vessel replicas made of the same fabrics and with the same temper and firing temperatures as the archaeological ones. The good news is that some wear traces seem to be quite consistent and easily recognizable, also with the naked eye, such as traces from shoving pottery around seen on both experimental and archaeological bottom sherds (e. g. van Gijn/Verbaas, this volume, fig. 18d). The traces of spalling that are commonly associated with alcohol (e. g. Arthur 2003; Hayashida 2008) were seen on a number of Mont Lassois sherds (Verbaas/van Gijn-Vix, this volume, tab. 3), but have not been experimentally replicated.

The spatial distribution of e. g. scratches also gives an indication of the activity that might have caused them. Scratches from stirring are more prominent on the bottom of vessels and have a predominantly circular directionality, whereas the, usually somewhat finer, scratches from cleaning are more developed along the entire vessel wall. This indicates that in order to conduct this type of analysis we really need large sherds and preferably complete vessel profiles. Rim sherds may bear indications of the way the contents of the vessel were consumed (e. g. scratches from a ladle), but obviously do not give clues about other aspects of the biography of these vessels, such as the degree of wear on the bottom. The latter could indicate long-term use of the vessel in question. As many ceramic assemblages consist of small ceramic fragments, mostly body sherds, the possible contribution of microwear analysis towards the interpretation of vessel biographies is often somewhat limited.

As pottery is a relatively soft material, traces develop differently than on most other materials studied (cf. Fig. 2). On flint for example, which is a very hard material, the surface of the object changes by frequent use, and next to rounding, striations and edge damage, polish forms. However, pottery is so soft and easily abraded, that there is generally hardly any build-up of polish, as attrition removes the surface before polish can develop to such an extent that diagnostic features emerge that allow for a functional inference. On pottery we therefore study the abrasion or attrition of the surface rather than a changed surface due to prolonged contact with the material worked. Consequently, there is a greater overlap in use-wear traces than is the case with other materials.

This study thus makes very clear that microwear analysis of pottery is not as straightforward as microwear analysis of flint. The variety of fabrics, size and type of temper as well as firing methods causes variation in surface properties which, in turn, determine to a considerable extent the way wear traces develop. The extensive fragmentation that ceramic vessels have frequently undergone, makes it even more difficult to infer the former gestures, activities and functions involved. These limitations come in addition to the limitations which are pertinent to all categories of materials: 1) the effect of post-depositional processes and post-excavation procedures; 2) some activities, especially when carried out for a short time, do not cause detectable traces of wear; 3) traces from different activities or contact materials can overlap in terms of their characteristics. It is therefore important to stress that all inferences about the functions and biography of these vessels should be considered interpretations, not determinations (van Gijn 2014).

What came out of this extensive and very laborious study?

In spite of the somewhat sobering statements concerning the inferential limits of functional analysis of ceramics put forward in the preceding paragraphs, the analysis of the archaeological samples from the Heuneburg and Mont Lassois actually produced some very promising results. The biographical approach including both the manufacturing and use stages of ceramic vessels, showed us not only how the vessels were made but frequently also how they were used. Despite the extensive handling much of this material had undergone after excavation, they were still in reasonably good state, especially those from Mont Lassois (Verbaas/van Gijn-Vix, this volume). We were able to interpret the function of a considerable number of finds, and in both sites we found evidence for the stirring, mixing and consumption of substances. We also observed traces that we contributed to cleaning, storage and extensive handling. This latter observation supports the interpretation that many of these vessels must have had a long or intensive use-life. One find from the Heuneburg has signs of having been repaired (van Gijn/Verbaas, this volume, 28 fig. 17c.d).

Traces from overhanging ladles, seen on several rim sherds from the Heuneburg (van Gijn/Verbaas, this volume, fig. 3c; 4b; 5b.c; 7c) indicate that vessels were used for serving and consuming substances, possibly supporting the idea that they figured in festive occasions. Vessels from both sites showed evidence for pitting, a feature that seems to be associated with acidic substances, possibly alcohol (Saurel in BEFIM 1; van Gijn et al. in BEFIM 1; Groat, this volume). Interestingly, all of the sherds from the Heuneburg that showed this feature derived from the Lower Town Settlement. Not present on the Heuneburg sites, but noted on several sherds from Mont Lassois were traces from spalling, a feature which has been seen ethnographically on vessels used for fermenting beverages like beer (Arthur 2003; Hayashida 2008). There was a strong association between the presence of spalling, which we observed on twelve sherds, and the results of the organic residue analysis which demonstrated bacterial fermentation markers on eight of these (Verbaas/van Gijn-Vix, this volume, tab. 3). This association between the results of the organic residue analysis and the use-wear study is encouraging and should be substantiated further. ORA provides information on the contents of ceramic vessels, use-wear or microwear analysis on the other hand is more suitable to identifying activities and gestures associated with the pottery. However, it is the combination of organic residue and use-wear analyses that gives us a glimpse of how humans actively interacted with these objects, bringing an archaeological find category to life.

Acknowledgments

First and foremost I would like to thank Philipp Stockhammer for inviting us in this project, knowing very well that the outcome of this investment would be uncertain. The meetings we had over the years were exciting and discussions vivid. I believe I am speaking on behalf of all of the Leiden participants that it was a very enjoyable project. We also want to thank all the other core members of the BEFIM project: Janine Fries-Knoblach, Dirk Krausse, Angela Mötsch, Maxime Rageot, Birgit Schorer, Stefan Schreiber, Cynthianne Spiteri and Thomas Hoppe. Thank you all for your help, comments and good spirits.

All of the Leiden participants, both students and staff, are represented in this volume as authors, except one very important one: Eric Mulder, our laboratory assistant who not only drew and photographed many of the finds, but also kept track of experiments and the various reports and other data that were generated over the course of the past years. Last, we like to thank Sasja van der Vaart-Verschoof of Sidestone Press for checking the English of the articles and for the layout of the book and Janine Fries-Knoblach for editing and formatting.

Bibliography

Adams 2013: J. L. Adams, Ground stone analysis: A technological approach (Salt Lake City 2013).

Arthur 2002: J. W. Arthur, Pottery use-alteration as an indicator of socioeconomic status: The ethnoarchaeological study of the Gamo of Ethiopia. Journal Arch. Method and Theory 9, 2002, 331-335.

Arthur 2003: J. W. Arthur, Brewing beer: Status, wealth and ceramic use alteration among the Gamo of south-western Ethiopia. World Arch. 34/3, 2003, 516-528.

Arthur 2014: J. Arthur, Culinary Crafts and Foods in Southwestern Ethiopia: An Ethnoarchaeological Study of Gamo Groundstones and Pottery. African Arch. Review 31/2, 2014, 131-168.

Beck 2010: M. E. Beck. Ceramic vessel use and use alteration: Insights from experimental archaeology. In: J. R. Ferguson (ed.), Designing Experimental Research in Archaeology: Examining Technology through Production and Use (Boulder 2010) 47-69.

Beck et al. 2002: M. E. Beck/J. M. Skibo/D. J. Hally/P. Yang, Sample selection for ceramic use-alteration analysis: The effects of abrasion on soot. Journal Arch. Scien. 29, 2002, 1-15.

Cuenca Solana et al. 2011: D. Cuenca Solana/I. Gutierrez Zugasti/I. Clemente Conte, The use of mollusc shells as tools by coastal human groups: The contribution of ethnographical studies to research on Mesolithic and early Neolithic technologies in northern Spain. Journal Anthr. Research 67, 2011, 77-101.

Dubreuil/Savage 2014: L. Dubreuil/D. Savage, Ground stones: A synthesis of the use-wear approach. Journal Arch. Scien. 48, 2014, 139-153.

Evans et al. 2014: A. A. Evans/H. Lerner/D. A. MacDonald/W. J. Stemp/P. C. Anderson (eds), Standardization, calibration and innovation: A special issue on lithic microwear method. Journal Arch. Scien. Special Issue 48/8, 2014.

Fanti et al. 2018: L. Fanti/L. Drieu/A. Mazuy/T. Blasco/C. Lugliè/M. Régert, The role of pottery in Middle Neolithic societies of western Mediterranean (Sardinia, Italy, 4500-4000 cal BC) revealed through an integrated morphometric, use-wear, biomolecular and isotopic approach. Journal Arch. Scien. 93, 2018, 110-128.

Fernández-Götz 2014: M. Fernández-Götz, Villages and cities in early Europe. Antiquity 88, 2014, 304-307.

Fernández-Götz 2018: M. Fernández-Götz, Urbanization in Iron Age Europe: Trajectories, patterns and social dynamics. Journal Arch. Research 26, 2018, 117-162.

Forte et al. 2018: V. Forte/S. Nunziante Cesaro/L. Medeghini, Cooking traces on Copper Age pottery from central Italy: An integrated approach comprising use wear analysis, spectroscopic analysis and experimental archaeology. Journal Arch. Scien. Report 18, 2018, 121-138.

Gosselain 2000: O. P. Gosselain, Materializing Identities: An African perspective. Journal Arch. Method and Theory 7, 2000, 187-217.

Gosselain 2002: O. P. Gosselain, Poteries du Cameroun méridional: Styles techniques et rapports à l'identité (Paris 2002).

Hahn/Weiss 2013: H. P. Hahn/H. Weiss (eds), Mobility, meaning and transformations of things. Shifting contexts of material culture through time and space (Oxford 2013).

Hayashida 2008: F. M. Hayashida, Ancient beer and modern brewers: Ethnoarchaeological observations of chicha production in two regions of the north coast of Peru. Journal Anthr. Arch. 27, 2008, 161-174.

Keeley 1980: L. H. Keeley, Experimental determination of stone tool uses. A microwear analysis (Chicago 1980).

Kelly/van Gijn 2008: H. Kelly/A. L. van Gijn, Understanding the function of coral tools from Anse à la Gourde: An experimental approach. In: C. L. Hofman/

M. Hoogland/A. L. van Gijn (eds), Crossing disicplinary boundaries and national borders. New methods and techniques in the study of archaeological materials from the Caribbean (Tuscaloosa 2008) 115-124.

Knutsson et al. 1990: H. Knutsson/K. Knutsson/J. Taffinder (eds), The interpretative possibilities of microwear studies (Uppsala 1990).

Krausse et al. 2016: D. Krausse/M. Fernández-Götz/L. Hansen/I. Kretschmer, The Heuneburg and the Early Iron Age Princely Seats: First Towns North of the Alps (Budapest 2016).

Lammers 2007: Y. Lammers, Tracing traces from present to past: A functional analysis of pre-columbian shell and stone artefacts from Anse à la gourde and Morel, Guadeloupe. PhD thesis, Faculty of Archaeology, Leiden University (Leiden 2007).

Lammers-Keijsers 2005: Y. Lammers-Keijsers, Scientific experiments: A possibility? Processing a general cyclical script for experiments in archaeology. euroREA 2, 2005, 18-24.

Longacre et al. 1991: W. A. Longacre/S. E. van der Leeuw/M. Harding/I. Hodder/M. W. Graves/W. R. DeBoer/B. A. Nelson/G. A. London/C. Kramer/ R. H. Thompson (eds), Ceramic ethnoarchaeology (Tucson 1991).

Lopez Varela et al. 2002: S. L. López Varela/A. L. van Gijn/L. F. H. C. Jacobs, Demystifying pottery production in the Maya Lowlands: Detection of traces of use-wear on pottery sherds through microscopic analysis and experimental replication. Journal Arch. Scien. 29, 2002, 1133-1147.

Maigrot 2005: Y. Maigrot, Ivory, bone and antler tools production systems at Chalain 4 (Jura, France), late Neolithic site, 3rd millennium. In: H. Luik/M. A. Choyke/C. E. Batey/L. Lõugas (eds), From Hooves to Horns, from Mollusc to Mammoth. Manufacture and Use of Bone Artefacts from Prehistoric Times to the Present. Proceedings of the 4th Meeting of the ICAZ Worked Bone Research Group at Tallinn, 26th-31st of August 2003. Muinasaja Teadus 15 (Tallinn 2005).

Marreiros et al. 2015: J. M. Marreiros/J. F. Gibaja Bao/N. Ferreira Bicho (eds), Use-wear and Residue Analysis in Archaeology (New York 2015).

Martineau/Maigrot 2004: R. Martineau/Y. Maigrot, Les outils en os utilisés pour le façonnage des poteries néolithiques de la station 4 de Chalain (Jura, France). In: P. Bodu/C. Constantin (eds), Approches fonctionnelles en Préhistoire. XXVe Congrès Préhistorique de France. Nanterre 24-26 Novembre 2000 (Paris 2004) 83-95.

Mathieu 2002: J. R. Mathieu (ed.), Experimental archaeology. Replicating past objects, behaviors and processes. BAR Internat. Ser. 1035 (Oxford 2002).

Mötsch et al. in BEFIM 1: A. Mötsch/M. Rageot/B. Schorer, Organic residues in pottery vessels from selected archaeological features of the Heuneburg. First results of a case study. In: Stockhammer/Fries-Knoblach 2019a, 61-76.

Mötsch et al. in BEFIM 2a: A. Mötsch/M. Rageot/B. Schorer/A. Ballmer/I. Balzer/D. Bardel/S. Cafisso/B. Chaume/Ph. Della Casa/F. Fougère/J. Fries-Knoblach/N. Nieszery/W. Reinhard/F. Sacchetti/K. Schäppi/St. Schreiber/A. Winkler/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, Essen und Trinken am Mont Lassois in Burgund. Neue Erkenntnisse zu Bedeutungen und Funktionen lokaler und importierter Keramik in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019b, 51-112.

Mötsch et al. in BEFIM 2b: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen“. Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Newcomer et al. 1986: M. H. Newcomer/R. Grace/R. Unger-Hamilton, Investigating microwear polishes with blind tests. Journal Arch. Scien. 13, 1986, 203-218.

Odell 1977: G. H. Odell, The application of microwear analysis to the lithic component of an entire prehistoric settlement: Methods, problems and functional reconstructions. PhD thesis, Harvard University (Cambridge 1977).

Outram 2008: A. K. Outram, Introduction to experimental archaeology. World Arch. 40/1, 2008, 1-6.

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/P. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, The dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Reynolds 1999: P. J. Reynolds, The nature of experiment in archaeology. In: A. F. Harding (ed.), Experiment and design: Archaeological studies in honour of John Coles (Oxford 1999) 156-162.

Saurel in BEFIM 1: M. Saurel, Grandes jarres et fosses allongées. La production de bière à l'âge du Fer en Champagne (France), entre le VII^e et le V^e siècle av. notre ère. In: Stockhammer/Fries-Knoblach 2019a, 135-152.

Schiffer/Skibo 1989: M. B Schiffer/J. M. Skibo, A provisional theory of ceramic abrasion. American Anthr. 91, 1989, 102-116.

Schorer et al. in BEFIM 1: B. Schorer/M. Rageot/A. Mötsch, Vessels from old excavations at the Heuneburg. New evidence for their functional interpretation. In: Stockhammer/Fries-Knoblach 2019a, 47-60.

Semenov 1964: S. A. Semenov, Prehistoric technology. An experimental study of the oldest tools and artefacts from traces of manufacture and wear (London 1964).

Skibo 1992: J. M Skibo, Pottery function: A use-alteration perspective (New York 1992).

Skibo 2013: J. M. Skibo, Understanding Pottery Function (New York 2013).

Skibo 2015: J. M. Skibo, Pottery use-alteration analysis in use-wear and residue analysis. In: Marreiros 2015, 189-198.

Skibo/Schiffer 1987: J. M. Skibo/M. B. Schiffer, The effects of water on processes of ceramic abrasion. Journal Arch. Scien. 14, 1987, 83-96.

Skibo et al. 1997: J. M. Skibo/T. C. Butts/M. B. Schiffer, Ceramic surface treatment and abrasion resistance: An experimental study. Journal Arch. Scien. 24, 1997, 311-317.

Spiteri et al. in BEFIM 2: C. Spiteri/M. Rageot/St. Buckley, Das Potential von Biomarkern und Isotopenanalysen für die Untersuchung alter organischer Rückstände. In: Stockhammer/Fries-Knoblach 2019b, 21-50.

Stockhammer in BEFIM 1: Ph. W. Stockhammer, BEFIM. Neue Perspektiven auf die Kraft interkultureller Kontakte in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019a, 21-28.

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Tsoraki 2011: C. Tsoraki, Disentangling Neolithic networks: Ground stone technology, material engagements and networks of action. In: A. Brysbaert (ed.), Tracing prehistoric social networks through technology: A diachronic perspective on the Aegean (London 2011) 12-29.

Unrath et al. 1986: G. Unrath/L. R. Owen/A. L. van Gijn/E. H. Moss/H. Plisson/P. Vaughan, An evaluation of micro-wear studies. A multi-analyst approach. In: L. R. Owen/G. Unrath (eds), Technical aspects of micro-wear studies on stone tools (Tübingen 1986) 117-176.

Van As 2004: A. van As, Leiden Studies in Pottery Technology. Leiden Journal Pottery Technology 20, 2004, 7-22.

Van As et al. 2010: A. van As/L. F. H. C. Jacobs/G. Hernández Sánchez, Present-day traditional and non-traditional pottery production in Amozoc, San Miquel Tenextatiloyan and Los Reyes Metzontla (Central Mexico). Leiden Journal Pottery Stud. 26, 2010, 5-40.

Van der Leeuw 1993: S. E. van der Leeuw, Giving the potter a choice. Conceptual aspects of pottery techniques. In: P. Lemonnier (ed.), Technological choices. Transformation in material cultures since the Neolithic (London 1993) 238-288.

Van Gijn 2006: A. L. van Gijn, Implements of bone and antler: A Mesolithic tradition continued. In: L. P. Louwe Kooijmans/P. F. B. Jongste (eds), Schipluiden. A Neolithic settlement on the Dutch North Sea coast c. 3500 cal BC. Analecta Praehist. Leidensia 37/38 (Leiden 2006) 207-224.

Van Gijn 2010: A. L. van Gijn, Flint in focus: Lithic biographies in the Neolithic and Bronze Age (Leiden 2010).

Van Gijn 2014: A. L. van Gijn, Science and interpretation in microwear studies. Journal Arch. Scien. 48, 2014, 166-169.

Van Gijn 2015: A. L. van Gijn, Stones on the move: The contribution of microwear analysis for understanding the Neolithisation process. In: T. Kerig/S. Shennan (eds), Connecting networks characterising contact by measuring lithic exchange in the European Neolithic (Oxford 2015) 55-63.

Van Gijn/Hofman 2008: A. L. van Gijn/C. L. Hofman, Were they used as tools? An exploratory functional study of abraded potsherds from two pre-colonial sites on the island of Guadeloupe, Northern Lesser Antilles. Caribbean Journal Scien. 44/1, 2008, 21-35.

Van Gijn/Lammers-Keijsers 2010: A. L. van Gijn/Y. Lammers-Keijsers, Toolkits for ceramic production: Informal tools and the importance of high power use-wear analysis. Bull. Soc. Préhist. Française 107/4, 2010, 755-762.

Van Gijn/Wentink 2013: A. L. van Gijn/K. Wentink, The role of flint in mediating identities: The microscopic evidence. In: Hahn/Weiss 2013, 120-132.

Van Gijn et al. in BEFIM 1: A. van Gijn/L. Jacobs/N. Groat/N. de Koning/D. Braekmans/A. Verbaas, Studying vessel biographies from the Heuneburg: An experimental approach. In: Stockhammer/Fries-Knoblach 2019a, 77-99.

Verbaas/van Gijn 2007: A. Verbaas/A. L. van Gijn, Querns and other hard stone tools from Geleen-Janskamperveld. In: P. van de Velde (ed.), Excavations at Geleen-Janskamperveld 1990-1991. Analecta Praehist. Leidensia 39 (Leiden 2007) 191-204.

Vieugué 2014: J. Vieugué, Use-wear analysis of prehistoric pottery: Methodological contributions from the study of the earliest ceramic vessels in Bulgaria (6100-5500 BC). Journal Arch. Scien. 41, 2014, 622-630.

Vieugué 2015: J. Vieugué, What were the recycled potsherds used for? Use-wear analysis of Early Neolithic ceramic tools from Bulgaria (6100-5600 cal. BC). Journal Arch. Scien. 58, 2015, 89-102.

Vuković 2009: J. B. Vuković, Non-abrasive pottery surface attrition: Blagotin evidence. Journal Serbian Arch. Soc. 25, 2009, 25-35.

Author information

Annelou van Gijn
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.l.van.gijn@arch.leidenuniv.nl

Experimentally forming Celtic vessels from the Heuneburg and the Mont Lassois

A sequential approach

Loe Jacobs

Summary

The reproduction of Celtic pots at the Laboratory for Material Culture Studies Leiden University followed the assumed technological choices made by the Early Iron Age potters at the Heuneburg and the Mont Lassois and was intended to provide use-wear researchers with experimental pottery. Unlike old archaeological examples, the new, fresh surfaces of these undamaged and complete pots only bear traces of production. A morphologically elaborate repertoire of Early Celtic pottery in the form of museum collections stood model for these reproductions. Production traces observed on this archaeological material were interpreted and thus roughly indicated the original sequences of production. Following these theoretical steps, some 80 pots were made from commercial clays, which were first modified according to archaeological prerequisites. To estimate the correct tempering of the clays, relevant fragments from the archaeological collection were analyzed microscopically. The results formed the basis for clay-pastes composed in agreement with their fabrics as to types and quantities of temper and workability properties. As a spin-off of our research, this chapter features the descriptions and pictures of the reconstruction processes, combined with material information and technological observations. The result is a detailed and illustrated review of the supposed materials and production techniques of Early Celtic pottery. The Iron Age pottery tradition refers, not only in style, but in part also in production technology to the Classical World, which was a source of inspiration to these native potters. For the making of pots several techniques were applied, most importantly pinching, coiling and a combination of molding and coiling. Only a small part of the collection was made by wheel-throwing and wheel-coiling. The remaking of the pottery once again showed that these pots were more than just individuals, but the result of an entire production system in which several steps were sequential and of influence on each other and on the appearance of the vessels in all aspects such as shape, surface structure, surface properties and finish. Next to the condition of the clay, the decisive factors of influence were the use of certain materials and tools and the procedures followed when firing these pots.

Keywords: *production traces, pottery reproduction, temper, materials, surface finish, firing atmosphere*

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 25-63.

Zusammenfassung

Die Nachbildung keltischer Keramikgefäße am Leidener Institut folgte den anzunehmenden technologischen Entscheidungen früheisenzeitlicher Töpfer auf der Heuneburg und dem Mont Lassois und diente dem Zweck, die mit der Untersuchung von Gebrauchsspuren befassten Wissenschaftler mit experimenteller Keramik zu versorgen. Anders als die alten archäologischen Stücke tragen die neuen unversehrten Oberflächen der unbeschädigten und vollständigen Behälter ausschließlich Herstellspuren. Ein morphologisch vielfältiges Repertoire an keltischer Keramik in der Form von Museumsbeständen stand Modell für diese Nachbildungen. Die am archäologischen Material beobachteten Produktionsspuren wurden interpretiert und zeigen grob die ursprüngliche Abfolge der Herstellschritte an. Auf der Grundlage dieser theoretischen Schritte wurden rund 80 Gefäße aus kommerziellen Tonarten hergestellt, die zuvor nach den archäologischen Gegebenheiten modifiziert worden waren. Um die korrekte Magerung der Tone zu bestimmen, wurden relevante Fragmente aus den archäologischen Sammlungen mikroskopisch untersucht. Die Ergebnisse bildeten die Grundlage für Tone, die in Hinblick auf Art und Menge der Magerungspartikel und Werkeigenschaften mit den alten Warenarten übereinstimmen. Als Nebenprodukt unserer Forschungen präsentiert dieser Beitrag die Beschreibungen und die Bilddokumentation der Nachbildungsprozesse in Verbindung mit Angaben zur Warenart und technologischen Beobachtungen. Das Ergebnis ist ein detaillierter und illustrierter Überblick über die mutmaßlichen Materialien und Herstelltechniken keltischer Keramik. Nicht nur hinsichtlich ihrer Form, sondern teilweise auch bei der Produktionstechnik bezog sich die eisenzeitliche Töpfertradition auf die klassische Welt, die für die einheimischen Töpfer eine Quelle der Inspiration bildete. Für die Herstellung von Gefäßen existierten mehrere Techniken, vor allem freies Quetschen des Tons, die Wulsttechnik und eine Kombination von Abformung und Wulsttechnik. Nur ein kleiner Teil der Bestände wurde auf der Töpferscheibe gezogen oder nachgedreht. Die Nachbildung der Keramik zeigte einmal mehr, dass Gefäße mehr als nur Einzelstücke waren, sondern vielmehr das Resultat eines ganzen Produktionssystems, in dem mehrere Arbeitsschritte aufeinander folgten und Einfluss aufeinander sowie auf die Erscheinungsform des Gefäßes in all seinen Aspekten hatten, z. B. auf seine Form, Oberflächenstruktur, Oberflächenbeschaffenheit und Endbearbeitung. Abgesehen von der Beschaffenheit des Tons kam es vor allem auf die Verwendung bestimmter Materialien und Werkzeuge sowie auf die Vorgehensweise beim Brennvorgang an.

Schlüsselwörter: *Produktionsspuren, Keramiknachbildung, Magerung, Materialien, Oberflächenbehandlung, Brennatmosphäre*

Introduction

Within the BEFIM project we tried to sharpen the view on specific habits related to the production and use of pottery by Early Iron Age populations. We did this through interpretation of pottery collections from the Heuneburg, a site in South-West Germany, and the Mont Lassois, a contemporaneous site in Eastern France. The intention was to establish whether traces of manufacture and traces of use left on vessels and vessel parts can give more detailed information on the feasting and drinking habits of the people living there, which were influenced by certain aspects of Mediterranean Culture. We concentrated on pots which, morphologically speaking, could be attributed to the preparation and consumption of beverages (van der Veen 2018, 1-13). Pots supposedly suited for containing, transporting, mixing, pouring, ladling and drinking liquids thus became our examples. Through research and interpretation of production traces and modes of surface finish, we were able to remake a number of these vessels according to authentic methodology and using comparable clays and tempers. Thus, following the sequence of production, after the principle of the *chaîne opératoire*, a part of the archaeological collection was copied. Because these replicated, or rather, reproduced vessels were new, unbroken and - most important - allowed to be damaged, their virgin surfaces formed an excellent basis for carrying out experiments related to drinking habits (see van Gijn et al., this volume).

Archaeological collection

The available archaeological material, now part of museum collections, was excavated during the last decennia. Pottery fragments from the Heuneburg were primarily large and often mostly complete so that the morphology of at least part of the vessels could be recorded. The pottery repertoire consists of cups, goblets, bowls, flasks, pots and jars, all of different shape and size, but attributable to recurrent types. The majority of the studied artifacts belong to a category of consumer ware, of which bowl-shaped pottery cups and goblets form the main part. The pottery from the Mont Lassois, on the other hand, is more fragmentary and, as a result, no drawings of complete profiles were arranged. This collection was therefore used primarily for technological observations and comparison.

The pottery in general can be classified as dense or compact, which is related to fine-sized tempers in the clay and the absence of the typical voids caused when organic fibers are added and burn. Due to shape and size, this pottery can be associated with drinking and the use of liquids. Additionally, there are small pinch-pots and so-called coarse ware, which is characterized by coarser fabrics and sturdy forms, a somewhat carelessly looking finish and sometimes additions such as a rope-like band on the shoulder or a rim with finger impressions. Though the archaeological material was studied as a collection, this description only covers part of the repertoire. Two criteria for the making of experimental reconstructions were an assumable affinity with the use of liquids and the availability of specific complete vessel-profiles. Fig. 1 and 2 show a number of the vessels that stood model for part of the reproductions. Though by far not representative of the entire Heuneburg pottery repertoire, nor showing all the reconstructed pots, these figures give an impression of the variation among the reconstructed pottery. Numerous smaller fragments from the Heuneburg and the Mont Lassois were also studied and used to collect traces of production, surface finish and additive fabric information.

Method

The pottery reconstructions are based on macroscopic and microscopic observations of the archaeological material followed by interpretation (Fig. 3). To start with, the original artifacts were examined and their shape, size, color, surface finish and fabric characteristics recorded. The pots were then shaped using a card-board profile template made according to the profile of the originals. The size of the template was enlarged in order to compensate for some 10 % clay shrinkage due to drying and later firing. For the applied clay bodies, shrinkage was estimated using test-bars made of the relevant materials. The surfaces of the archaeological artifacts - which were not only studied as unique individuals, but considered as part of an elaborated repertoire - were meticulously inspected for traces of production. This implies that the ceramics were first grouped on common technological characteristics according to the approach of the "Leiden Studies in Pottery Technology" (van As 2004, 7-22). Quite often only limited indications and few reliable traces of production are


a
b
5 cm
e
2.5 cm
c
f
d
g
10 cm
h

Figure 1 (opposite page): Range of vessel types present in the archaeological assemblage of the Heuneburg. (a) Wheel-thrown bottles, e. g. HB-VB-001, and bowls. Bottles form a minority of the repertoire. (b) Medium size wheel-made bowl. (c) Cups, e. g. HB-VB-065, and small goblets. In the front a cone-necked goblet. (d) Differently shaped hand-made goblets of medium size, e. g. HB-VB-039 (fine ware). (e) Small delicate hand-made bowl. The fracture pattern indicates the use of coiling (fine ware). HB-VB-007. (f) Fragment of a medium size bowl (fine ware). The arrows indicate fractures, characteristic of coiling. HB-VB-048. (g) Medium size hand-made s-curved bowl with smoothed graphitized and burnished surface. Fořt-Linksfeiler 1989, 213 F49-50 (fine ware). (h) Medium size hand-made open bowl with a rim diameter of 23 cm. HB-VB-006 (fine ware). (© a, c, d = Landesmuseum Württemberg Stuttgart, H. Zwietasch; b, g = B. Schorer, e, f = Laboratory for Material Culture Studies Leiden University, h = A. Mötsch).

visible on the many vessel-fragments which form the archaeological collection. In exceptional cases important information on the ancient shaping methods can be found in the breaking pattern of original pots. This is because pots tend to break at the weakest points, where coils were connected, a phenomenon referred to as preferential breaking. This can be seen, for example, in a fragment of an archaeological original, bowl HB-VB-048 (Fig. 1f).

However, the number of such diagnostic pieces, fragments and sherds is limited. This is the case, because potters constructed their vessels carefully and finished them intensively in order to obtain good quality items which could not only survive the drying and firing processes, but also the stress of daily use. Finishing was an action that, intentionally or not, mostly obliterated all former traces of production - a rule confirmed by the experimental remakes. This is why the presence of visible traces of production on pottery is more exception than rule. Affinity with pottery production processes in general may offer the ability to deduct aspects of production. With most studied vessels, indications of the forming process lay hidden in the shape itself and are not directly visible as traces. Indications of certain production methods found in the breaking pattern, which become visible after refitting several sherds, are to be considered exceptional. Examples of preferential breaking are indicated with yellow arrows in Fig. 1 and 2. The word “fabric” used in ceramic research, is a terminology borrowed from the world of textile production. When observing ceramics, it refers to the entire appearance of the composition. By its nature, the ceramic fabric is best observed on a freshly broken and, if relevant, prepared edge of ceramic objects. To explain this, old or existing breaks are often not ideal for collecting fabric information because they are polluted with post-excavation handling and also may be dark in colour, which makes identification of inclusions difficult. Permission was given to refire a limited number of small fragments under standardized conditions, which were studied under 10x to 40x magnification (Fig. 4b-d). Refiring pottery and pottery fragments is a current method for standardizing some aspects of the sherds under investigation. With a second heat-treatment in a controlled oxidizing atmosphere they are fired to a temperature slightly higher than the original one. By this treatment dark carbon is burned and only light colours of the fabric remain, which enhances the visibility of inclusions. Moreover, this treatment improves comparability of colours by standardization.

However, for the majority of the material a fresh cut was not allowed to be made and thin-sections were also not available. In order to not damage the archaeological ceramics further, information on fabrics had to be obtained by alternative ways. Though not ideal, it was derived from combining surface observations (Fig. 4a.e-f) with observations on edges of clean sherds and fragments, as well as clean cuts, when available (Fig. 4g). The latter, though also limited in number, confirmed the other observations. Apart from that, a few thin-sections were at our disposal (Fig. 4h). Their information confirmed the sizes and types of temper used for the production of certain categories, e. g. fast wheel-thrown pottery. Though both methods, surface-observation and fabric-analysis, were used, their accuracy differed qualitatively and quantitatively. Fig. 4 shows the differences between both approaches, including thin-section analysis. However, by combining results and connecting them to


a
b
5 cm
c
5 cm
d
5 cm
e
10 cm
f
2.5 cm
g
10 cm
h
5 cm

Figure 2 (opposite page): Further examples of vessels from the Heuneburg. (a) Bowl from Fig. 1h seen from above. Preferential breaks refer to coiling. (b) Medium size hand-made, close-shaped and s-curved bowl (fine ware). HB-VB-025. (c) Medium size, hand-made bowl with preferential fracture pattern. Rim diameter 21 cm. HB-VB-011. (d) Rather shallow hand-made bowl. Fabrication by coiling is revealed by both the fracture pattern and deviation from circularity. HB-VB-002. (e) Cone-necked vessel with a content capacity of some 10 l. All the pottery was first restored by museum staff. (f) A pinch-bowl. HB-VB-004. (g) Coarse ware pot with evidence of coiling. HB-VB-024. (h) Coarse ware vessel with preferential fractures, indicative of coiling. HB-VB-071 (© a, g = Laboratory for Material Culture Studies Leiden University, b-d, f, h = A. Mötsch, e = B. Schorer).

Figure 3: Information from surfaces and edges was obtained by stereomicroscopy (© Laboratory for Material Culture Studies Leiden University).

ware-categories, we obtained enough specific fabric information to serve as a basis for composing the necessary clay pastes or clay bodies (Fig. 5) (Jacobs 1983; Stienstra 1985).

Restricting factors

The archaeological pottery was often rather fragmentary and had to be handled with care in order to avoid damage. Observability of fabric aspects in relation to the estimation of clays and tempers was thus limited. Being an important technological factor of pottery production, clays and tempers are of influence on the mechanical and chemical properties of pots during their life as utensils. Aspects of clays and tempers may have influenced traces of use developed on the pots in the past, which are subject of a related use-wear study (van Gijn/Verbaas, this volume; Verbaas/van Gijn-Vix, this volume). Grain types can best be studied qualitatively and quantitatively when fabrics are well visible, a situation which implies that the related fragments are clean, have a fresh break and are light in color. Many artifacts from the museum collections were not in agreement with these demands, because they were dark in color and/or covered with a secondary layer. The latter could be dirt of post-depositional origin, patina or an intentionally applied layer for sealing the surface as well as remainders of the content. Most often, however, the dark color is caused by remainders of carbon from combusted fine vegetable material in the clay and soot deposited during the firing process under reductive conditions. This implies a process in absence or with a minimum of oxygen, and where the pottery was in direct contact with the fuel.

Especially with the elaborate and diverse collection of hand-made pottery, categorization based on correlation between fabric and morphological types is complicated. This correlation between shape-types and fabrics is more divergent in

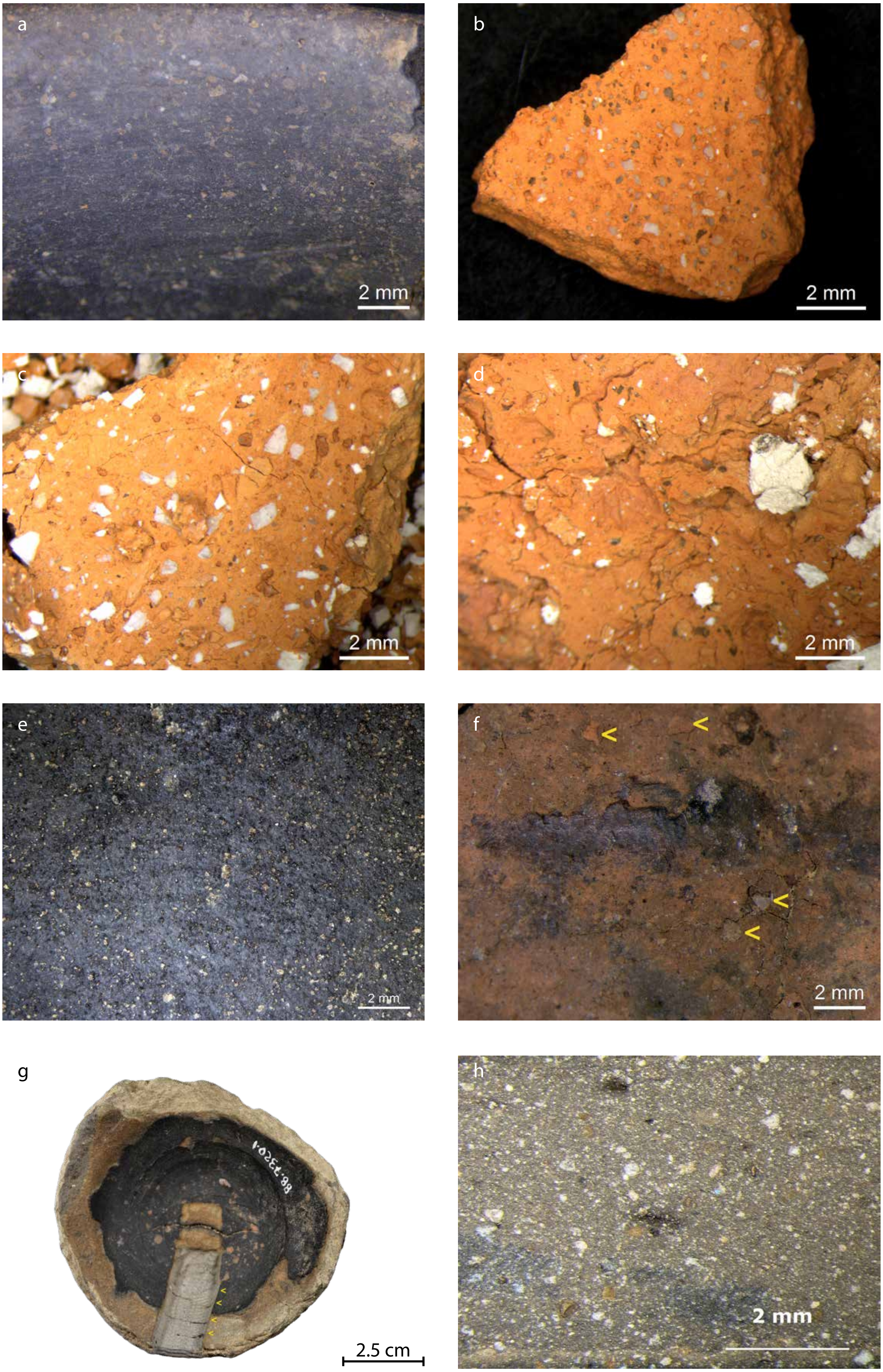
a
2 mm
b
2 mm
c
2 mm
d
2 mm
e
2 mm
f
2 mm
g
88.7320.1
2.5 cm
h
2 mm

Figure 4 (opposite page): Different conditions of fabric observations, some more ideal than others. (a) Surface of HB-VB-007, macroscopic observation. (b) Fragment of HB-VB-007 prepared for fabric analysis by refiring and characterized as fine ware. Sorting is good. (c) Sample of a cone-necked vessel HB-VB-070, prepared for fabric analysis and characterized as fine to medium ware. (d) Fragment of HB-VB-071 prepared for fabric analysis by refiring and characterized as coarse ware. Sorting is moderate to poor. (e) Macroscopic surface information of HB-VB-048. The bowl was characterized as fine ware. (f) Macroscopic surface observation of HB-VB-006. Certain types of temper, e. g. grog and quartz, were identified (fine ware). (g) Part of wheel-made vessel with indications of wheel-coiling. Fabric information was obtained at a fresh cut (fine ware). Vix-ALT-135. (h) Thin-section showing the fabric of fast wheel-thrown fine ware. Grain-types quartz and feldspar < 250 µm. Very good sorting (© Laboratory for Material Culture Studies Leiden University).

some regards for the category of hand-made pottery than for wheel-made pottery. Given the fact that comparable fabric recipes may be used for different shapes and *vice versa*, quite some fabric variety exists within the same morphological categories of hand-made pottery.

Fabric information

Within the repertoire, frequently occurring temper-types are quartz, feldspar, muscovite, gneiss, volcanic rock-fragments, calcite and grog (chamotte). Part of the grains, namely quartz, feldspar and muscovite, were natural inclusions in the clays. More and other grains were assumedly added by the potters on purpose when preparing their pastes, but grog and calcite were certainly added to part of the pottery. Grains are mostly present in quantities around 20 to 25 %. Based on grain-size, sorting and density, the ware can be roughly divided into categories, e. g. fine ware, fine to medium ware, and coarse ware. Frequently occurring selections of size are very small grains < 250 µm (0.25 mm) and also grains < 500 µm (0.5 mm). The smallest grains appear to have been used for the preparation of clays intended to produce pottery on the potter's wheel, and also for delicate hand-made pieces (Fig. 1a-f; 4b.e.h). Next to that fractions up to 1 mm and, less often, up to 1.5 mm form a large group of pottery classified as fine ware and, at the other range of the spectrum, fine to medium ware (Fig. 1g-h; 2a-e; 4c). A group of coarse ware is characterized by grains up to 3 mm and sometimes even more in size, but their fabrics also contain all smaller sizes. In this ware class the occurrence of grog, calcite and also organic matter next to smaller amounts of quartz, feldspar and basalt were observed (Fig. 2f-h; 4d). Based on fabric information derived from the archaeological collections, such as particle sizes, quantity of grains and types, five main clay compositions or pastes were inferred. This way it became possible to categorize this complex information, with many minor individual differentiations and exceptions, especially observed on hand-made objects, which form the majority of the collection. Fabric differences between artifacts attributed to the same category may consist of small varieties in quantity and size of grains, combinations of grains-types, distribution of grains, color and the like, yet be not clear or great enough to justify their being split up into different categories.

Materials for the reconstructions

Preparing clay pastes

Sands used for tempering were sorted on mineral types and adapted by adding crushed minerals. Grain sizes were selected by sieving. The clay pastes or clay bodies were prepared by manually mixing the commercially obtained clay with the selected sizes and types of sand (Fig. 5a). Five clay-sand compositions, pastes 1 through 5, were prepared conform to the fabrics of the archaeological materials (Fig. 5b):

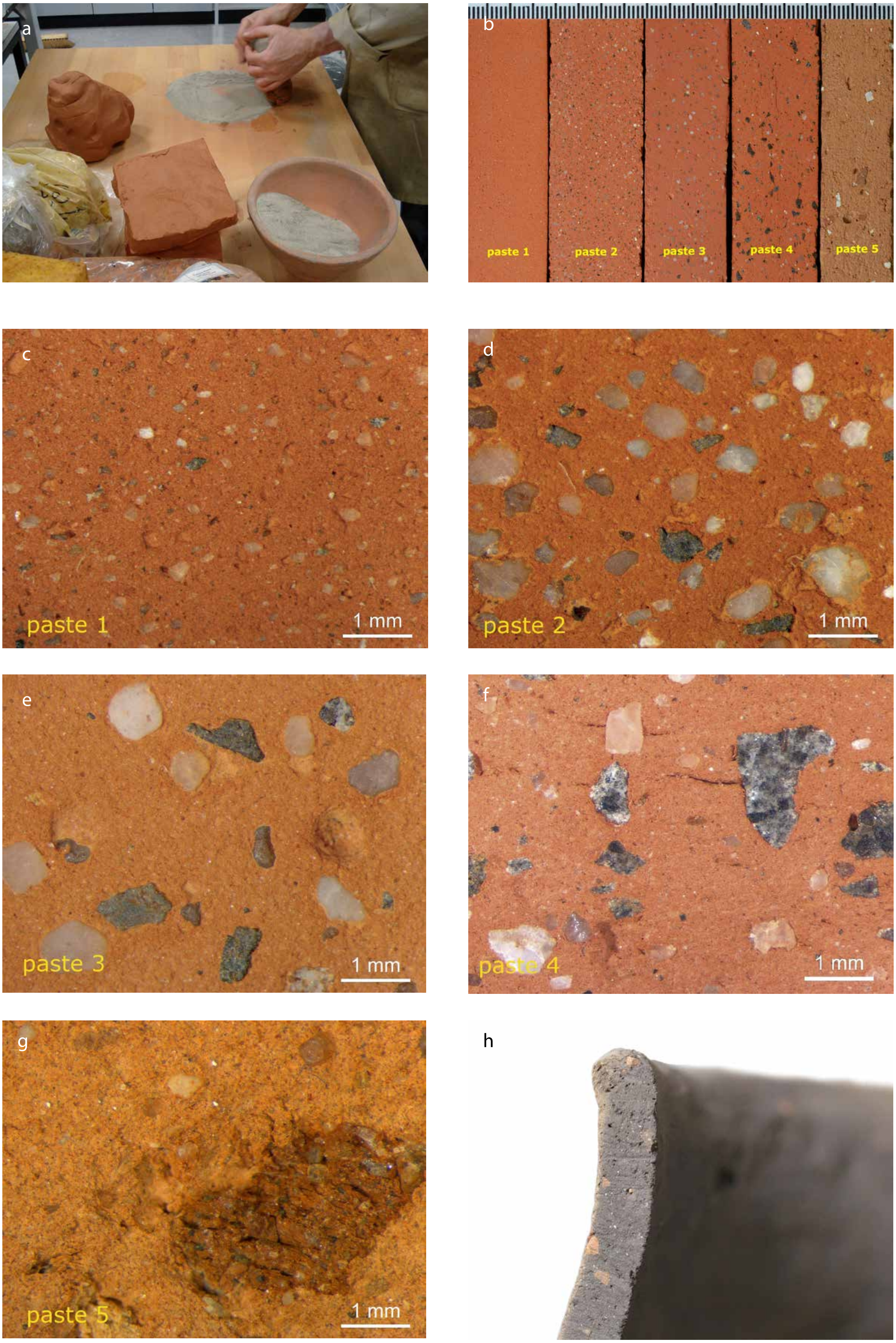
a
b
paste 1
paste 2
paste 3
paste 4
paste 5
c
paste 1
1 mm
d
paste 2
1 mm
e
paste 3
1 mm
f
paste 4
1 mm
g
paste 5
1 mm
h

Figure 5 (opposite page): Visual information concerning the clay pastes that were used for making the reconstructions. (a) Clay pastes used for the pottery reconstructions were prepared by mixing clay with grains of selected sizes and types, based on comparison with the archaeological fabrics. (b) Paste groups based on fabrics of the archaeological material. Grain sizes correspond to the mm scale above the picture. (c) Paste 1, fine ware (taken at 10x original magnification (OM)). (d) Paste 2, fine ware (10x OM). (e) Paste 3, fine ware (10x OM). (f) Paste 4, medium fine ware (10x OM). (g) Paste 5, coarse ware. Fine quartz and grog (10x OM). (h) Cut-through of reconstruction according to HB-VB-024 (Fig. 2g), made with paste 5. Grog and some cavities caused by burned vegetable matter (© Laboratory for Material Culture Studies Leiden University).

Paste 1 (Fig. 5c), the finest mixture, is comparable to material from natural drift-sands and so-called loess deposits. It contains 20 to 25 % of grains, mainly quartz and some muscovite ≤ 250 µm (0.25 mm) in size. This very fine paste was mainly used for throwing reconstructions on the fast potter's wheel (Fig. 1a-b). For the production of fine, hand-made ware, a variety of this paste, where quartz is completely or partly replaced by different quantities of finely grained, crushed crystalline calcite, was used when relevant.

Paste 2 (Fig. 5d), is coarser and contains 20 to 25 % of a mixture of mainly quartz grains, some feldspar, some basalt and some muscovite ≤ 500 µm (0.5 mm) in size. Varieties of this clay body occur, where quartz is completely or partly replaced by different quantities of crushed crystalline calcite. As mentioned, it was difficult to attribute this information to morphological types, because the same archaeological types seem to occur with and without, and with different quantities of added calcite. This paste was used to reconstruct hand-made fine ware pieces (e. g. Fig. 1c-e).

Paste 3 (Fig. 5e), again coarser, contains 20 % of a mixture of quartz grains, some feldspar some basalt and some muscovite. Grains except for the muscovite shivers, which are usually much smaller, are up to 1 mm in size. There are varieties of this clay body where quartz is completely or partly replaced by grains of crushed crystalline calcite, eventually of different grain-sizes. This paste was used to reconstruct slightly coarser fine ware (e. g. Fig. 1g-h; 2a-b).

Paste 4 (Fig. 5f), is a mix of basalt grains with mainly quartz and feldspar. The total amount of grains is around 20 % and their size is limited to 1.5 mm at a maximum. It is slightly coarser than paste 3 and was used to reconstruct pots with a fabric characterized as fine to medium-fine ware (Fig. 2c-d). The number of vessels which can be categorized as fine to medium-fine ware is limited, compared to fine ware. In some cases, there is a small overlap with fabrics of slightly finer tempered vessels (Fig. 2a-b). When preparing a paste for reconstructing a big cone-necked vessel HB-VB-070 (Fig. 2e), the basalt was replaced by calcite and a bit of grog (Fig. 4c).

Paste 5 (Fig. 5g) results in a porous ceramic due to the cavity of burned organic matter and is provided with additions of grog (Fig. 5h), some quartz and, if relevant, crushed crystalline calcite. The portion of non-plastics is around 25 % and the maximum size is 2 mm. However, bigger grains may occur sporadically. This paste and varieties of it, where crystalline calcite was added, were used to reconstruct coarse ware vessels (Fig. 2g-h).

Since the clay substance for this ware contained rotten organic matter, it may have been derived from wetlands somewhere along the shores of a river or smaller stream. Such organic non-plastics of natural origin, from very fine to relatively coarse, occur in this paste in combination with grain-shaped mineral tempers, like rock-fragments, quartz and feldspar. The grainy materials were certainly in part added to the clay in order to improve the workability properties, so to form a paste of firm consistency. Grog made of crushed pottery and in particular cases also broken calcite, were at the same time added to the paste for reconstructing certain coarse ware pots (e. g. Fig. 2h). Calcite was probably intended to improve specific properties during use or perhaps only because the Mediterranean example was followed (Santacreu 2014, 60-65; 63 in particular).

Figure 6 (opposite page): Raw materials (upper half) and the shaping of pottery with the potter's wheel (lower half) (© Laboratory for Material Culture Studies Leiden University unless stated otherwise). (a) Potters speak of "adding bones to the clay" to indicate the changed consistency. This clay body was used to remake coarse ware. (b) Fabric comparable to paste 1, but about one third of the quartz-grains was replaced by finely crushed calcite (the white grains) of the same size (fine ware). (c) Paste 5 corresponding to HB-VB-071 (Fig. 2h) showing grog and calcite grains, both added. Coarse ware. (d) Broken crystalline calcite. (e) Reconstructed wheel-made bottle, thrown on the fast potter's wheel based on HB-VB-001 (Fig. 1a). (f) Forming the rim of a bowl on the fast potter's wheel. Reconstruction based on the archaeological example in Fig. 1b (© E. Mulder). (g) A stand foot was formed after a while when the clay had stiffened. To do so, the bowl was fixed upside down. (h) Small Proto-Geometric pot with indication of wheel-coiling, rim diameter 10 cm (Archaeological Museum Larisa, Thessaly) (© L. Jacobs).

Only the maximum grain size of these pastes is mentioned since all of them also contain a mixture of smaller grains of the same types. Moreover, only grains > 70 µm in size (0.07 mm) were counted and indicated as percentages, consequently no grains of silt fraction were recorded. As the archaeological collection is elaborate and varied, there are many different fabric compositions. The pastes so far are not individuals, but roughly cover that part of the pottery repertoire relevant to our research. Moreover, grain-types of volcanic origin such as phonolite, pyroxene etc. may be present in individual cases as part of the total quantity of grains.

Tempering the clay

Among potters it is normal practice to prepare and improve clay before making pottery out of it. A widely spread way to reduce shrinkage and at the same time to improve water transport through the clay mass is by adding sand or non-plastic material. This practice, by which the structure is opened, is called tempering or opening of the clay. After tempering and mixing we speak of prepared clays, pastes or clay bodies. Another advantage of adding non-plastics to the clay is that it makes the substance or paste firmer, which markedly improves its workability. In this context potters speak of "adding bones to the clay" as an indication for the changed consistency and increased firmness (Fig. 6a).

For practical reasons the reconstructions were not made of clays found near the excavations. Instead, standard commercially obtained potter's clay was adapted in such a way that it became representative for the original clay bodies. For mixing, we started with fine red-firing clay which contained no grains at all and is sold as potter's clay K143. According to provider Sibelco, its chemical composition is as follows: SiO_2 67 %; Al_2O_3 15.6 %; CaO 5.5 %; K_2O 1.8 %; Na_2O 0.2 %; Fe_2O_3 8.5 %; TiO_2 0.8 %; MgO 0.5 %. We adapted this clay to our particular purpose by adding different tempers and workable quantities of the above mentioned clay-temper mixtures were prepared.

To bring the commercial clay paste in accordance with the ancient fabric recipes, only grains > 62 µm in size were included, and silt fractions were not specifically added. Compared to modern commercial clay, most natural clays tended to be somewhat higher in silt content. There is a tendency, that the higher the silt content ($\alpha < 62$ µm) of a clay, the softer the resulting fabric will be, and this may explain small differences in hardness between some of the reconstructions and the original pots. It is interesting that archaeologists were able to detect small differences in hardness between archaeological Iron Age pottery and its reconstructed equivalents by "feeling". Such differences can be avoided, but this would involve elaborate sampling of clays and allied materials in the production area, a step that was bypassed for practical reasons. Moreover, apart from clay composition, small differences in hardness are also due to slightly divergent firing temperatures between individual artefacts.

For each individual pot to be reconstructed, one of the pastes (1 to 5) was adapted, when necessary, by adding finer or coarser grains of specific minerals or stone types, e. g. calcite, vulcanite or basalt. In other cases, the amount of temper was decreased,


a
b
+ calcite
1 mm
c
paste 5
1 mm
d
e
f
g
h

which could be realized by adding measured portions of pure clay, thus reducing the total content of grains or non-plastics.

By this method the entire repertoire could be covered, e. g. goblets HB-VB-039 (Fig. 1d). These goblets contain 15 to 20 % of very fine sand, mainly composed of quartz grains represented by paste 1. However, in the case of the smaller goblet (Fig. 1d in the back, on the left), about one third of the quartz-grains was replaced by finely crushed calcite grains of the same size (Fig. 6b) in order to compose the paste in agreement with the fabrics of the archaeological originals. About 5 % of slightly coarser quartz grains was added to the paste for the somewhat larger goblet (Fig. 1d in the background on the right), in order to adapt it to the archaeological example, also categorized as fine ware.

Another example from the elaborate category of consumer ware, where the standard paste was first adapted by adding crushed calcite, is the s-curved bowl from Fig. 2b. To compose a clay body, matching with the archaeological original, paste 2 was provided with 10 % of crushed calcite with a maximum grain size of 1.5 mm. Such adaptions were also made for the coarse ware. To paste 5, used for reconstructing a specific coarse ware type (Fig. 2h), next to grog, calcite was added, which resulted in a fabric specific for the case (Fig. 6c). Grainy mineral tempers like quartz, feldspar, basalt, grog and crushed calcite were certainly partly added to the clay in order to improve the workability properties of the paste during forming, but the latter also may have been intended to influence properties of use (Santacreu 2014, 67-75). The addition of the mineral crystalline calcite (Fig. 6d) to clays for pottery production was assumedly done on purpose. In the Near East and the Mediterranean this material was traditionally added rather frequently to clays intended for pottery associated with food preparation (Franken 1992, 105-117; London/Schuster 2011, 233-247). In the repertoire from the Heuneburg and Mont Lassois, crystalline calcite was added to only part of the vessels. Why this was done, is difficult to say. In the category of fine wheel-thrown pottery a preference for quartz and feldspar tempers seems to exist, and small portions of fine crystalline calcite were sometimes detected, e. g. in Vix-ALT-125 and -141. However, the calcite was mainly added for hand-made ware and it may have been a habit that existed among occasional potters, only producing on a small scale. Portions of calcite were added, but by far not always and not in fixed quantities. Limited quantities of fine muscovite particles are common in many fabrics as natural constituents of clay deposits originally exploited by Celtic potters. Therefore small amounts of the material were added to the commercial clays we used for the reconstructions. These flat particles are sometimes very small and as such sometimes hard to observe microscopically, but their presence is often betrayed by light reflections at the surface. Though small and sometimes low in quantity, they have some influence on the workability of the clays. Due to their flat shape these mica particles tend to increase the cohesive strength of the plastic material.

Shaping techniques

Wheel-made pottery

Wheel-thrown pottery

A relatively small part of the studied material is wheel-made using a fast rotating potter's wheel, where centrifugal forces played a role, e. g. HB-VB-001 (Fig. 1a-b). Such a wheel had enough momentum for continuous rotation and, if only during part of the production, allowed a rotation speed of more than 40 rpm. This pottery, as a rule, was made of fine tempered clays comparable to paste 1, but clays in agreement with the slightly coarser paste 2 were also used for wheel-made pottery.

Compared to hand-made pottery the production of wheel-made ware is supposed to have been more organized and to have depended on a different level of permanent spatial organization. This means that production on the potter's wheel presumes a workplace with fixed equipment. Output is normally larger and firing capacity correspondingly also. Because the production of wheel-made pottery is mostly the work of specialists, skill and training are other components which make the technique less flexible, compared to small scale production of hand-made pottery. However, within the limits of a certain shape repertoire, a lot of variety is still possible and to be expected. Some general characteristics of fast wheel-thrown pottery are:

- a higher degree of symmetry;
- horizontal throwing ridges continuing over the entire surface;
- a throwing spiral most often on the inside of the pots;
- a firm profile with limited curvature and no sudden or sharp changes of direction in the wall profile;
- wall thickness slightly decreasing upwards;
- well finished uniform outer surface, often very smooth and regular;
- rather perfect circularity; and
- preferential breaking is oblique.

When three or more of these characteristics occur together, we may conclude that a particular pot was wheel-made. The lower part of Fig. 6 shows some examples of wheel-made reconstructions based on archaeological examples from the Heuneburg with these characteristics.

Wheel-coiling

Next to the throwing of pots on a fast potter's wheel, there are technological varieties where wheel-made pottery is composed of several parts, one of them described as wheel-coiling. This technique is a combination of coiling and wheel fashioning (Rückl/Jacobs 2016, 297-321). In the Near East and the Levant comparable methods had already existed for a long time, especially for the production of large vessels. There are indications that wheel-coiling in the Aegean begun at the end of the Middle Bronze Age (Choleva 2012, 343-381) and that this particular method for the production of small and medium sized pottery continued to exist during the Proto-Geometric period and later (Fig. 6h). Especially to produce small pots, wheel-coiling is much slower compared to normal fast-wheel throwing. However, because more control over the shape and the material is obtained, the application demands comparatively less skill. The start is a separately hand-formed rough-out, made by coiling clay rolls, which is fixed on the wheel (Fig. 7a). As a result, less clay needs to be transformed during the next step, when rotation gets involved (Fig. 7b), and the condition of the clay during that part of the procedure, when wheel-forming is involved, is still firmer. Due to this way of working, control over the shape is better or easier as compared to fast-wheel throwing, and given that the coils are fixed well together, the chance of failure is noticeably reduced. Wheel-coiling is considered an additive method, and so the application of finely tempered clays is to be expected. Fabric pastes 1 and 2 are suited to the method. This methodical variety of wheel-made pottery was also detected for the Mont Lassois (Balzer 2009, 200) and experimentally verified for ceramics found in Bourges, France (Augier 2013, 117-120). Several fragments from the Mont Lassois, all belonging to vessels of limited size, showed traces of fast-wheel rotation. One of them had indications of wheel-coiling, namely VIX-ALT-135 (Fig. 7c). An issue with wheel-coiling is that due to careful finishing of the pottery, the method is not easy detectable, especially not on fragmentary material. Because of reduction firing, which was probably intentional, the majority of the objects appeared grey in color, with a dark grey to black surface. The surfaces of these pots were always well smoothed and mostly polished making use of rotation or alternatively by hand.


a
b
c
d
e
f
g
h
2.5 cm

Figure 7 (opposite page): Different shaping techniques, wheel-coiling, coiling, pinching and combination with molding (© Laboratory for Material Culture Studies Leiden University unless stated otherwise). (a) Fixing a hand-coiled rough-out on the potter's wheel (© St. Rückl). (b) Shaping a coiled rough-out on the fast potter's wheel. To improve visibility, coils are differently colored for this experiment. (c) Fragment Vix-ALT-135 from Mont Lassois, France, with traces of wheel-coiling, visible only where a part was cut away. (d) In some cases of hand-made pottery a striking similarity with wheel-made pottery was obtained by careful finishing. (e) Reconstruction of hand-made ware based on HB-VB-007. A very fine clay paste comparable to that of wheel-thrown pots was used. By intensive finishing the vessel may look wheel-made, but it is less circular and less regular. It was made without rotation. (f) Characteristics of pinched pots are their limited size, the simple half-globular bowl-shape and overlapping fingerprints. (g) Surface of pinch-bowl with horizontal striations caused by hand forming and wrist rotation. (h) Pinch-bowl used to insert clay directly into a mold. A strong firm wall of equal thickness is quickly made.

Hand-made pottery

Only a limited number of pots were wheel-made, and the majority of the pottery from the Heuneburg studied in Leiden consists of hand-made objects. However, in a number of cases it appears that the potter tried to make it look like wheel-thrown pottery: the particular pots are hand-made, but comparatively much care was taken to make them symmetrical and round, and they are finished intensively. Besides esthetical reasons, a plausible motivation for this behavior could have been a kind of competition among potters. A high valuation of or admiration for wheel-made pottery could have contributed to this attitude. Despite an assumed admiration for imported wheel-made pottery of Mediterranean origin, it cannot have been easy for individual local Iron Age potters to switch from hand-made household production techniques towards throwing pottery on the fast potter's wheel. Apart from the necessary skills, they must have lacked the logistic structure for such a professional approach. Wheel-coiling and the use of a *tournette* for finishing hand-made pottery may have been solutions for this issue. Certain completely hand-formed vessels look like wheel-made pottery. In some cases, the slow rotation of a *tournette* was used to finish the surface and to make it as firm as possible. This resulted in a striking equality with the surface of wheel-made pottery (Fig. 7d). In most cases, however, the surface was carefully finished and smoothed just by hand, doing so mainly in a horizontal direction. Especially when comparing small fragments, the identification of applied techniques was complicated (Fig. 7e).

Pinching

The pinching method was used for making certain small goblets and other small pots. Pinching was also applied as a start for making the lower part of, for the rest, coiled pots. Characteristics of pinched pots are their limited size, mostly simple, roughly half-globular bowl-shape (Fig. 2f) and overlapping fingerprints on the surface caused by repeated rhythmical pinching (Fig. 7f). Eventually, the surface was finished by rotation of the wrist, in which case it slips between the thumb and the fingers of one hand. This way of finishing may result in a rather neat surface with horizontal striations (Fig. 7g), but this can easily be distinguished from wheel-finished surfaces through close observation. The pinching technique is well suited for making small pots and bowls. In principle these objects are pressed from a single piece of clay by pinching the substance between thumb and fingers. For the production of crack free pots the clay needs to possess quite some plasticity, but if the walls are not thinned out for too long and the paste is worked in a soft condition, even highly tempered clays such as paste 5 can be used. In that case the technique is suitable for making small thick-walled crucibles. When properly executed, it results in a seamless construction with no weak spots, e. g. HB-VB-004 (Fig. 2f) and HB-VB-055.

Pinching combined with coiling and molding

The pinching technique is also suitable for making the bottom part of vessels which, for the remainder, are constructed by coiling. Because eventual traces are obliterated by further reworking of the rough-outs, the lack of direct evidence could hamper


a
b
c
HB VB 065
7039
d
e
f
g
h

Figure 8 (opposite page): Coiling beakers and goblets, and using a mold in combination with coiling (© Laboratory for Material Culture Studies Leiden University unless stated otherwise). (a) On the upper edge of the lower part thin clay rolls were applied and fixed by pinching and smearing. (b) A shell with appropriate curves proves a very effective scraper. It also connects the thin coils firmly and removes surplus clay from the inside. (c) The inside of the rim was finally fashioned with a rounded pebble. (d) Fired cup reconstructed after HB-VB-065 (Fig. 1c). Rim diameter 8 cm. (e) The same shell tool was used to shape a stand foot. (f) Reconstruction of goblet based on HB-VB-065 (Fig. 1c). The surface was polished, and the black color is due to reduction-firing. Rim diameter 10 cm. (g) The lower part of certain vessel types was made by putting clay coils into a mold and pressing these against the porous wall (© V. Brigola). (h) As the mold provided the necessary firmness to the lower wall, the vertical part was built on it by adding, fixing, pinching and smearing several clay coils (© V. Brigola).

identification of such combinations of techniques. The combined method is especially useful for making narrow shapes, like cups or mugs, e. g. HB-VB-065 (Fig. 1c). When a pinch-bowl is used to insert clay directly into a mold, a strong firm wall of equal thickness can quickly be made (Fig. 7h). Except for a suitable mold, no tools or other equipment are necessary for successful application of the method. Because these cups are small and not very heavy, the clay can be removed from the mold almost directly after it has been pressed against the support. To provide for this, the mold is made of porous ceramic material and as such will absorb moisture from the inserted clay quickly. Therefore, the soft clay will not stick to the dry ceramic mold. Depending on the condition of the clay, the new vessel to be formed only has to stay in the support-mold for a few minutes. When it is removed from the mold, the clay is firm enough, yet not too dry to allow new thin coils to be added and fixed. The vessel is now further formed by adding and fixing new thin coils, alternated with pinching, smearing and tapping a bit (Fig. 8a). After a while, when the clay has stiffened further, the cup can be reworked by scraping and pressing. In this stadium a shell scraper of the right size with appropriate curves proves very effective for adapting and correcting the inside as well as the outside profile (Fig. 8b). Finally, the inside of the rim is fashioned with a rounded pebble (Fig. 8c). After smoothing the entire surface, the object is dried partly, and then the cup or goblet, if relevant, is polished horizontally. It is now ready to be fired, a procedure by which the color will change completely (Fig. 8d).

The method of combined pinching-coiling, in combination with molding was applied for making several types of cups and small goblets with closed shapes. By small adaptions in the shape of the body and the upper and lower part, a lot of variety could be obtained. By the addition of a stand-foot, a small goblet was made and the rim executed in agreement with the archaeological example (Fig. 1c). The stand foot was pinched from a piece of clay and then fashioned with a shell tool (Fig. 8e), which proved very convenient for this work. After the smoothed surface was almost dry, it was polished in horizontal strokes and dried further to be fired, a treatment that, since executed under reducing conditions, resulted in a dark appearance (Fig. 8f). Combinations of coiling and molding with pinching seem most appropriate to produce relatively small pots.

Coiling combined with molding

For making the bottom and lower wall of coiled pottery, a support-form or mold was likely used more often than we are able to prove. When dealing with open shapes like most bowls and dishes, this is a relative sure and quick way of production which enables good control and uniformity of shape. Clay was inserted by putting coils into a mold and then pressed against the inner wall. On doing so, the lower vessel-part is made identical to the shape of the support-form or mold (Fig. 8g).

Several vessel shapes with an s-profile from the Heuneburg and Mont Lassois were produced using this combined method. This is because when forming a vessel just by coiling, control over the exact wall curve is not entirely optimal. The combination of molding and coiling therefore seems to have been a technological choice. By putting coils into a support-mold, the intended wall profile can easily and quickly be realized,

Figure 9 (opposite page): Steps from the chaîne opératoire of the forming process, combined molding with coiling. (a) For small vessels a slab of clay, instead of some coils was used alternatively. (b) The lower part was fashioned with some tools which eased the making of the desired curves. (c) Two goblets hand-made after HB-VB-039 (Fig. 1d). A graphite layer was applied and the surface polished with a pebble. (d) Goblets HB-VB-039 and HB-PL-014 share the same profile for their lower part. (e) Reconstruction according to goblet HB-PL-014. The surface was burnished with a pebble by rubbing horizontally. (f) Reconstruction of close-shaped bowl HB-VB-025. Production started by pressing clay coils into a support-mold. The coils were connected by pressing and smearing. (g) During forming, the lower section was supported by a mold, and the wall was further built up by piling coils on top of each other, which were all connected by pressing and smearing. (h) A protruding ridge marks the former position of the mold. The bowl was only placed on a tournette for the picture. It was made without rotation (© d = Landesamt für Denkmalpflege Esslingen, others = Laboratory for Material Culture Studies Leiden University).

without the danger that the soft clay deforms or that the wall becomes too thick or tears apart. The upper section of the vessel which, if relevant with regard to its morphology, tends to develop inwards, is leaning on the lower part and as such is built on top of the part that rests in the support during at least part of the further process. The method described here is comparable to the production method of related "Marne Pottery" (van den Broeke 2012, 202-207). Following this way of working may explain the construction of s-shaped profiles, typical of the lower wall of much Early Celtic pottery. At first observation, these particular pots may seem a bit collapsed or deformed, an impression that may be articulated in cases when the hand-made pottery happens to be a bit shallow. However, it can be concluded from the high frequency of occurrence that unintended deformation rarely happened. Awareness of the fact that the particular morphology is intentional, helps us to appreciate these designs.

Goblets like HB-VB-039 (Fig. 1d) are examples of pottery made by the described combination of molding and coiling. For the making of these vessels' lower walls a mold was used. The support-mold, which has the shape of a low bowl, is not easily identifiable as such. The object was first made from a slab of clay and some coils. All appropriate bowl-shaped ceramic vessels of simple open form could have been used for the purpose and, once part of the archaeological record, are not easily reconnected to such function. The reconstruction process of two goblets from the Heuneburg (Fig. 1d) started with applying clay into a support-mold (Fig. 8g), and because this mold provided the necessary firmness, the vertical wall part could be built by adding, fixing, pinching and smearing several clay coils on top of it (Fig. 8h). For the vertical wall, part a slab of clay, instead of some coils was used alternatively (Fig. 9a).

After a while, once the clay had stiffened further, the rough-out was separated from the mold and a clay coil fixed under its base. From this coil a kind of ring-shaped stand-foot was formed by pinching and smearing. As a next step and after the clay had again stiffened a bit, the wall was reinforced, thinned, corrected and thus given its proper shape by scraping with several tools. The use of differently shaped scrapers hereby eased the making of the desired curves (Fig. 9b). Finally the surface was smoothed by sweeping with the fingers or eventually with a piece of soft material like sponge or leather. Goblets with a similar lower part, but a different shoulder (e. g. HB-PL-014) are possibly related. It is not unthinkable that both were made from the same mold or a related type, whereas the upper part was executed differently (Fig. 9c-e). In other words, within certain limits, several varieties and sizes of goblets can be made using the same mold.

A reconstruction based on HB-VB-025 (Fig. 2a) shows and explains the sequential steps of the combined coiling-molding technique for a close-shaped bowl. The making of this and similar bowls was started by pressing clay coils into a support-mold, in order to shape the base and lower wall (Fig. 9f). Due to the support of a mold during forming, wall-thickness in the low section could be controlled and reduced immediately, when the clay was still in a smearable condition. A lot of scraping in a later stage was thus avoided. The clay was pressed firmly and smoothed with the fingers, by smearing out the surface. Next, the slightly inwards bending upper wall


a
b
c
d
e
f
g
h
3168
HB-VB-025

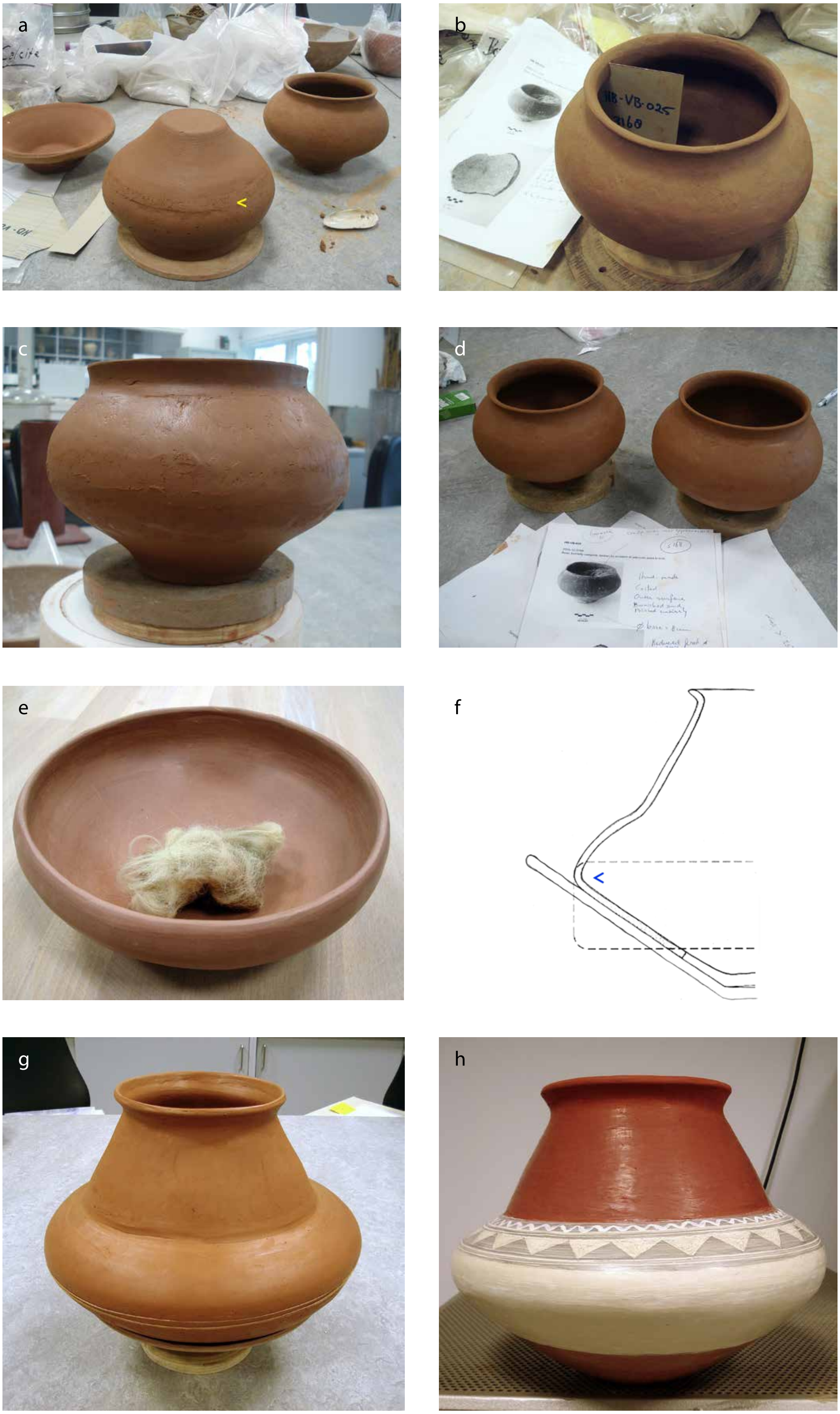
a
b
c
d
e
f
g
h
Calcite
HB-VB-025
Hand-made
Coiled
Outer surface
Burnished and
Polished smoothly

Figure 10 (opposite page): More vessels were reconstructed using coiling combined with molding. (a) The bowl was removed from the mold and turned upside-down. Next, the ridge which had marked the edge of the support-mold was removed by scraping. (b) The inner profile of the vessel was made in accordance with archaeological example HB-VB-025. The rim diameter was calculated to become 15 cm. (c) The surface was wetted and smoothed by smearing and wiping with the fingers, which resulted in a skin of fine self-slip. (d) Irregularities were finally removed by smoothing. (e) Reconstruction of fine ware bowl, based on archaeological original HB-VB-048, but still unfired. (f) The sharp bend halfway down the carinated profile in combination with the size, points to the use of a mold for the production of this type of vessel. (g) Reconstructed cone-necked vessel based on archaeological example HB-VB-070 (Fig. 2e). The vessel with a content of some 10 l was built from clay coils while placed in a mold for the lower part. (h) After applying slip layers and a decorative band around the shoulder, the vessel was ready to be fired (reconstruction based on HB-VB-070) (© Laboratory for Material Culture Studies Leiden University).

was made by adding three clay coils piled on top of each other, followed again by pinching, smearing and scraping (Fig. 9g). The bonding areas of the coils were made oblique, in order to enlarge the contact surface and so make better connections and the structure stronger. Thus the coils were firmly pressed together, followed by scraping of the inside in a mainly horizontal direction. Locally, connections were fixed by smearing and the inner profile was shaped with a scraper according to the archaeological drawing. If necessary, scraping was combined with some light tapping on the outside of the wall.

Temper had been added to the clay during preparation in order to give the paste firmness or “bones”. Because the clay body was prepared from paste 2, with a limited quantity of crystalline calcite added, the construction proved rather firm. This is a property that could be taken advantage of because it offered the possibility to continue with finishing after only a short period, during which the vessel could dry a bit further. Meanwhile another vessel of the same type was made simultaneously. After adding and fashioning two more coils for the upper part of the shoulder and the rim, the bowl was removed from the mold. A protruding ridge that marked its former position now became visible (Fig. 9h). The vessels were finished by scraping, first on the inside, but after the mold had been removed also on the outside. In an upside-down position, the ridge which had marked the edge of the support-mold was removed by scraping and tapping if relevant, after which the wall was straightened by smearing (Fig. 10a).

During and after shaping, the inner profile of the vessel was checked and adapted by scraping when needed, in order to be in accordance with a cardboard template made of the archaeological example (Fig. 10b). Next to that, the outer surface was locally corrected by slightly tapping, as well as by scraping and smearing a bit. Finally, it was wetted and smoothed by smearing and wiping with the fingers, which resulted in a skin of fine “self-slip” formed over the entire surface (Fig. 10c-d). A good example of a low open-shaped bowl formed with the aid of a mold, in combination with coiling and with a smoothed self-slip surface is HB-VB-048 (Fig. 10e).

The production of cone-necked vessels was similar in principle. Cone-necked vessels like HB-VB-070 (Fig. 2e) were also coiled while, during production, a mold was used as a support for the lower part. Though direct indications from the archaeological record in the form of traces on the surface are limited (except for preferential breaking) a clear indication lies hidden in the shape and the size of the vessels themselves. The sharp bend halfway down the carinated profile in combination with the large size of some of these vessels point to the described approach. A mold into which clay was applied coil-wise, was used for the lower part and the upper section was just coiled. According to this hypothesis a reconstruction was made (Fig. 10f-h).

Coiling

Not all the pots from the Heuneburg repertoire were made by a combination of molding and coiling. For part of the repertoire, coiling alone was used to build up

Figure 11 (opposite page): Coarse ware vessels were also formed by coiling, but without the use of a mold. (a) Much of the former traces were obliterated during production. The coils were connected firmly by smearing. The same tool was used as was for scraping, but the position and the angle with the clay wall differed. Reconstruction based on HB-PL-008. (b) Reconstructed coarse ware. The small pots in the front are based on HB-VB-024. The big vessel with rope-like application is based on HB-VB-071 (Fig. 2h). (c) During reconstruction, a support rope was used to prevent the clay, which was low in plasticity and cohesive strength, from tearing apart under the weight of coils piled on top. The rope was removed later. (d) The pots were shaped according to the profile template of an original. The size of the template was compensated for 10 % of clay shrinkage on drying and firing. Lower part of body provided with "slap and pat". (e) The inside was scraped with a shell to thin the wall and connect the coils firmly to each other, and to obtain a more globular shape in agreement with the original. (f) The coils were connected by pinching, smearing and scraping. However, all traces of coiling were deleted by later steps of the forming process. (g) "Slap and pat" shortly after application. This finish is applied by patting thick clay slip to the surface with the hands. (h) Close-up of "slap and pat" taken after drying (© Laboratory for Material Culture Studies Leiden University).

the body, often in combination with a base made from a flattened-out clay slab. This approach is not specific to fine or coarse ware, but more or less shape related. The wall profile in the lower section of these pots is mostly rather vertical (e. g. Fig. 11a).

A category of coarse pottery, "Grobe Ware" (Fig. 11b), is made just by coiling. It is distinguishable not by a completely different forming technique, but by differences in size, shape, execution, finish, color and fabric, all related to the use of different clays. The coarse ware differs from the other, more delicate and compact pottery because the clay paste used for making it contained a considerable portion of organic material. To make the paste for the production of this coarse pottery, peaty clay to which grains were added was used. This clay body led to a more porous, softer and coarser ware-type. Bold and relatively thick-walled pottery was formed from this material (Fig. 6a). It is recognizable by firm simple shapes and is often a bit asymmetrical or crooked due to the coiling technique. The vessels may be provided with a typical rim finish, made by repeatedly pressing a finger oblique-wise on top of the rim, or alternatively just straight (Fig. 11b).

The reproduction of a big vessel was started by pressing rolled clay coils on the edge of a circular slab, first made by pressing clay onto a flat surface. On top of the first row, more coils were piled, fixed, pressed and smeared to form the wall. Next, the body was further formed, straightened and reinforced, and the walls were thinned by scraping a few times. During forming a temporary support rope was used (Fig. 11c) to give extra hold to the soft lean clay, in order to prevent the wall from tearing apart under the weight of added clay coils in combination with the forces of smearing, scraping and tapping.

Further on as a next step of the shaping process, the rope was removed and its traces left behind in the soft clay smeared and scraped away, thus giving the pot its final shape. It is possible that the rope-like decoration on the shoulder, applied at the end of the forming process, was originally inspired by impressions of formerly used rope left behind in the clay. During forming, but after removal of the support rope, the inside was scraped with a shell, not only to thin the wall and to connect the coils firmly among each other, but also to obtain a more globular shape by forming the walls in agreement with the original (Fig. 11d-e). Finally, the surface was finished by smoothing and applying "slap and pat" onto the surface of the vessel's lower part, smearing and sweeping with moistened fingers, or alternatively only provided with "slap and pat" finish (Fig. 11d, lower part of the body).

The smaller coarse ware pots according to original HB-VB-024 were also made by coiling, but a support rope was not necessary during production because of their smaller size. The coils were connected by pinching smearing and scraping (Fig. 11f). After forming, the surfaces were finished by scraping, smearing and smoothing. All traces of the coiling process were removed by these later steps of the process. However, preferential fracturing of some originals still betrays their shaping method (Fig. 2a.c.g-h).


a
b
c
d
e
f
g
h

Figure 12 (opposite page): Scraping can be a step of the shaping process, but in other cases is just a finishing technique. (a) In a lot of cases scraping is to be considered an integral part of the shaping method. Production detail of reconstruction according to HB-VB-025. (b) Traces of scraping inside a bowl according to HB-VB-011. The oblique surface of the rim is roughened by scraping in order to make the next coil adhere better. (c) Scraping of soft clay in order to connect coils firmly and to shape the wall, so to create the desired profile according to HB-PL-008. (d) Scraping a surface with the edge of a flint tool is effective to remove surplus clay, but also to shape the wall. Due to coarse grains trapped by the flint scraper, deep groves tend to appear in the surface, which is to be reworked later. (e) Scraping to remove surplus clay. This treatment reinforces the wall structure and makes the goblet lighter and stronger. Compare to HB-VB-065 (Fig. 1c). (f) A shell-tool proves very effective for scraping the concave curves on the inside of bowl-shaped pottery. The photo refers to a reconstruction according to archaeological example HB-VB-048 (Fig. 1f). (g) Scraping the inside of a goblet reconstructed according to HB-VB-039 (Fig. 1d). Alternatively, a thin metal blade was also used as a tool for scraping. (h) The flint-scraper is used for reworking the outer surface of the bowl depicted in Fig. 12f. The finely tempered clay was in firm leather-hard condition. Traces are typical of a flint-scraper (© Laboratory for Material Culture Studies Leiden University).

Several modes of surface finish

Several ways of finishing could be identified on the archaeological material. Having a thorough understanding of the traces produced by various ways of finishing was obviously important for the reconstruction of the *chaîne opératoire* of this pottery production. This was especially crucial as such traces needed to be distinguished from subsequent traces of use.

"Slap and pat"

A surface finish typical of the category of coarse ware from the Heuneburg is "slap and pat" ("schlickgeraut"). This finish was often applied in combination with scraping and smoothing, but may also occur in combination with burnishing or polishing, which implies that several parts of the same pot or vessel were differently treated. For example, the upper part was smoothed by sweeping with the fingers and the lower part applied with "slap and pat" (Fig. 11g). This finish, termed "slap and pat", was experimentally verified as thick clay slurry, equal to the body in composition and irregularly applied with the hands over the surface by "slapping and patting". After drying this treatment results in a locally rough surface which facilitates handling when full and heavy (Fig. 11h).

Scraping

Scraping, often followed by smoothing, is a frequently occurring finish in all categories of the repertoire. Scraping of differently tempered clays, in several stages of paste condition and by making use of a variety of tools, therefore demands special attention. In the context of Early Celtic pottery from the Heuneburg and the Mont Lassois, the operation is applied rather often in combination with coiling. Traces of this finishing technique are visible on many ceramic surfaces. Quite often scraping has to be considered as integral part of the shaping method, yet it is also a finishing technique (Fig. 12a).

The aim of scraping is three-fold. At first, in many situations scraping is intended to firmly connect coils to each other (Fig. 12b.c). Secondly, by adapting its position and exerting more or less pressure on the scraper one can change the shape of the wall profile radically and correct it where necessary. Depending on specific corrections, this can be done by exerting pressure from the inside (Fig. 11e) or from outside (Fig. 12d). Third, a considerable quantity of clay can be taken away, by which the wall is thinned and, as a result, the pottery becomes lighter, stronger and also easier to handle (Fig. 12e). The inclination of a scraper during execution is always of concern since by changing its position, more or less material will be removed. At the same time, the surface is opened or alternatively densified. With the scraper kept in a more upright position, grains will be caught and tend to protrude, whereas with a smaller angle, less material is removed and

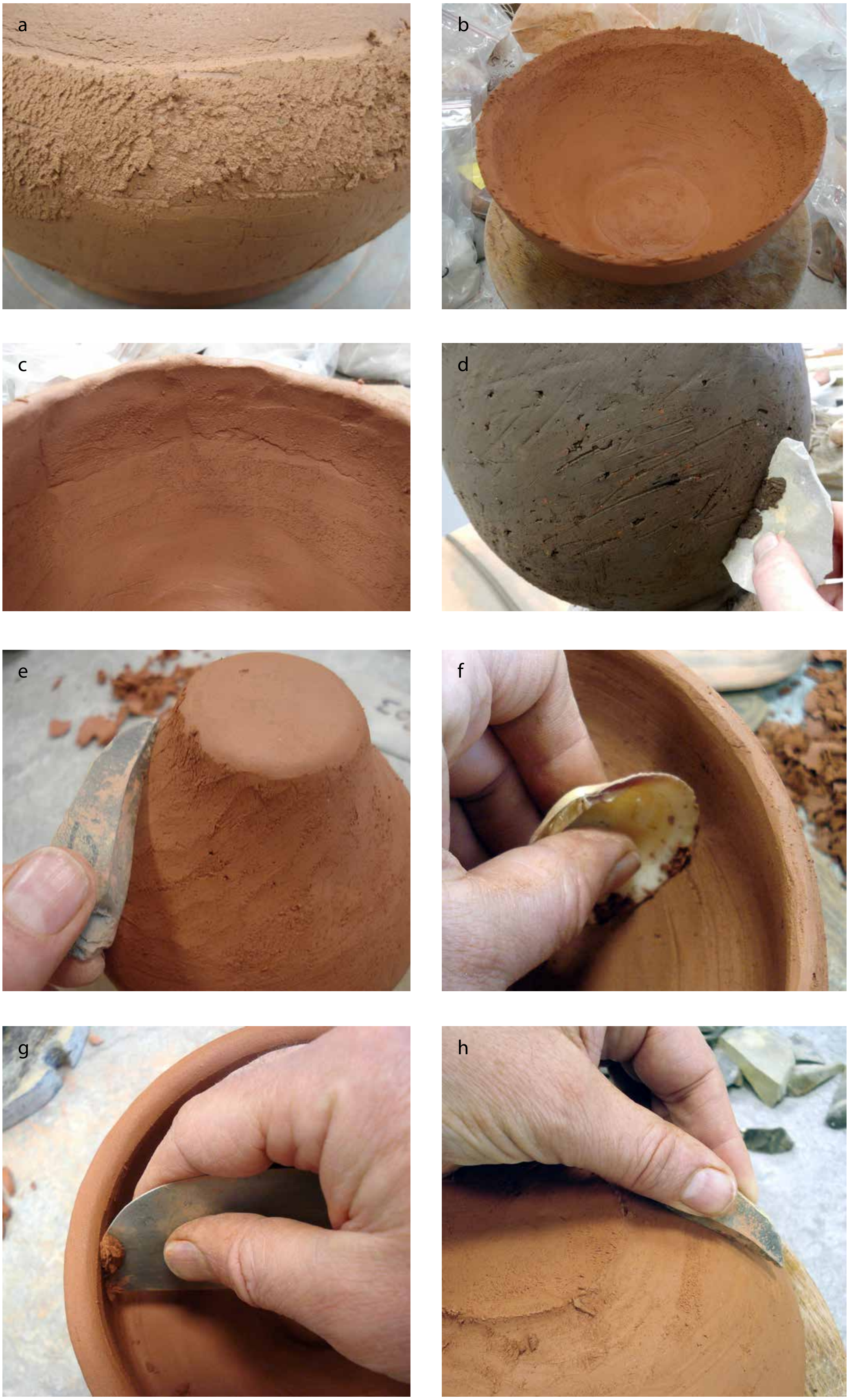
a
b
c
d
e
f
g
h

Figure 13 (opposite page): Several modes of surface finish. (a) The surface was smoothed with water, creating self-slip. Reconstruction according to HB-VB-011 (Fig. 2c). (b) Surface finished by sweeping with moistened fingers. Reconstruction according to HB-VB-048 (Fig. 1f). (c) The surface of wheel-thrown pottery is provided with self-slip, just by throwing. Lubrication with some water is necessary to prevent the clay from sticking to the fingers. (d) Smoothed surface of remade coarse ware vessel of paste 5. Scraping was only followed by rubbing the surface with wet fingers. (e) A slip layer was applied by smearing fine clay slip over the not yet completely dried surface with a piece of leather. Through this treatment the surface is densified and coarse grains are covered. (f) Archaeological original where clay slip was applied in a decorative way. Fine white clay was used for the light part. Next, slightly contrasting linear motifs were painted on. The clay slip used for the neck was enriched with iron oxide. (g) Reconstruction of bowl HB-AS-036 before being fired. Slight beveling caused by the regular strokes of a hard polishing tool is characteristic of most polished surfaces. (h) Irregular traces of polishing inside a goblet. Reconstruction according to HB-VB-065 (Fig. 1c) (© Laboratory for Material Culture Studies Leiden University).

the clay surface becomes more smeared (Fig. 11a). The latter treatment by which grains are pressed into the clay surface, makes coils adhere to each other better and also results in a denser surface. For this specific treatment a blunt tool made of different materials such as wood or bone can be used, but in practice, the same scraper is often used for both activities.

Apart from the inclination of the scraper and the material it is made of, other variables are of influence on the results of the scraping process, e. g. the pressure exerted on the tool and its shape. Though differences sometimes can be minimal, a flint scraper gives another result compared to one made of bone, coral, wood, metal or shell. The curved edges of appropriate shell-tools can be very effective for scraping the concave curves on the inside of cups, goblets and bowls (Fig. 12f). Alternatively, a metal blade of the correct shape can be used (Fig. 12g). Many variables are thus of influence on an, at first view simple, action as scraping. One of them is the condition of the clay. Scraping a dry surface differs from scraping the clay in soft or leather-hard condition (Fig. 12h), while quantity, dimensions, and kind of grains added as temper, if relevant, also play an important role. Finally, a scraper with a serrated edge can be very effective to press clay into a mold.

Scraping was mostly followed by one or more other treatments, like smoothing, slipping and in specific cases also graphitizing. Some of these surface treatments are mentioned below and all of them, including polishing, will once again change the surface.

Smoothing

Surface treatments such as smearing, tapping and scraping are often followed by smoothing. Smoothing is done to remove irregularities from the surface. It is carried out next to forming, when the clay is still in a rather soft condition, alternatively after some drying, but there is room for variation in the condition of the material. Smoothing is done by simply sweeping the surface with the fingers, or by making use of some tool, e. g. a piece of cloth, soft leather or a sponge. The aim is to apply and spread fine clay particles over the surface and at the same time to level out irregularities somewhat (Fig. 13a-b). This final treatment can be done during several stages of the leather-hard condition. However, when the surface gets too dry, particles will not move and when sweeping is continued, or when more water is added, they tend to come off, which results in an irregular and rougher surface than before. Therefore, smoothing is to be done when the surface is still slightly plastic.

When the vessel is made of a normally tempered clay body, like pastes 1 to 3, the addition of extra clay slip is not necessary and the surface can be characterized as smoothed and self-slipped (Fig. 13b). To produce a self-slip, only a bit of water is added. For this reason, surfaces of fast wheel-made pottery are self-slipped (Fig. 13c), unless they are later treated or reworked. While throwing, the potter moistens the hands with water, which acts as lubrication so that the rotating soft clay can easily slide through the fingers. Self-slip is a concentration of fine particles from the clay


a
b
c
d
e
f
Ort: 2004-12, Heuneburg-Vorburg
Objekt:
g
h

of the vessel at the surface. If a coarsely tempered clay with sharp grains, undesirable for making pottery on the potter's wheel, is used or when the quantity of grains in the clay paste is high, i. e. more than 25 % of non-plastics, potters may decide to add a layer of specially prepared fine clay slip, in order to cover and improve the surface. However, this requires extra effort, which is probably the reason why, quite often, pottery surfaces are only smoothed, particularly those of coarse hand-made ware (Fig. 13d).

Slip layer

A slip layer, also called "barbotine", is applied by smearing fine clay slip over the surface with the fingers or with a piece of cloth, leather or the like (Fig. 13e). A separately applied slip-layer mostly has a slightly different structure due to particle size and color, but distinguishing between slip and self-slip is sometimes difficult. Slip can be applied to improve the surface of coarsely tempered vessels, and - apart from some densification - the treatment mostly makes it more regular and the structure slightly less permeable and easier to clean. Surfaces intended to be painted are often first improved with a slip layer of fine clay (Fig. 13f). Such separately applied layers sometimes are vulnerable and may come off during use or after the object was discarded due to post-depositional taphonomic processes. Only in the case of "slap and pat" (Fig. 11h, described above) the surface became rougher by the application of a slip layer.

Polishing

Polish or burnish is the result of a surface treatment executed when the pottery is in a condition between leather-hard and dry. The technique consists of systematically rubbing the surface with a tool, e. g. a pebble or one made of another hard material such as agate, glass, bone or metal. Softer materials like wood normally do not work. The glossy appearance of pottery is caused by alignment of tiny clay particles parallel to the surface, which altogether reflect the light in the same direction (Lepère 2014, 144-155).

The dryer the surface, the more gloss is obtained. However, on too dry a surface, the tool begins to scratch and gloss is lost. Depending on clay properties more or less gloss can be achieved. Coarsely tempered clays are not very well suited to being burnished or polished, since scratches tend to develop around protruding grains, resulting in a matt surface. Polishing is therefore frequently applied after improving the surface with a suitable slip-layer. With fine fabrics like those resulting from clay pastes 1 to 3 a separate layer is unnecessary.

In general, clays naturally composed of fine particles and low in salt content are suitable to be polished. Reduction firing is not of much influence on the degree of gloss, but when clays are rich in iron oxide, a nice shiny black usually remains (Fig. 8f). However, the presence of salts in the clay and, in specific cases a firing temperature over 950° C, can be factors of negative influence on the gloss. This is to say that, depending on clay properties, gloss may actually disappear. Wheel-polishing is executed by keeping a special pebble firmly against the rotating surface (Fig. 6e), and when temper is fine, no slip needs to be added for a very regular result. Smooth and shiny surfaces can also be created by manually rubbing the surface with a polishing stone. By intensively rubbing in a horizontal direction good results, almost similar to the very regular results of wheel-polishing, can be obtained. Characteristic of polished surfaces is a slight beveling due to strokes made by the hard pebble (Fig. 13g). In addition, the surface structure is densified somewhat by intensive pressure of the burnishing tool. Because the thus created dense layer of fine clay particles often shrinks a bit differently from the rest, micro-cracks tend to develop on the surface. Burnishing may add to esthetic and practical qualities of treated pottery, but it does not result in impermeability. In contrast to the often very regular results of polishing on outer surfaces, the inside of narrow closed shapes with a bent concave surface, like cups and goblets, may appear more irregular and sometimes even a bit clumsy. An explanation for this is the difficulty involved in reaching such surfaces with a polishing tool (Fig. 13h).

Painted decoration

Celtic potters painted abstract linear motifs on their pots according to a style that fits in the Early Iron Age tradition (Franken/Jacobs 1983, 27-31). They used a thin brush to apply clay slips, sometimes only slightly different in color from the background. By making use of natural differences in color between available clays, contrast was achieved. Alternatively, clay slip was enriched with iron oxide. After painting motifs, the expected approach was to burnish the entire surface, decorated areas included. This way of working would have resulted in glossy surfaces all over. However, we observed a different technique on quite some vessel fragments from the Mont Lassois. The entire surface was first covered with monochrome clay slip, which was enriched by adding red iron oxide and, after a period of drying, polished. Next to that, linear decoration was painted onto the polished and almost dry surface with a small brush. By this slightly different approach, not only a color contrast was obtained but also, at the same time, the painted motifs appeared as matt lines on the polished surface. The lines were, in some cases, painted with a watery clay slip (Fig. 14a). Alternatively, the lines were painted with a rather thick and less fine grained clay slip, but also over the polished surface. By doing so, the dull lines appeared a fraction higher compared to the surrounding surface. In other words, these lines form a pattern of slightly protruding motifs (Fig. 14b). As clay slip for painting, light-firing clay poor in iron components was selected. Both varieties of this remarkable type of decoration were applied pre-firing and maintained their contrasting properties after firing under both oxidizing and reducing conditions.

Graphitizing

A number of cups, goblets and bowls were provided with a finish of graphite. This treatment, which results in a metal-like surface, was therefore also experimentally explored. The surface was made by the application of finely ground graphite, combined with polishing. Rough surfaces are first improved with a coating of clay slip, but fine ware most often is just smoothed. Before being entirely dry, the object is smeared with finely stamped graphite powder. To divide the powder, which tends to be a bit sticky, it is manually swept over the surface (Fig. 14c). Next, in an almost dry condition, the object is polished with a pebble. By the latter treatment a good fixation and consolidation of the graphite particles is obtained (Fig. 14d). Depending on the quantity of moisture still in the clay and on the type of graphite, a more or less glossy surface results. Normally the relation is that the dryer the surface, the more gloss is obtained. However, the clay should not be completely dry in order to avoid a scratched appearance. Subsequently, the object is fully dried and fired under reducing conditions. Oxidized firing would result in the graphite, a form of carbon, burning away. An alternative method of application is to mix the graphite with clay powder and water. The mixture, a clay slip, is then smeared over the surface and after drying, but before being entirely dry, also polished with a pebble or a comparable tool. The advantage of this way of doing it is that, after firing, the layer is more stable and will not tend to rub off, but both methods of application are difficult to distinguish after the object is polished and fired. They both yield a shiny surface with a black-silver gloss, which gives the treated objects a metal-like appearance (Kreiter et al. 2014, 129-142). All the "finishing modes" mentioned here occur within the late Early Iron Age pottery repertoire. They are of importance because they were of great influence on the appearance of the pots.


a
b
5 cm
c
d
e
f
5 cm
g
h

Figure 14 (opposite page): Several modes of surface finish in which the firing process plays a crucial role (© Laboratory for Material Culture Studies Leiden University unless stated otherwise). (a) Polished surface of fragment Vix-ALT-131 from Mont Lassois. The light colored, matt lines were painted pre-firing on a red slipped burnished background. This way, a double contrast was created. (b) Part of a decorated original from Mont Lassois, Vix-ALT-149. This vessel was hand-made by coiling and reduction-fired, including the protruding linear decoration (© B. Schorer). (c) The application of graphite by rubbing the leather-hard surface with the powdered material (© V. Brigola). (d) The leather-hard surface of HB-VB-039 was polished with a polishing stone by which the graphite was consolidated. This pebble neatly fits into the curves in order to reach the entire surface (© V. Brigola). (e) Dark colored pots were fired under protected conditions, surrounded by burnable material and in saggars. (f) Reconstruction of bowl HB-VB-025 with an s-shaped profile. Reduction-fired, partly spotted due to penetration of oxygen. (g) The same fabric, but fired under oxidizing and reducing conditions, both at 850° C. The oxidized bar starts to crack. Considering the reduced bar, calcite is not turned into quicklime, demonstrating that reduction-firing successfully counteracts disintegration. (h) During firing, the cone-necked vessel was filled with small pots which were intended to become completely black reduced. By preventing the conversion of calcite into quicklime, destructive lime-spalling was avoided.

Drying and firing

Drying

Before being fired, pottery should be entirely dry or “bone-dry”, in order to avoid damage. The drying process can take a few days to a few weeks, depending on weather conditions and density of the paste and should not be sped up to avoid cracking caused by tensions due to uneven drying. A strong motivation to fix coils firmly together is to avoid drying cracks. Once they occur, drying cracks are virtually impossible to mend. The general procedure is thus to prevent this kind of defect, by pressing and fixing parts together well while forming and by thoroughly finishing the places of the joints. Adding temper to reduce shrinkage and to open up the clay structure is another precaution resulting in more even drying of the products.

Firing

In general, we distinguish oxidizing versus reducing as opposite modes of firing, where respectively much, to only a limited quantity, or no oxygen at all, is permitted during the process. These opposite pyrotechnical treatments result in mainly clear and light colors when the pots are fired under oxidizing conditions and in dark colors in the alternative situation. An entirely dark grey or black colored fabric and surface indicates that pottery was fired under reducing conditions. A spotted surface, where light and dark colors are combined may indicate that pottery was fired in direct contact with the fuel. The reconstruction of a bowl shows that under such conditions one and the same pot can be partly reduced and partly neutrally fired (Fig. 14f). Light parts are neutrally fired and dark parts including the inside under reduced conditions. Purely oxidizing conditions were avoided, because such would have been destructive, since the firing temperature was around 850° C and the crystalline calcite in the clay (Fig. 14g) would have turned into quicklime. There are indications that Iron Age potters were aware of this mechanism, which is confirmed by archaeological fragments, indicative of the ancient firing circumstances.

Firing pottery is a process which, depending on the method, nowadays is rather controlled. Though the ancient firing process certainly was also partly controlled, unexpected events could happen from time to time. There always was an unpredictable part in unprotected firing, where pots were totally or partly in direct contact with the fuel. The reconstructions were fired as much as possible in accordance with the wood-fired historical pottery, but under laboratory conditions and by making use of a gas-fired kiln. The colors of the reconstructions consequently are close to those of the historical examples, but they may deviate. The latter is also the case, because no original clays were used but commercial clay was adapted (see section “Materials for the reconstructions”) to be in agreement with the archaeological material. In order to obtain the desired dark colors, some of the reconstructed pots were fired under protected conditions, surrounded by burnable organic material and by making use of saggars, large coarse ware vessels provided with a cover to prevent penetration of oxygen (Fig. 14e). For spatial efficiency, the vessels in the saggars were piled nested and surrounded with wood chips, small branches and straw. Less strict protection resulted in spotted or partly spotted pots, due to the penetration of oxygen (Fig. 14f). The oxidized, light colored vessels were fired under more open conditions, but assumedly also in part in contact with the fuel. The color of ceramic objects in general strongly depends on two factors, clay composition and firing circumstances. The color of archaeological pottery can also be influenced by use and post-depositional changes. As for clay composition, the reconstructions were all made of commercially obtained iron rich clay that fires to a red color (MSCC 10R5/6 red), when circumstances are oxidizing. Refired fragments of Heuneburg pottery (Fig. 4b-d), are only slightly lighter in color (MSCC 2.5YR 6/8 light red) due to a somewhat lower iron content. Though not entirely the same in composition, the modern clay variety, used for practical reasons, has comparable characteristics.

The way the pottery was fired certainly has been of influence, not only on its appearance, but also on some of its more hidden aspects such as hardness, strength, acid resistance, porosity and permeability. Besides vegetable material, grain shaped inclusions of mineral or bio-mineral origin may react differently to opposite ways of firing. Reducing conditions were preferable when the surface was provided with a coating of graphite. The labor-intensive graphitizing only made sense when the concentration of special carbon particles remained intact during firing. Therefore we know that in these cases the firing process intentionally was reducing, e. g. for HB-VB-039 (Fig. 1d).

A remarkable category of pottery where specific firing conditions also were of importance are the “cone-necked” vessels. Their outer surface, which is provided with a band of decoration, was exposed to oxygen in order to obtain a color-contrast and make the different surfaces of slip layers and painted motifs visible. At the same time, the inside of the vessel and most of its wall, needed to be fired under reducing circumstances so to prevent calcite grains from converting into lumps of quicklime, a process which tends to happen when firing temperature rises over 750° C and also when excess oxygen is available. Therefore, when correctly executed, firing will result in a sherd which is light-colored in only a thin zone at the outer surface and dark-grey reduced for the rest. Good results were possibly reached by filling the vessels with organic matter during firing, while their opening was carefully covered to prevent air from penetrating. Only at the end of the firing process were the vessels uncovered and air was allowed during a limited span of time to oxidize the outer skin of the pot, a technique resembling the tripartite firing technique invented in 7th cent. BC Corinth and fundamental for all black-figured or red-figured Greek pottery (Scheibler 1995, 103 f.). The same phenomenon is observable on original sherds from the Heuneburg. At the same time, during such firings big vessels were possibly filled with one or more small pots and goblets, intended to become completely black reduced (Fig. 14h). Though the majority of the excavated pottery points to a rather high pyrotechnical standard, there are also quite some pots where the firing process was not executed entirely spotless, (e. g. Fig. 15). Part of the Iron Age pottery was probably fired in kilns or protected hearths where the pots were in more or less direct contact with the flames. Such conditions easily result in spotted surfaces or vessels with unequal colors at different parts. If we assume that entirely oxidized, light colored objects and well reduced, uniformly dark colored pots were intentionally made, we should also realize that one or both conditions sometimes must have failed, which in those cases resulted in a spotted surface.

Figure 15: *Archaeological fragment Vix-ALT-152 with assumedly unintended discolorations caused by the original firing process, confirming that the decoration was applied pre-firing (© B. Schorer).*

Comparing the *chaîne opératoire* of Heuneburg and Mont Lassois ceramics

In agreement with observations from the Heuneburg repertoire, the Mont Lassois material also displayed specific correlations between the applied shaping techniques and several fabric types. At Mont Lassois, where the evidence for wheel-made pottery is much more prominent than in the Heuneburg assemblage, the wheel-made pottery is made of clays provided with well sorted, fine grained tempers, very similar to the choices made at the Heuneburg. At both sites, clay bodies in agreement with pastes 1 and 2 (Fig. 5c-d) were applied by the ancient potters for throwing on the wheel, and there was a preference for the finest of both clay bodies.

For the production of the ubiquitous hand-made pottery, fabrics comparable to pastes 2 and 3 were equally applied, and only sometimes the fabric corresponds to the slightly coarser paste 4. This means that grain sizes of tempering material for hand-made pottery were roughly estimated from around 0.5 mm increasing up to 1.5 mm in size. Only sporadically, even coarser mixtures, with grain sizes incidentally up to 3 mm, were detected.

As for grain-types, the situation on the Mont Lassois was also roughly comparable to that on the Heuneburg. Apart from specific individual differences, quartz and rock-fragments like basalt and feldspar occur. Low quantities of hematite and mica are considered natural to the clays. Sometimes, apart from other tempers, the ancient potters also added grog to their clays. In specific cases crystalline calcite was also added as temper (Fabbri et al. 2014, 1899-1911). It occurs in the category of hand-made pottery, but the application of calcite in wheel-made pottery seems to have been exceptional. Wheel-made pottery was preferably tempered with fine quartz grains, e. g. Vix-ALT-135 (Fig. 7c). A limited part of the Mont Lassois pottery, including the application of a technological variety termed “wheel-coiling”, was produced on the potter’s wheel.

The hand-made pottery from Mont Lassois was made according to the same technology as described for the Heuneburg. This means that coiling and a combination of coiling and molding were the most frequently applied techniques of the production process. The preferential fracture pattern of certain fragments such as Vix-ALT-101; -105; -111; -113; -119; -147; -148; -164 still betrays the popularity of this construction technique.

From this we may conclude that on the Mont Lassois, as on the Heuneburg, slightly coarser clay bodies were intentionally used for the production of hand-made pottery. From a purely technological point of view this regularity makes sense, if we realize that building up the body of a vessel in the coiling technique is an additive method that thus asks for slightly more coarsely tempered clay. The use of finely tempered clays, however, is more appropriate for production on the fast potter's wheel, including a variety of throwing called wheel-coiling. Provided that the available fragments were not too small, the pottery could be divided into wheel-made and hand-made wares. Within the latter and largest category, the most frequently detected shaping techniques are coiling and coiling combined with molding, both at the Heuneburg and the Mont Lassois. Considering surface treatment and finish, it was interesting to experimentally discover treatments such as "slap and pat" and graphitizing. These applications were principally observed on pottery from the Heuneburg. Graphitizing appears to be closely connected to firing conditions and its successful application by Celtic potters confirms that they had good control of their firing process.

Conclusions

This contribution to the BEFIM project started with the detection of relevant production and finishing techniques, mainly by observation of archaeological material, in order to allow responsible reproduction of this collection of late Early Iron Age pottery. Care was taken to follow the same sequential steps of production as were hypothetically used by Celtic potters and to apply comparable materials. The reconstructed pottery was intended to form the basis for a reference collection of use-wear experiments on pottery, later to be executed on these particular pots.

In order to first reconstruct the pottery in theory and be able to create pots with reliable, authentic traces of production, it was important to analyze their material composition and to detect and read the original archaeological pottery as a comprehensive but coherent collection. This was followed by experimental reconstructions, whereby the formerly observed traces on the archaeological material guided the technological choices of materials and methodology. Therefore, analyses of fabrics and paste or clay body composition, preceding the actual forming of the experimental vessels played an important role. As for the materials, comparable commercial clays had to be adapted by adding several temper types to bring them in accordance with the archaeological material. Within this rather divergent collection of pottery, many small varieties appear to exist as to quantity, size of grains, combination of grains-types, and their distribution and color.

The variable morphology of the repertoire certainly has been a complicating factor in relation to its reproduction. To explain this, potters in comparable ethnographic situations produce only a few different forms or types, in which they become very skilled, because experience with the making of specific forms and sizes has to be gathered and learned through repetition of motor skills (Creese 2012, 43-60). For each specific form or type, a set of motor skills exists and to become familiar with this may take a while of continuous production. A high reproducibility of motor skills is possible, because traditional potters intensively produce the same set of ceramic shapes over several years (Gandon/Roux 2019, 229-239). Ethnographic studies confirm that the type repertoire is often limited and that only a few types are produced by the same

Figure 16: Part of the reconstructed pottery (© Laboratory for Material Culture Studies Leiden University).

potter. An individual potter produces very limited forms for household consumption (Salem 2006, 51-63). However, concentrating on a limited number of vessel shapes and acquiring the associated motor skills, did not entirely match the constraints imposed by the BEFIM project, which was focused on a large repertoire believed to be associated with Celtic drinking habits. Additionally, the use-wear study required the reproduction of this complete repertoire. A lack of specific motor skills with the production of certain Early Celtic pottery types surely existed in the beginning, but this situation improved later on by the production of more comparable beakers, goblets and bowls.

This experimental work underlines that the several steps of the production process are connected and that these sequential parts influence each other in detail. Together they estimate the final appearance, the functionality and the properties of each object, and its meaning in a cultural context. The execution of the experiments and their results confirm that most of the Celtic potters must have had good control over their production and firing process and knew very well how to make pottery meeting their practical demands. During the project, our admiration for the quality of the technical execution of some of the finest thin-walled, yet entirely hand-made pots kept growing. Considering the whole collection and comparing the outer appearance of the pottery, we carefully may conclude that in relation to firing pottery, a kind of shared knowledge must have existed. Otherwise, the many uniformly dark colored bowls and goblets as well as the entirely uniformly light colored and thus fully oxidized vessels as results of a well-controlled and conscious firing process could hardly be explained.

As a potter, it has been a valuable experience to learn in a practical way about production and finishing details of these important pottery repertoires. The reconstructions I made (Fig. 16) revealed the *chaînes opératoires* followed by the ancient Celtic potters when producing their pottery. In the end, some 80 experimental pots were produced, most of which were used in experiments related to supposed drinking habits during the Iron Age (van Gijn et al., this volume), and which are now part of an experimental reference collection available in the Laboratory for Material Culture Studies.

Bibliography

Augier 2013: L. Augier, Versuche zur Keramiktechnologie am Ende des 6. und 5. Jahrhunderts v. Chr. in Bourges (Cher, France): Scheibengedrehte Keramik und Stempelverzierung. In: A. Kern/J. K. Koch/I. Balzer/J. Fries-Knoblach/K. Kowarik/Ch. Later/P. Ramsl/P. Trebsche/J. Wiethold (eds), Technologieentwicklung und -transfer in der Hallstatt- und Latènezeit. Beiträge zur Internationalen Tagung der AG Eisenzeit und des Naturhistorischen Museums Wien, Prähistorische Abteilung, Hallstatt 2009. Beitr. Ur- u. Frühgesch. Mitteleuropa 65 (Langenweißbach 2013) 117-120.

Balzer 2009: I. Balzer, Die Drehscheibenkeramik aus den Altgrabungen des mont Lassois - ein Zwischenbericht. In: B. Chaume (ed.), La céramique hallstattienne de France orientale: Approches typologique et chrono-culturelle. Actes du colloque international de Dijon, 21-22 novembre 2006 (Dijon 2009) 51-68; 200.

Choleva 2012: M. Choleva, The First Wheelmade Pottery at Lerna: Wheel-Thrown or Wheel-Fashioned? Hesperia 81, 2012, 343-381.

Creese 2012: J. L. Creese, Social Contexts of Learning and Individual Motor-performance. In: W. Wendrich (ed.), Archaeology and Apprenticeship. Body knowledge, identity and communities of practice (Tucson 2013) 43-60.

Fabbri et al. 2014: B. Fabbri/S. Gualtieri/S. Shoval, The presence of calcite in archaeological ceramics. Journal European Ceramic Soc. 34, 2014, 1899-1911.

Fořt-Linksfeiler 1989: D. Fořt-Linksfeiler, Die Schüsseln und Schalen der Heuneburg. Heuneburgstud. VII = Röm.-German. Forsch. 47 (Mainz 1989) 135-240.

Franken 1992: H. J. Franken, Excavations at Tell Deir ʿAllā: The late Bronze Age sanctuary (Louvain 1992).

Franken/Jacobs 1983: H. J. Franken/L. F. Jacobs, Decorated pottery from the early La Tène periodfrom Friesland, the Netherlands. Newsletter Dep. Pottery Technology 1, 1983, 27-31.

Gandon/Roux 2019: E. Gandon/V. Roux, Cost of motor skill adaption to new craft traits: Experiments with expert potters facing unfamiliar vessel shapes and wheels. Journal Anthr. Arch. 53, 2019, 229-239.

Jacobs 1983: L. F. Jacobs, Notes about the relation between filler and clay, and filler and shrinkage, respectively. Newsletter Dep. Pottery Technology 1, 1983, 51-63.

Kreiter et al. 2014: A. Kreiter/Sz. Czifra/Zs. Bendő/J. E. Imre/P. Pánczél/G. Váczi, Shine like metal: an experimental approach to understand prehistoric graphite coated pottery technology. Journal Arch. Scien. 52, 2014, 129-142.

Lepère 2014: C. Lepère, Experimental and traceological approach for a technical interpretation of ceramic polished surfaces. Journal Arch. Scien. 46, 2014, 144-155.

London/Schuster 2011: G. London/R. Schuster, Calcite: A Hard Habit to Break. In: M. S. Chesson (ed.), Daily Life, Materiality, and Complexity in Early Urban Communities of the Southern Levant. Papers in Honor of Walter E. Rast and R. Thomas Schaub (Winona Lake 2011) 233-247.

Rückl/Jacobs 2016: St. Rückl/L. Jacobs, With a little help from my wheel: Wheel Coiled Pottery in Protogeometric Greece. Hesperia 85, 2016, 297-321.

Salem 2006: H. J. Salem, Cultural transmission and change in traditional Palestinian pottery production. Leiden Journal Pottery Stud. 22, 2006, 51-63.

Santacreu 2014: D. A. Santacreu, Materiality, Techniques and Society in Pottery Production. The technological study of archaeological ceramics through paste analysis (Warsaw, Berlin 2014). https://www.academia.edu/9623351/Materiality_Techniques_and_Society_in_Pottery_Production

Scheibler 1995: I. Scheibler, Griechische Töpferkunst: Herstellung, Handel und Gebrauch der antiken Tongefäße ^{2}(München 1995).

Stienstra 1985: P. Stienstra, Technological research on composition and texture of ancient pottery - a note on sense and nonsense. Newsletter Dep. Pottery Technology 3, 1985, 10-14.

Van As 2004: A. van As, Leiden Studies in Pottery Technology. Leiden Journal Pottery Technology 20, 2004, 7-22.

Van den Broeke 2012: P. W. van den Broeke, Het Handgevormde Aardewerk uit de IJzertijd en de Romeinse tijd van Oss-Ussen. Studies naar de typochronologie en herkomst (Leiden 2012).

Van der Veen 2018: V. van der Veen, Form Follows Function. A new approach to determining vessel function. Internet Arch. 50 (Nijmegen 2018). https://doi.org/10.11141/ia.50.2.

Author information

Loe Jacobs
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
lfhc.jacobs@casema.nl

Studying the life history of vessels

Creating a reference collection for microwear studies of pottery

Annelou van Gijn, Annemieke Verbaas, Jan Dekker,
Terrilya Feisrami, Nicole de Koning, Merel Spithoven,
Tessa Timmer & Fiona Vernon

Summary

As part of a study on the function of ceramic vessels from the Early Iron Age hillforts the Heuneburg and Vix-Mont Lassois, an experimental program was set up to explore wear traces related to the use of vessels for various purposes. This study formed part of the interdisciplinary research project BEFIM ("Meanings and Functions of Imported Mediterranean Vessels in Early Iron Age Central Europe") led by Philipp W. Stockhammer and dedicated to the question of "What did the early Celts drink?" The experimental vessels used were replicas of vessel types observed at the Heuneburg and selected because of their possible use in food and drink preparation, storage and consumption. We conducted experiments with a range of gestures related to the various activities that these vessels could have been involved in, including post-depositional and post-excavation treatment.

Keywords: *experimental archaeology, microwear analysis, vessel function, ceramic studies*

Zusammenfassung

Als Teil einer Studie zur Funktion früheisenzeitlicher Keramikgefäße aus den Höhensiedlungen der Heuneburg und des Mont Lassois bei Vix wurde ein experimentelles Forschungsprogramm aufgesetzt, um die Gebrauchsspuren zu analysieren, die durch die Benutzung der Gefäße für unterschiedliche Zwecke entstanden waren. Die Untersuchung bildete einen Zweig des von Philipp W. Stockhammer geleiteten interdisziplinären Forschungsprojekts BEFIM (Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa) zum Thema „Was tranken die frühen Kelten?". Die verwendeten Versuchsgefäße waren getreue Nachbildungen von Gefäßformen von der Heuneburg, die wegen ihrer möglichen Verwendung bei der Zubereitung, der Lagerung und dem Konsum von Speisen und Getränken ausgewählt worden waren. Wir führten dazu Versuche mit einer Vielzahl von Handbewegungen durch, die mit den vielfältigen Aktivitäten zusammenhingen, bei denen diese Gefäße möglicherweise

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 65-107.

in Gebrauch waren, einschließlich Sekundärgebrauch und Handhabung nach der Ausgrabung.

Schlüsselwörter: *experimentelle Archäologie, Gebrauchsspurenanalyse, Gefäßfunktion, Keramikstudien*

Introduction

The central research question of the BEFIM project ("Meanings and Functions of Imported Mediterranean Vessels in Early Iron Age Central Europe") led by Philipp W. Stockhammer was "What did the early Celts drink?" (Stockhammer/Fries-Knoblach 2019a). What was the function of the imported sherds of Attic ware found in the Early Iron Age hillforts the Heuneburg and Vix-Mont Lassois? Did these import vessels play a role in drinking habits, as was the case in the lavish feasts (*symposion*) documented for Southern Europe? What was the function of the locally made wares, especially of the highly crafted specimens of fine ware?

These questions were addressed by an interdisciplinary study encompassing both a thorough typo-morphological and contextual analysis by Mötsch and Schorer (Mötsch et al. in BEFIM 1; Schorer et al. in BEFIM 1), organic residue analysis (Rageot et al. 2019 a; 2019b) and microwear analysis (van Gijn et al. in BEFIM 1; van Gijn/Verbaas, this volume; Verbaas/van Gijn-Vix, this volume). We decided to set up an experimental program that was focused on the questions posed by the BEFIM project because microwear analysis of vessel use is still in its infancy and few experiments have been published. Our experiments could serve as a reference for the interpretation of the function of the Early Iron Age vessels from the Heuneburg (van Gijn/Verbaas, this volume) and Vix-Mont Lassois (Verbaas/van Gijn-Vix, this volume).

Our departure point was a selection of pottery sherds and vessels from the Heuneburg that were brought to the Leiden Laboratory for Material Culture Studies. During the month that the Heuneburg finds were in the laboratory, they were carefully examined for fabric, temper and manufacturing traces by expert potter Loe Jacobs (Jacobs, this volume). Jacobs' observations formed the basis for his reconstructions of a series of Celtic vessels, such as goblets, bowls, cups and cone-necked vessels. These experimental vessels were documented for visible traces of production before being used for a variety of tasks related to food and drink practices. It was essential to familiarize ourselves with the range of manufacturing traces visible on both the archaeological material from the Heuneburg and the experimental reproductions, so as not to confuse them with wear marks.

In addition to studying the traces of manufacture on the Heuneburg sherds, we also described all the traces that we thought may be related to use. These preliminary observations and consequent hypotheses about associated pottery function formed the basis for a systematic program of experiments intended to replicate the various stages of use and the treatment the vessels may have undergone, most of which related to possible drinking patterns. In this chapter the results of this experimental program will be described in detail, using a "traditional" microwear approach as was originally elaborated for the use-wear analysis of flint (Keeley 1980; Vaughan 1985; van Gijn 1990). This entailed the use of not only a stereomicroscope, but also a metallographic or incident light microscope that enabled much higher magnifications (up to 500x) and therefore a much closer look at the details of the traces. In the next paragraph this methodology will be further elaborated on. A total of 62 experiments (Tab. 1) was conducted in the context of the BEFIM project, all carried out on actual vessel shapes present in the Heuneburg ceramic assemblage (Mötsch et al. in BEFIM 1 and BEFIM 2; Schorer et al. in BEFIM 1; Rageot et al. 2019b). Additional to the use-wear experiments, we also performed experiments with post-depositional and (post-)excavation processes. In this paper all experiments are described, and wear traces are illustrated. For a discussion of microwear analysis, in particular on pottery, and its inferential limits and possibilities, the reader is referred to the introduction of this volume (van Gijn, this volume).

Methods of study and methodological issues

It should be emphasized at the outset that the present experiments are based on an examination of a sample of sherds and vessels from the Early Iron Age site of the Heuneburg (Jacobs, this volume; van Gijn/Verbaas, this volume). The observations on clay paste, temper used and firing method (oxidizing or reductive atmosphere, firing temperature) seen in this sample, along with the shape of the vessels in question, determined the kind of vessels that were made for the experimental program.

Prior to being used for various activities, all experimental pots were analyzed in order to document traces of manufacture and the general appearance of the surface of the vessel. This was, in most cases, done by stereomicroscope (Leica M80 and Wild M3Z) at magnifications between 10x and 60x, but also by incident light or metallographic microscope (Leica DM6000 and DM2700) with magnifications up to 500x. Photos were made with Leica LAS software and Leica DFC 450 and MC120HD cameras. The locations of the photos were marked on drawings so that we could, as much as possible, find the same locations after the vessels had been used. This turned out to be quite difficult as characteristic spots are rare in vessel walls so it was not always possible to locate exactly the same spot after use, especially since the use of the vessel often substantially changed the original surface. Sometimes interesting features appeared after an experiment had taken place on locations that were not previously photographed. All photos were given numbers and marked on the drawings. All experimentally used vessels were cleaned in lukewarm water. Sometimes it was necessary to soak the vessel. No brushes or other utensils were used to clean them, as these would create wear traces. They were left to dry on a paper towel. Chemical cleaning was not used.

The use-wear experiments were carried out by a team of researchers and students, resulting in two MSc theses (Groat 2017; de Koning 2018) and four internship reports (Feisrami 2018; Timmer 2017; Spithoven 2018; Vernon 2018). The studies by de Koning, Feisrami, Spithoven, Timmer and Vernon are incorporated in this chapter, whereas the experiments and research on alcohol fermentation by Groat is published as a separate article (Groat, this volume).

The experimental set up followed the sequence of actions in which the vessels could have been involved using, as much as possible, the vessel shapes that were distinguished from the Heuneburg along with their hypothesized function (Mötsch et al. in BEFIM 1 and BEFIM 2; Schorer et al. in BEFIM 1). For the most part bowls were chosen for the experiments, as these constituted the largest archaeological sample in the first place and also displayed wear traces most frequently. Apart from a range of bowl shapes, Jacobs also made goblets, a cone-necked vessel (not used for experiments), pots and small vessels. The activities that we chose to carry out with these vessels were food and drink preparation, storage of drinks, consumption, cleaning and handling. Only a few cooking experiments were carried out because evidence for soot was not seen very frequently on the archaeological sherds (cf. Tab. 1). All these experiments, except for the storage and fermenting ones, were carried out for 60 min, and we only did one experiment per vessel. In a few cases, those related to serving and cleaning, several experiments were conducted on one pot, but always on separate locations. We did this to limit the number of pots necessary for our experiments. Last, we also conducted experiments involving the last stages of vessel biographies: breakage, post-depositional damage from trampling, and excavation and post-excavation processing.

Exp. Nr.	Motion	Contact material	Fragmented	Remarks
3349	Scooping	pottery and wine	-	with small scooping pot 3353
3350	Scooping	copper spoon and wine	yes	
3352	Stirring	wooden spoon, wine, herbs and honey	yes	
3353	Scooping (active)	pottery and wine	-	scooping from large bowl 3349
3465	Fermenting	honey wine	-	see Groat, this volume
3467	Fermenting	honey wine	-	see Groat, this volume
3483	Fermenting	honey wine	-	see Groat, this volume
3485	Storing	honey wine	-	
3486	Storing	white wine	-	
3487	Storing	red wine	-	
3488	Fermenting	honey wine	-	see Groat, this volume
3493	Scooping (active)	honey wine	-	see Groat, this volume
3502	Fermenting	honey wine	-	see Groat, this volume
3503	Cooking	wooden spoon and porridge	-	
3504	Pounding/stirring	fruits, honey, wooden spoon	-	
3505a	Cleaning	bundle of heather and water	-	
3505b	Cleaning	pig's bristle brush and water	-	
3505c	Cleaning	cloth, sand and water	-	
3505d	Cleaning	bundle of grass and water	-	
3506a	Cleaning	bundle of heather and water	-	
3506b	Cleaning	pig's bristle brush and water	-	
3506c	Cleaning	linen cloth, sand and water	-	
3506d	Cleaning	bundle of grass and water	-	
3539	Storing	apple sauce	-	
3540	Mixing	batter and hazel whisk	-	
3541	Mixing	batter and wooden spoon	-	
3590	Scooping	porridge and wooden spoon	-	
3591	Mixing	butter cream and pine wood whisk	-	
3592	Shoving	clay floor	yes	
3593	Shoving	wooden surface	-	
3594	Hanging from rim	copper spoon	-	
3595	Hanging from rim	horn spoon	-	
3596	Hanging from rim	wooden spoon	-	
3597	Hanging from rim	iron spoon	-	
3598	Scooping	porridge and bone spoon	-	
3599	Pounding	herbs and wooden pounder	-	
3600a	Bumping	pottery	-	with vessel 3600b
3600b	Bumping	pottery	-	with vessel 3600a
3601	Cooking	meat stew	-	
3621a	Drinking	human mouth and water	-	
3621b	Handling	human hand	-	
3622a	Eating	porridge and wooden spoon	-	
3622b	Resting against rim	wooden spoon	-	
3623	Mixing	white wine, herbs, honey, wooden spoon	-	pot impregnated with beeswax
3624	Fermenting	cabbage	-	

Table 1 (continued on opposite page): Overview of experiments conducted. All experimental vessels which were fragmented were included in the post-depositional and/or post-excavation experiments.

Exp. Nr.	Motion	Contact material	Fragmented	Remarks
3626	Stacking	pottery	-	with vessel 3629
3627	Shoving	clay floor	yes	
3628	Stirring	white wine, honey, hazel whisk	-	
3629	Stacking	pottery	-	with vessel 3626
3630	Covering	pottery lid	-	with vessel 3636
3631a	Cleaning	soap, linen cloth, water	-	
3631b	Cleaning	soap, pig's bristle brush, water	-	
3632	Storing	soap	-	
3635	Covering	cloth and rope	-	
3636	Covering	pottery lid	-	with vessel 3630
3637	Covering	beeswax cloth	-	
3638a	Covering	lid of apple wood	-	
3638b	Storing	white wine	-	
3639	Storing	red wine	-	
3768	Stirring	white wine, herbs, spoon of olive wood	yes	
3769	Unused	unused, impregnated with beeswax	yes	
3771	Unused	unused	yes	

Cooking experiments

Several researchers performed experiments with cooking (Fanti et al. 2018; Forte et al. 2018) and in general cooking traces, like soot on the outside of the vessel, are relatively easy to recognize. As the focus of the BEFIM project was mostly on drinking habits we only performed two cooking experiments.

Cooking porridge (Experiment 3503)

Oatmeal and water were cooked in an open bowl for 60 min in an open fire (Fig. 1a). The bowl was a replica of vessel HB-VB-011. The porridge was stirred with a wooden spoon (Experimental tool 3484). Traces of soot and a shiny black surface on the exterior of the bowl were visible after the cooking was done (Fig. 1b). The experiment proved to be very aggressive to the interior of the vessel wall as it caused the clay skin inside the upper part of the pot to flake off, exposing the temper underneath (Fig. 1c.d). The residue of the oatmeal was in places difficult to remove, despite soaking. Manufacturing and use-wear traces were largely removed and wear traces could not be described.

Cooking beef (Experiment 3601)

Beef stew was cooked for 60 min in an open bowl after frying the beef in a bit of butter. The pot was placed in a cooking pit with birch wood as fire wood (Fig. 1e). During the cooking the contents were stirred continuously with an iron spoon. The stirring caused tiny scratches on the bottom inside the vessel. However, residue was present on much of the surface, even after cleaning in lukewarm water, and inhibited the visibility of possible wear traces.

Preparing food and drinks by stirring and mixing

Scratches and abrasion were observed on a number of archaeological objects from the Heuneburg (van Gijn/Verbaas, this volume). These were usually located in the lower


a
b
c
d
2 mm
e
f
g
h
2 mm

Figure 1 (opposite page): (a) Cooking oatmeal and water in experimental vessel 3503. (b) Exterior of vessel 3503 after cooking, soot is clearly visible. (c) Flaking of the outer skin on the inside wall of vessel 3503, used to cook oatmeal, exposing the temper underneath. (d) Idem (taken at 10x original magnification (OM)). (e) Cooking beef stew in vessel 3601. (f) Pounding fruits in vessel 3504. (g) The mixture of fruits, honey and water in vessel 3504. (h) Rough and abraded surface with visible temper and short and wide scratches on vessel 3504 after pounding and stirring fruits with honey (10x OM) (© Laboratory for Material Culture Studies Leiden University).

part of the vessels. As we interpreted them as the result of repeated stirring, we performed a number of experiments in an attempt to replicate these features. These experiments involved different substances and various stirring devices.

Mixing fruits, honey and water (Experiment 3504)

For this experiment a large open bowl (replica of HB-VB-011) was used (Fig. 1f) in which fruits and honey were pounded, stirred and mixed with a wooden spoon. The fruit consisted of 250 g of blueberries and 250 g of blackberries. During the pounding of the fruit, which took about 15 min, the berries released a lot of juice. After 15 min raw honey was added which was easily mixed into the mash. When these ingredients were mixed well, water was added to make a kind of syrup (Fig. 1g). The motion executed with the spoon was initially more pounding and mixing, later on, when the fruits were mashed, a stirring movement predominated. The liquid inside the vessel was a dark purple/red/pink color, and some foam developed along the edges of the vessel, suggesting possible fermentation. The interior of the pot turned a dark purple color, which could only partially be removed by cleaning. The pH of the mixture in the end was 3.5. The total stirring time was 60 min.

The use-wear that developed partly obliterated the manufacturing traces, especially the marks from smoothing the inside of the vessel wall largely disappeared. The inner surface became rough, with the degree of roughness increasing towards the bottom of the vessel. The temper was laid bare, and scratches became visible (Fig. 1h). Clearly observable were the pounding traces, spots where repeated impact created depressions in the surface (Fig. 2a). The bowl also changed color, and after rinsing the pot in water, residue continued to be present.

Stirring wine with herbs and honey in wax covered pot with beech wood spoon (Experiment 3623)

For this experiment a bowl was impregnated with beeswax inside. This was done by heating the pot to 150° C in a conventional oven and pouring molten beeswax onto the surface of the pot. To spread the wax evenly, it was swirled around for several minutes in the bowl before being poured out. The bowl was left upside down to cool. After applying beeswax, the production traces were partly obscured. Most depressions were covered in beeswax, but some were still open. The experiment consisted of stirring wine with honey and herbs, using a spoon of beech wood (Fig. 2b). The spoon was used to crush the herbs and mix them into the liquid. This was done for 60 min. The mixture had a pH of 4 by the end of the experiment.

The stirring motion caused the beeswax to wear away in the bottom of the bowl. On the lowest part of the wall the beeswax cover is still present, but deep scratches are visible in the beeswax. The stirring and crushing concentrated in the bottom of the bowl and less so on the lower wall. Higher up the wall the beeswax cover is still present. On the bottom, where the beeswax has partly disappeared, relatively short, narrow scratches with a variable directionality are visible (Fig. 2c.d).

Stirring wine with herbs and honey with a spoon of olive wood (Experiments 3352 and 3768)

White wine was mixed with green herbs (tarragon and mint) and honey in an open bowl by using a spoon of olive wood for 60 min (Fig. 2e). This worked well, but

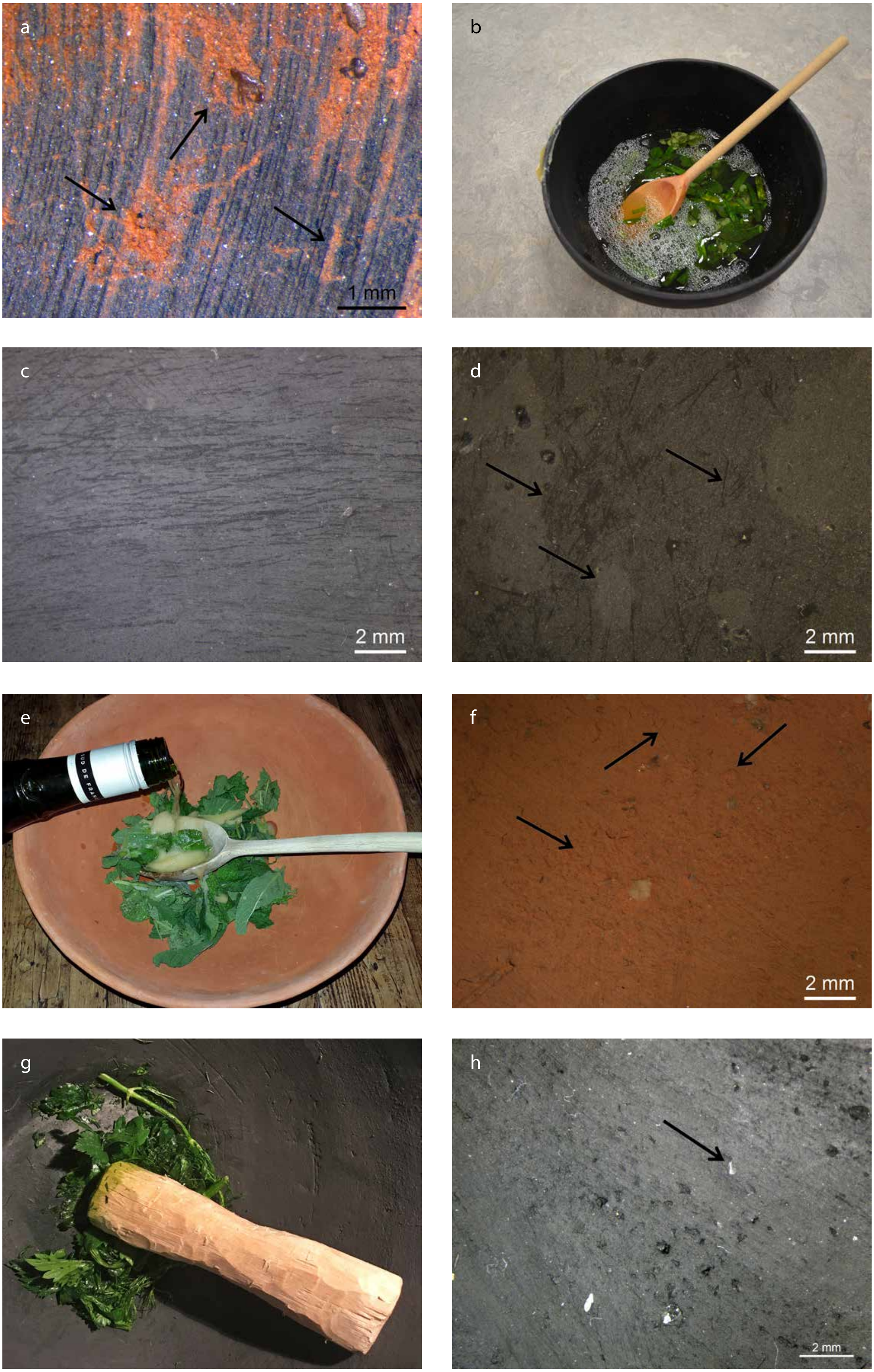
a
1 mm
b
c
2 mm
d
2 mm
e
f
2 mm
g
h
2 mm

Figure 2 (opposite page): (a) Pounding traces, discoloration and worn-away production traces inside experimental vessel 3504 after pounding and stirring fruits with honey (taken at 10x original magnification (OM)). (b) Mixing herbs and honey with white wine in a pot impregnated with beeswax (experiment 3623). (c) The surface of vessel 3623 before use (7.5x OM). (d) Disappeared beeswax and short and narrow scratches with a variable directionality on the surface of vessel 3623 after mixing wine, honey and herbs (7.5x OM). (e) Stirring wine with herbs and honey with a spoon of olive wood in vessel 3352. (f) Use-wear traces on vessel 3352 after stirring wine with herbs and honey: the top layer of clay is removed, with exposed and dislodged particles of temper. Some long and wide scratches are visible as well (7.5x OM). (g) Pounding and crushing herbs in vessel 3599. (h) Abrasion and flattening of pieces of temper due to pounding and crushing herbs in vessel 3599 (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

the stirring and the crushing of the herbs also removed quite a lot of the clay skin. The clay particles mixed with the wine and colored the contents murky and reddish and therefore less attractive to drink. It should be stressed that this happened after 60 min of intensive stirring, something you would normally not do when mixing contents. The mixture had a pH of 4.

The stirring caused considerable damage to the inner bottom and wall of both experimental vessels. The top layer was removed, laying the calcite temper bare and dislodging temper particles as well (Fig. 2f). It also caused scratches to develop which had a clear directionality, reflecting the rotating motion executed during the experiment. Last, pitting is visible, a feature that seems to be associated with wine. This is especially visible at the bottom of the vessel.

Pounding herbs (Experiment 3599)

A pounder of birch wood was used to pound herbs, namely dill and celery, for 60 min (Fig. 2g) in a vessel. A rather thick-walled vessel was used because the grinding and pounding motion required a sturdy wall. The herbs were replaced every 10 min when the previous batch was completely ground. The pot was placed on a table during the experiment. Contrary to our expectations, there did not seem to be heavily developed wear traces from this relatively abrasive activity. The bottom is only slightly abraded, and particles of temper were removed or flattened (Fig. 2h).

Mixing batter with wooden whisk (Experiment 3540)

In a replica of a *kannelierte* bowl a mix of 200 g full grain flour, one egg and 225 ml water were whisked (Fig. 3a). The pH was 6. The whisk was made with hazel wood twigs and was mainly used in a rotating motion. After 20 min the batter became dry and another 50 ml of water was added. After use it was difficult to clean the bowl as it had absorbed water with the batter firmly glued to the pottery walls.

Where the whisk was in contact with the bowl, the surface is worn away and production traces started to disappear. The clay skin has largely been removed (Fig. 3b). On the bottom less wear is visible than on the lower part of the pot wall. This is the case, because the tool was not used as much on the bottom of the pot and rather came in contact with the vessel walls.

Mixing batter with a spoon of beech wood (Experiment 3541)

This experiment was identical to experiment 3540 but instead of a whisk of hazel twigs a beech wood spoon was used (Fig. 3c). The shiny clay skin of the surface wore away, similar to experiment 3540, and production traces disappeared. The temper was therefore laid bare, revealing some linear "holes", actually the last remnants of the manufacturing striations. Some small pits are visible as well, but these are clearly exposed pores in the clay surface or ripped-out pieces of temper, they are not a result of the influence of the batter on the vessel wall (Fig. 3d.e).

Whisking butter, milk and egg yolks (Experiment 3591)

A wooden whisk, made from the top part of a pine tree, was used to whip milk (400 ml raw milk), two egg yolks and 250 gr butter to a smooth substance for


a
b
2 mm
c
d
2 mm
e
2 mm
f
g
2 mm
h
2 mm

Figure 3 (opposite page): (a) Whisking batter in experimental vessel 3540. (b) Use-wear traces produced thereby: abrasion and disappearing production traces (taken at 7.5x original magnification (OM)). (c) Mixing batter in vessel 3541. (d) Surface of 3541 before use (7.5x OM). (e) Removal of the skin, disappearing production traces and visible temper after use of 3541. The small holes visible are pores in the clay (7.5x OM). Compare to Fig. 3d. (f) Whisking milk, egg yolks and butter in vessel 3591. (g) Short and deep scratches due to this experiment (12.5x OM). (h) Short and deep scratches caused on the omphalos of vessel 3591 (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

60 min in an open bowl (Fig. 3f). The bowl contained fine calcite temper, was polished and was fired under reducing circumstances. The whisk was very effective and could easily be used with a whisking motion as well as by rotating it between the hands. Use-wear traces consisted of short but very deep scratches near the bottom inside the pot (Fig. 3g). Identical scratches were seen on the *omphalo*s (Fig. 3h).

Stirring white wine with honey (Experiment 3628)

A red ceramic bowl was used to mix 400 ml of white wine with a spoonful of honey, using a whisk of twigs for 60 min. The pH of the mixture was 3.5 throughout the experiment. The traces resulting from the stirring comprised a loss of the top layer of the surface, laying the surface below and the temper bare. All over the interior, also on the less intensively used areas where some of the burnished surface is still present, many long and multidirectional scratches are visible, sometimes occurring in groups. In some locations the circular movement of the whisk is visible in the wear traces. Where the quartz temper particles are exposed, these are polished and sometimes worn flat and some pitting is visible (Fig. 4a).

Production and storage of acidic substances

One of the main research questions of the BEFIM project was whether the Early Celtic elites in Central Europe drank wine from the fine vessels they imported from Southern Europe, or whether these were used for other consumables, like e. g. beer. A related research question was whether the finely made local tableware was used to consume alcoholic beverages or for other foods or drinks. In the literature pitting is sometimes mentioned as an indication for the presence of an acidic substance (Saurel in BEFIM 1, 141; van Gijn et al. in BEFIM 1, 88-89), a feature which we found on a number of vessels from the Heuneburg (van Gijn/Verbaas, this volume). Our hypothesis is that the acidic contents, e. g. from wine, react with the calcite temper that is so frequent in the Heuneburg vessels (Jacobs, this volume). These calcite particles dissolve, leaving voids of variable size and shape, related to the grainsize of the temper, often referred to as inclusion loss (also Groat, this volume). In addition, there are little round pits which seem to be associated with wine. We therefore decided to conduct a series of experiments with alcoholic beverages, including a number of storage experiments, described below, and a number of fermentation experiments carried out by Nicholas Groat. The latter were focused on honey mead production and are discussed elsewhere (Groat, this volume).

Storing white and red wine inside a pot (Experiments 3486, 3487, 3638b and 3639)

For these experiments modern white or red wines were poured into small vessels with calcite temper. The vessels were covered with plastic and left standing, as if storing wine in the vessels. The experiments were done in two sets. In 3486 (white wine) and 3487 (red wine) wine was stored for 35 d, in 3638 (white wine) and 3639 (red wine) wine was stored for 40 d. As the pots are highly permeable, we had to refill the pots several times (Verbaas/van Gijn-Permeability, this volume). We used the same

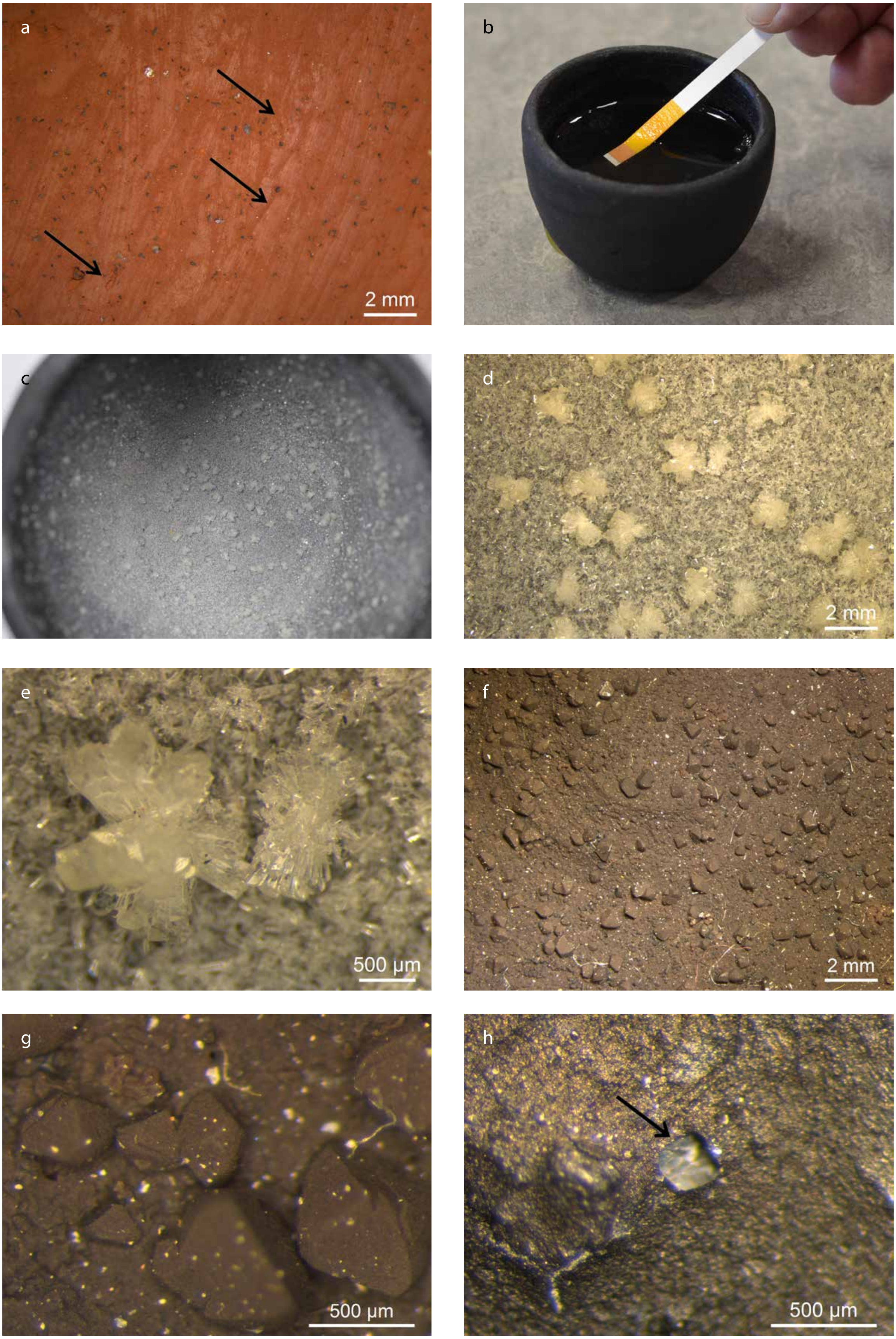
a
2 mm
b
c
d
2 mm
e
500 µm
f
2 mm
g
500 µm
h
500 µm

Figure 4 (opposite page): (a) Deep and irregularly shaped and distributed scratches with a circular directionality, as well as pitting on experimental vessel 3628 used to mix wine with honey (taken at 7.5x original magnification (OM)). (b) Measuring the pH in the wine storage experiment on vessels 3486, 3487, 3638 and 3639. (c) Crystals on the inside of vessel 3486 used for storing white wine. (d) Idem (7.5x OM). (e) Idem (32x OM). (f) Crystals on the interior of vessel 3487 used to store red wine (7.5x OM). (g) Idem (60x OM). (h) Clearly rimmed hole where the calcite dissolved inside vessel 3638 used to store white wine (60x OM) (© Laboratory for Material Culture Studies Leiden University).

wine from the same bottle for each experiment (wine was fresh for the first filling, but later fillings were from the same bottles hence somewhat sourer). We measured the pH of the wine in the pot before and after every filling (Fig. 4b). Whenever new wine was added a chemical reaction was visible, with bubbles appearing for quite some time. Probably the calcite temper reacted to the acidity of the wine. When new wine was added the pH was between 3 and 4. After storing the wine for several days the pH rose to 6-7, again indicating a chemical reaction taking place. This reaction also resulted in crystals growing inside the pots (Fig. 4c). Crystal flowers and small crystal rods developed for the white wine (Fig. 4d.e) and rounded, pyramid shaped crystals for the red wine (Fig. 4f.g). Since it was almost impossible to remove these without damaging the surface of the vessels, we decided not to remove the crystals for experiments 3486 and 3487. Unfortunately, we did not have the chemical expertise nor the time to explore further the reasons for this crystal formation. The second set of pots developed mold over the Christmas holidays, and we had to remove the crystal growth to remove the mold. Even though the surface was slightly damaged, underneath the growth and the crystals some clearly rimmed and round holes appeared (Fig. 4h), similar to the pitting that we observed on some archaeological sherds and that we believe is due to the dissolving of the calcite temper. In the pot in which we stored red wine, we also found smaller and more rounded pits, as well as pits similar to the ones found in the pot in which we stored white wine (Fig. 5a.b).

Leaving honey in pot (Experiment 3485)

As part of the same series of storage experiments 3486 and 3487, we also left honey from the comb in an identical small vessel. The initial pH was 4.5 and this never changed during the 35 d that the honey stayed in the vessel. No evaporation took place. After cleaning in water no clear traces were visible, certainly not the pitting we observed archaeologically on some vessels and which we assumed to be related to an acidic substance, e. g. wine. Honey, therefore, does not seem to react with the calcite temper. More (chemical) research needs to be done to explore this matter further.

Leaving apple sauce in a pot (Experiment 3539)

Apples were stewed in water without any other ingredients and poured into the vessel when the mixture was still warm (Fig. 5c). It was then left in the refrigerator for 8 d, covered with a lid. The pH varied between 3 and 5. After this time the pot was cleaned in warm water by softly rubbing off the residue which stuck to the vessel. The vessel developed mold some time afterwards as it was probably not cleaned sufficiently. The apple sauce did not change the surface of the pot in any way. This activity did not leave any traces of wear, which coincides with the results of the honey storage experiment (3485).

Fermenting cabbage (Experiment 3624)

Chinese cabbage (*Brassica rapa*) was cut and mixed thoroughly with water and salt. Water was added regularly and the mixture was left to ferment for several weeks. Chinese cabbage was used for this experiment, as this is the cabbage most closely related to the cabbage available in the Iron Age (C. C. Bakels, pers. comm.). There were no wear marks visible after this procedure (Fig. 5d.e). Lactic acid fermentation therefore does not seem to leave any traces.

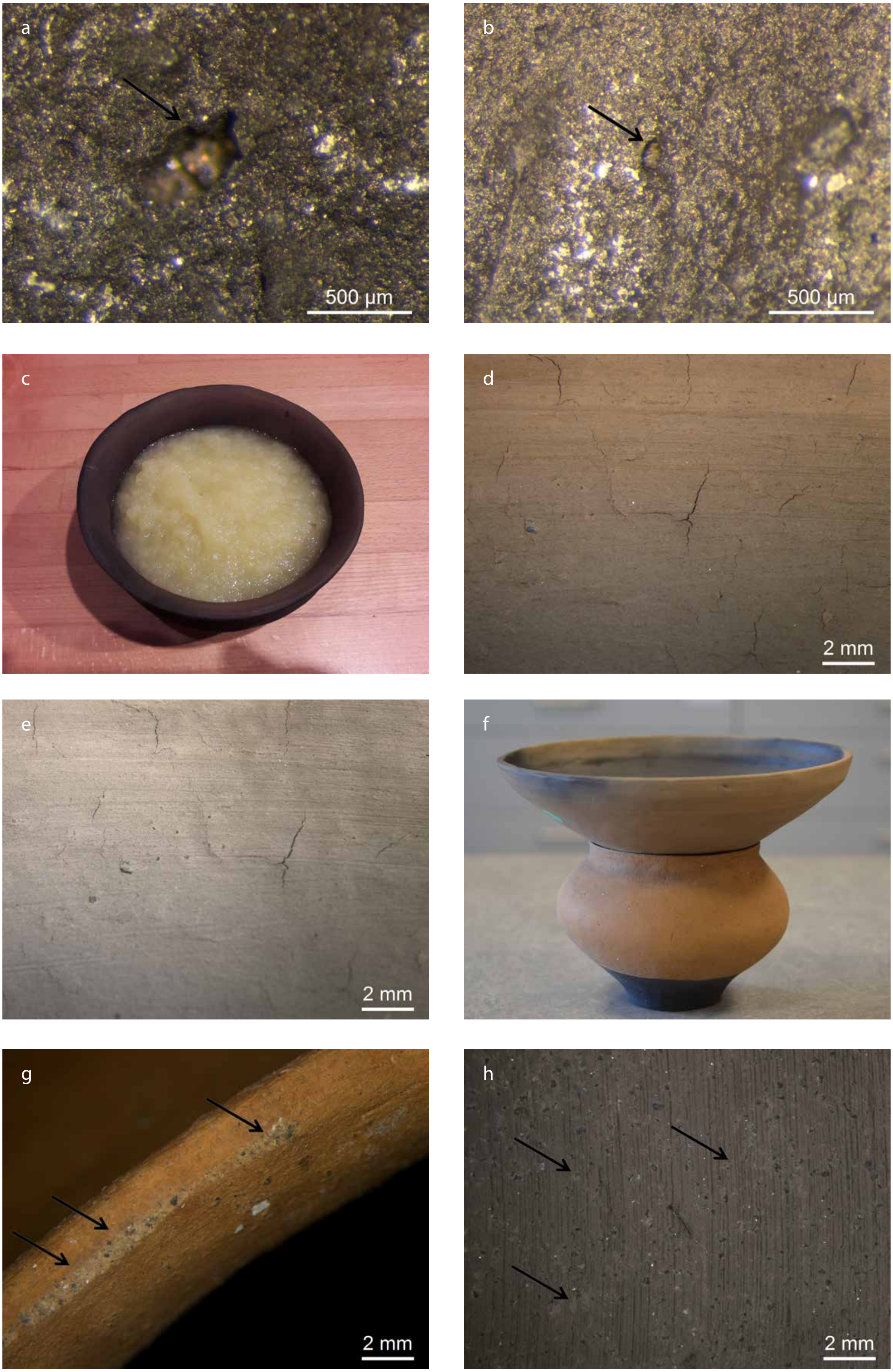
a
500 µm
b
500 µm
c
d
2 mm
e
2 mm
f
g
2 mm
h
2 mm

Figure 5 (opposite page): (a) Clearly rimmed hole where the calcite dissolved from the inside of experimental vessel 3639 used to store red wine (taken at 60x original magnification (OM)). (b) Idem (60x OM). (c) Storing apple sauce in vessel 3539. (d) Internal surface of vessel 3624 before being used to ferment cabbage (7.5x OM). (e) Idem after fermenting cabbage (7.5x OM). (f) Ceramic lid (vessel 3630) used to cover vessel 3636. (g) Abrasion and flattened surface with very wide and shallow scratches on the rim of vessel 3636 left by the pottery lid (7.5x OM). (h) Heavily developed abrasion and very short wide, impact-like scratches on lid 3630 used to cover vessel 3636 (7.5x OM). The scratches are oriented perpendicularly to the production traces (© Laboratory for Material Culture Studies Leiden University).

Covering

The preliminary inspection of the Heuneburg sample revealed possible traces of wear on the rims of some vessels that were hypothesized to be due to the vessels having been covered with some sort of lid. We therefore carried out experiments investigating the use-wear created by a pottery lid, a linen cloth wrapped and tied around the neck of the vessel with a piece of rope, a wax cloth and a wooden lid.

Covering with a pottery lid (Experiments 3630 and 3636)

A ceramic lid (experimental vessel 3630) was repeatedly put on a pottery vessel (experimental vessel 3636) for 60 min (Fig. 5f) to simulate covering and uncovering. As we have not found any lids in the assemblage, Jacobs created a vessel shape that could serve as a lid. It is a slightly concave shape, touching the inside of the pot rim. At the locations where the lid touched the rim of the vessel (experimental vessel 3636), use-wear traces were already visible with the naked eye. The top layer of the pottery is worn away, and the differently colored core is exposed. With the stereomicroscope a flattened surface with faint very wide scratches indicating the direction of covering can be seen (Fig. 5g). Where the lid touched the pot (experimental vessel 3636), the surface is highly worn, with clearly developed striations; in places the temper is laid bare (Fig. 5h).

Covering with cloth and rope (Experiment 3635)

Experimental vessel 3635 was covered with an undyed linen cloth tied with a piece of lime bark rope (Fig. 6a). The cover was removed and attached over and over again for the duration of 60 min. The outside of the rim displays a very slight rounding and a vague transverse directionality. Where the rope was tied, a slight smoothing of the surface can be seen on the external wall of the vessel. These traces, however, are so vague that it was impossible to photograph them. On archaeological vessels, traces created in the way of this specific experiment would no longer be visible due to post-depositional wear. More extensive use or utilization of a coarser or more abrasive cloth would leave traces that are also archaeologically visible. We have observed such traces on some of the archaeological vessels.

Covering with a wax cloth (Experiment 3637)

A piece of wax cloth was used to cover this pot, which was removed and replaced for 60 min. After use all locations where there had been contact between the cloth and the pot displayed a thin layer of beeswax (Fig. 6b). This beeswax could not be removed and it was impossible to clearly see the traces underneath. However, there seems to be a little rounding of the outer rim visible and some smoothing of the surface where the cloth was shaped around the neck of the vessel.

Covering with a wooden lid (Experiment 3638a)

A wooden lid, made from apple wood and weighing 570 g, was used to cover and uncover an open bowl (Fig. 6c). This was done for 60 min, making about 50 movements of covering/uncovering actions per minute. During this experiment, it was noted that the lid frequently slid from the vessel rim. The protruding parts of

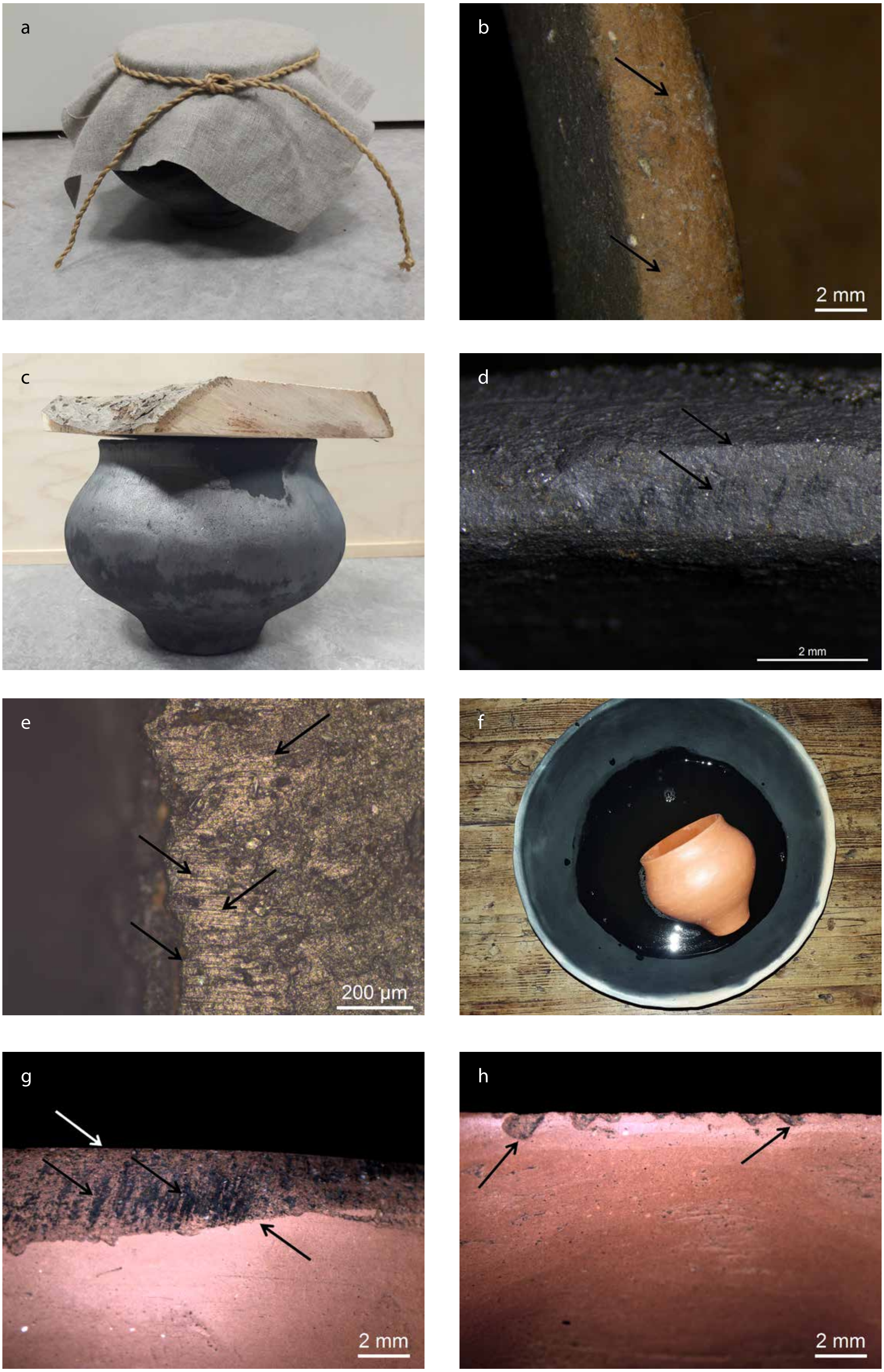
a
b
2 mm
c
d
2 mm
e
200 µm
f
g
2 mm
h
2 mm

Figure 6 (opposite page): (a) Covering experimental vessel 3635 with a piece of linen cloth. (b) Beeswax on the rim of vessel 3637 left by a beeswax cloth, obscuring the possible traces of use (taken at 7.5x original magnification (OM)). (c) Experiment with covering vessel 3638a by a wooden lid made from apple wood. (d) Flattened rim with short, wide and multidirectional scratches on vessel 3638a due to covering with a wooden lid (16x OM). (e) Smooth, bright polish with striations showing the direction of the motion involved, from contact with a wooden lid (100x OM). (f) Using a small vessel (vessel 3353) to scoop wine from vessel 3349. (g) Heavy abrasion with long and wide striations on vessel 3353 after scooping wine from vessel 3350 (7.5x OM). (h) Small flakes taken off the rim towards the inside after the same experiment (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

the rim, where there was frequent contact with the lid, were flattened due to use. Striations are visible on these flattened patches (Fig. 6d). Under the metallographic microscope a smooth, striated polish is visible, mainly located on the higher locations (Fig. 6e). As the amount of use-wear increased, these small spots of polish connected into larger patches.

Serving and consumption

On the Heuneburg sherds, different wear traces possibly related to serving and consumption of beverages and food were observed. On the internal body of vessels, traces were present that could relate to scooping or ladling the contents from the bowls. On the rims rounding, abrasion and, occasionally, transversely oriented scratches were seen. The location and distribution of these traces suggest that they may have been the result of a spoon or ladle. As these practices of serving and consumption are the focus of this research, we further explored these activities to see whether we could observe traces from different gestures associated with serving and consumption and whether it was possible to discriminate between them.

Scooping wine from a large bowl with a small cup (Experiments 3349 and 3353)

In this experiment, 1 l of dry white wine (pH 3) was poured into a large bowl (experimental vessel 3349) and scooped out with a small vessel (experimental vessel 3353) for 60 min (Fig. 6f). There was a lot of attrition between the two vessels. Especially vessel 3353 developed extensive damage on its rim and belly where it touched vessel 3349, resulting in heavily developed abrasion with long and wide striations (Fig. 6g). Where the rim is worn thin, small flakes were removed towards the interior of the pot (Fig. 6h). On the large bowl 3349 the temper was laid bare, and striations developed that could be seen with the naked eye. Microscopically, a leveled, but rough surface is visible with scratches of medium length and width (Fig. 7a). Such extensive damage was not seen archaeologically, so it is unlikely that the small ceramic cups were used to ladle out liquids from the larger vessels.

Scooping wine with a copper ladle from a large bowl (Experiment 3350)

For this experiment white wine was repeatedly scooped out from the vessel with a copper ladle for 60 min (Fig. 7b). The ladle touched the bottom of the vessel with almost every scoop and the bowl was turned around repeatedly in order to allow the ladle to come into contact with all of the vessel wall. The vessel was completely emptied before pouring the same wine back into the vessel to begin scooping again. This was to try to replicate a more realistic use than just scooping and immediately letting the liquid fall back into the same vessel. Clay particles turned the wine dark after a while. Since this bowl was also to be used for the breaking and taphonomic experiments, the same activity was repeated on the walls of the bowl (also for 60 min), in order to create enough traces to use several sherds with use-wear in the post-depositional experiments.


a
2 mm
b
c
2 mm
d
e
2 mm
f
g
2 mm
h

Figure 7 (opposite page): (a) Heavy abrasion with visible temper and long and wide striations inside experimental vessel 3349 after scooping the wine from it with a small pottery vessel (taken at 7.5x original magnification (OM)). (b) Scooping wine from vessel 3350 with a copper ladle. (c) Remnants of production traces visible as long and thin interrupted scratches on the interior of vessel 3350 after scooping white wine out of the vessel (7.5x OM). (d) Eating porridge with a bone spoon from vessel 3598. (e) Dull polish and flattened pieces of temper caused by this (10x OM). (f) Hanging a curved copper ladle from the rim for experiment 3594. (g) Slight abrasion with both narrow and very wide scratches on the inside rim of the vessel left thereby (16x OM). (h) Hanging a curved horn spoon from the rim for experiment 3595 (© Laboratory for Material Culture Studies Leiden University).

Under the microscope substantial abrasion is observable, and production traces are mostly worn away. The remnants of these traces are still visible as long, thin and interrupted scratches (Fig. 7c). In some locations pieces of temper are laid bare or ripped out.

Eating porridge with a wooden spoon (Experiment 3590)

Oatmeal porridge was eaten from a small bowl with a wooden spoon for 60 min. The spoon was used to scoop and scrape the porridge from the bowl and mostly made contact with the bottom of the vessel. No use-wear traces were observed on the contact area after usage. This is probably because the glue-like porridge worked as a lubricant between the spoon and the bowl.

Eating porridge with a bone spoon (Experiment 3598)

This experiment was similar to 3590 except that a bone spoon was used (Fig. 7d). The spoon came in contact mostly with the internal bottom of the pot when scraping the bottom to scoop out as much porridge as possible. The oatmeal porridge was replaced every 15 min to prevent the contents cooling down. Contrary to 3590 and 3622 traces did develop. This was probably due to the type of spoon used as the experimenter was the same person. The bone spoon of this experiment has a relatively sharp edge and may have cut through the glue-like layer of porridge to the vessel wall, in that way creating traces. The wear traces consist of a dull polish all over the contact area, and the temper particles are flattened (Fig. 7e). On the higher locations of the inner vessel wall, where there was less intensive contact with the spoon, only scratches are visible. They are relatively short and of medium width. The graphitized layer has partially disappeared, and scratches are invisible on the softer layer underneath.

Placing spoons of different materials on the rim of a graphitized bowl (Experiments 3594-3597)

In order to limit to some extent the required number of vessels, we occasionally used one vessel for different experiments, provided that the use-wear traces of the different uses did not affect each other. For the experiments with hanging a ladle or placing a spoon against the rim, we divided an open bowl into four equal parts: each quarter of the rim constituted one experiment. The experiments involved hanging a spoon on the rim and repeating this action for 60 min.

The first experiment, experiment 3594, involved hanging a curved copper ladle from the rim. The ladle was hung on the inside of the vessel so the contact area was the rim of the pot as well as the internal wall against which the ladle was leaning (Fig. 7f). The wear traces resulting from this usage are visible on the interior of the rim and encompass a very slight abrasion and fine scratches, combined with wide "gouges". The direction of the scratches and gouges was perpendicular to the rim (Fig. 7g). Polish was seen on the inside edges of the vessel.

The second experiment, number 3595 involved a spoon made from horn. Again, the spoon was hung repeatedly over the rim for 60 min (Fig. 7h). Slight abrasion and small scratches could be observed on the contact area. The direction of the scratches was downwards, similar to the motion of the spoon (Fig. 8a). The reflective top layer of the surface was worn away, resulting in a slightly duller surface.

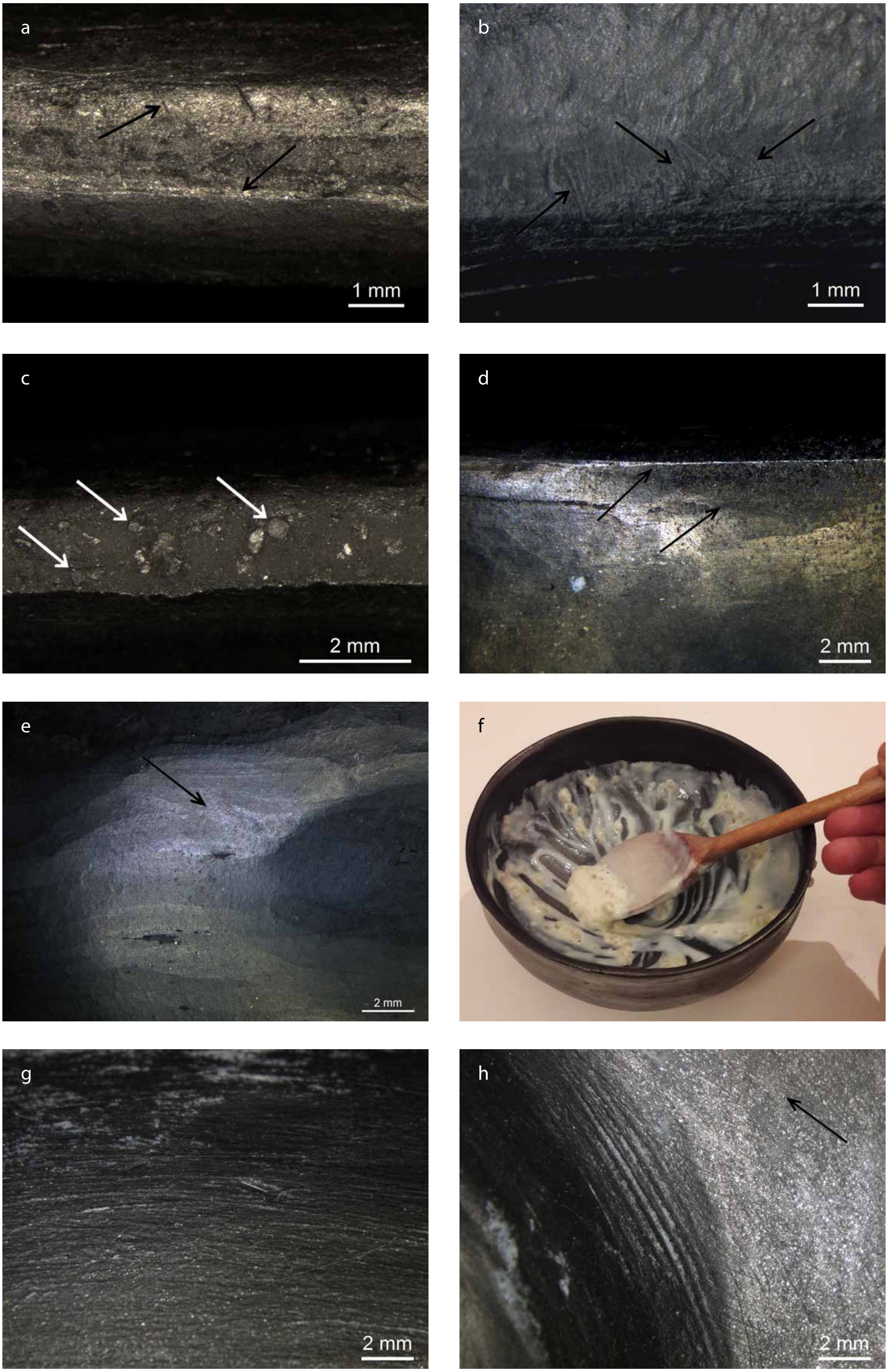
a
1 mm
b
1 mm
c
2 mm
d
2 mm
e
2 mm
f
g
2 mm
h
2 mm

Figure 8 (opposite page): (a) Slight abrasion, long and thin scratches and removed reflective top layer of the rim of experimental vessel 3595, hanging a horn spoon from the rim (taken at 16x original magnification (OM)). (b) Slight abrasion and wide scratches on the rim of vessel 3596, hanging a wooden spoon from the rim (16x OM). (c) Abrasion and exposed temper particles from hanging a curved iron spoon over the rim of vessel 3597 (16x OM). (d) Disappearing production traces and slight gloss on the rim of vessel 3621 used to drink water out of (7.5x OM). (e) Worn and lightly polished outer surface on vessel 3621 after repeated handling (7.5x OM). (f) Eating porridge from vessel 3622 with a wooden spoon. (g) Slight flattening of the production traces caused thereby (7.5x OM). (h) The shiny top layer of the pottery has disappeared from the rim of vessel 3622 due to placing a spoon against the rim (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

The third experiment, number 3596, was identical to the previous two, except that it involved a wooden spoon with a curved end and not a ladle. The contact area was slightly abraded and wide scratches are visible (Fig. 8b).

The fourth experiment, number 3597, involved an iron spoon with a curved end that hung over the rim of the vessel. The iron spoon appeared to be very abrasive and left behind major use-wear traces, including a "sharpening of the edge" because of the nibbling of the very rim. The surface of the contact area on the rim was completely removed and the temper particles were extremely eroded. Linear scratches are visible in the surface that was not removed yet (Fig. 8c). This extreme effect was probably due to the hardness of iron.

Drinking and handling water from a bowl (Experiment 3621)

Water was consumed from a small bowl for 60 min. Contact was with the lips on the rim and handling on the outside body. The contact between the lips and the rim was limited to one specific zone of the rim. After 60 min of repeated continuous contact, the rim had become abraded and slightly rounded where the lips kept touching it. There is also a slight loss of manufacturing traces, and a lightly developed polish is visible (Fig. 8d). On the body of the bowl the surface is worn, but also slightly polished (Fig. 8e). When this polish is observed under high magnifications it is slightly dull, with light pitting and without directionality similar to the polish resulting from handling on other materials, e. g. on bone tools (van Gijn 2006, 218-219).

Eating porridge from a bowl and placing a wooden spoon against the rim (Experiment 3622)

A small bowl, a replica of HB-PL-002, was filled with porridge (oatmeal), and a wooden spoon was used to scoop out the contents for 60 min (Fig. 8f). The motion was variable and touched all sides of the bowl. The spoon was also made to lean against the rim on the same place for 60 min, in the way you would when taking a break or after finishing the meal. Scooping porridge from the bowl left hardly any traces. There is a slight flattening of the production traces, but this is minimal (Fig. 8g). The reason may be that - as was said before - oatmeal porridge is a very smooth, glue-like substance. This probably works as a lubricant between the pot and the spoon, protecting the vessel wall. Placing the spoon against the rim left some very vague traces. The top shiny layer of the pottery is worn off (Fig. 8h), but this is such a light change, that this would not be visible on archaeological sherds.

Cleaning

Abrasion is sometimes visible all over the internal surface of the vessels, sometimes with a slightly different abrasion on the bottom of the vessel. As we suppose that ceramic vessels are generally not seen as throw-away items, we postulated that these traces may be the result of cleaning. Sometimes rinsing with water is enough to clean, and we do not expect to find traces in these cases, but we assume cleaning


a
b
c
d
e
f
g
2 mm
h
2 mm

Figure 9 (opposite page): (a-d) Cleaning experimental vessels 3505 and 3506 with: (a) A heather brush (3505). (b) A pig's bristle brush (3505). (c) A cloth and sand (3506). (d) A bundle of grass (3506). (e-f) Overview of vessels: (e) 3505 after use. (f) 3506 after use. (g-h) Surface of vessel after cleaning with a heather brush and water: (g) 3505 with partly removed manufacturing traces and exposed temper with long and narrow multidirectional scratches (taken at 10x original magnification (OM)). (h) 3506 with abraded surface, disappearing production traces and exposed temper (10x OM) (© Laboratory for Material Culture Studies Leiden University).

tools were also used. We therefore set up a series of experiments in cleaning vessels. One experiment was done on different vessels, to see whether the use-wear traces differ.

Cleaning with different cleaning tools (Experiments 3505 and 3506)

The two experimental pots were divided into four zones. Each zone was cleaned for 60 min with: 1) a heather brush (Fig. 9a); 2) a pig's bristle brush (Fig. 9b); 3) a piece of linen cloth and sand (Fig. 9c); 4) a bundle of grass (Fig. 9d). The two vessels were made in a different way in order to evaluate whether temper size, polishing and firing temperatures influenced the development of wear traces. Both are made from the same clay, but experimental vessel 3505 is based on Mediterranean pottery and has an *omphalos*. It is fired at a temperature of some 850° C under reducing circumstances. It is wheel-thrown, and the temper is < 250 µm. Its surface is polished with flint. Vessel 3506 is a replica of a local bowl, its surface is finished by smoothing, and its temper is coarser than that of experimental vessel 3505. It was fired in oxidizing conditions around 800° C. Its surface is dull and supposedly more permeable than its counterpart number 3505. Although the pots were fired around similar temperatures, the surface of experimental vessel 3505 is harder and less porous due to the polishing and reducing firing. Both pots were divided into four sections, each for a different cleaning experiment. For all sub-experiments water and a cleaning "tool" were used. Each cleaning action was performed for 60 min. The resulting wear traces will be described for both pots at the same time, arranged by cleaning tool. Two pictures (Fig. 9e.f) provide macroscopic overviews of the vessels after use, showing the difference in wear between the different zones.

Zone 1: heather brush

On both vessels the top layer of the surface with the manufacturing traces was partly removed during use. The temper is exposed, and on the relatively rough surface small, multidirectional and sometimes curved scratches are visible (Fig. 9g.h). On vessel 3505 some light pitting is also seen. These are very small, shallow pits with an irregular shape, giving the surface a slightly rough appearance.

Zone 2: pig's bristle brush

This section was cleaned by using a pig's bristle brush. On the surface of pot 3505 many light scratches have developed (Fig. 10a) but on the surface of pot 3506 only a few (Fig. 10b). As the top layer is worn away, the surface underneath is visible, exposing the temper. Pits are visible especially on 3505, but also in the surface of 3506. They are shallow, irregularly shaped depressions that give the surface a rough appearance. These pits probably result from bits of temper and clay being removed from the surface.

Zone 3: cloth and sand

The surface of both experimental vessels was highly damaged by cleaning with water, cloth and sand, removing the clay surface and exposing the temper underneath. Pieces of temper and clay are removed from the surface, creating pits where the temper is removed (Fig. 10c.d). This way of cleaning is so aggressive that it was probably done only sporadically, if at all.

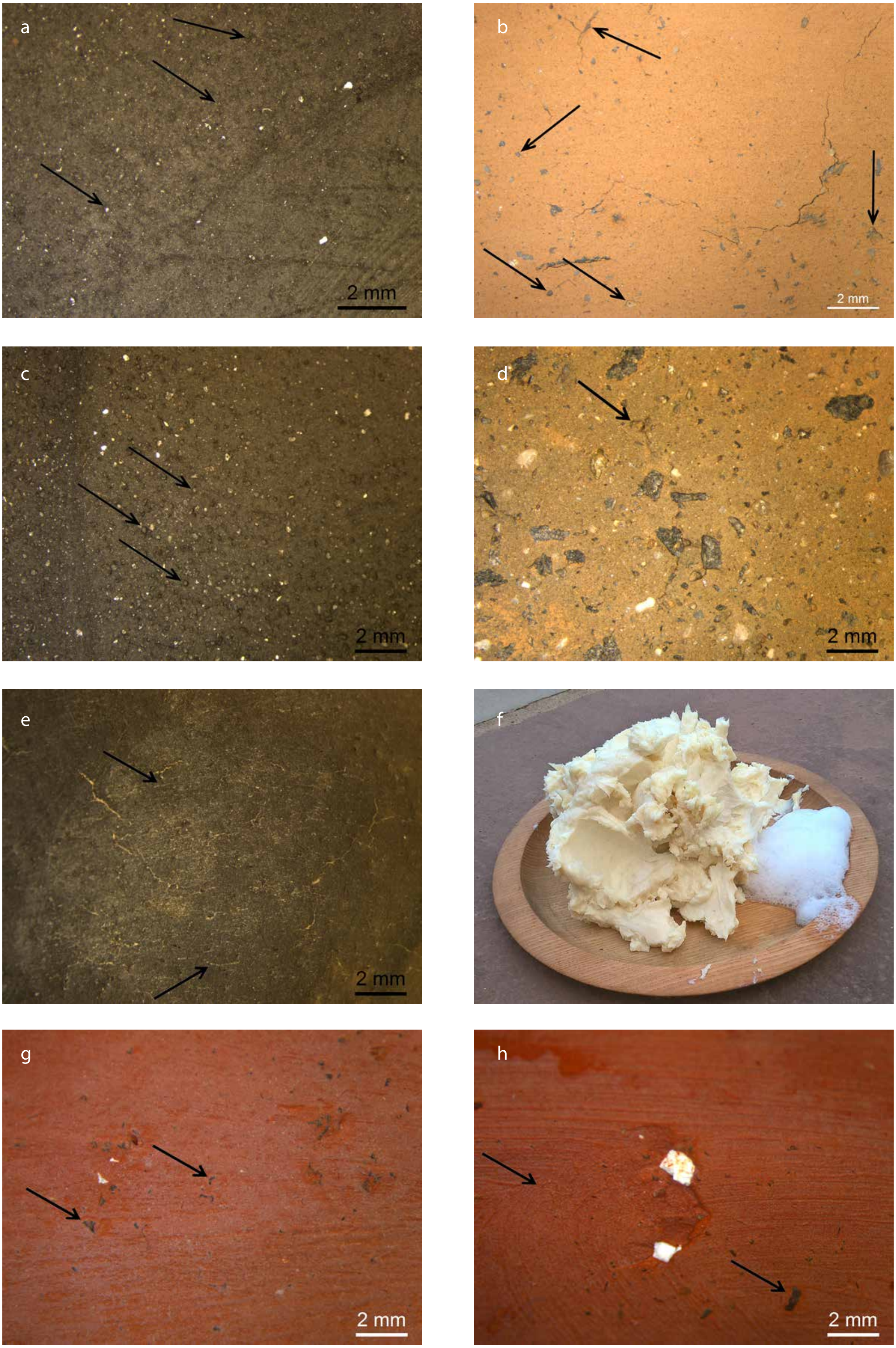
a
2 mm
b
2 mm
c
2 mm
d
2 mm
e
2 mm
f
g
2 mm
h
2 mm

Figure 10 (opposite page): (a-b) Surfaces with disappearing manufacturing traces and increasing size of flaws. Top surface is removed and temper exposed with some small pits, where pieces of temper have disappeared after cleaning with a pig's bristle brush and water: (a) Experimental vessel 3505, with many lightly developed scratches (taken at 10x original magnification (OM)). (b) Vessel 3506, with only few scratches (10x OM). (c-d) Highly damaged and abraded surfaces with dislodged pieces of temper after cleaning with cloth, sand and water: (c) 3505 (10x OM). (d) 3506 (10x OM). (e) Traces of wear after cleaning vessel 3506 with a bundle of grass and water. Production traces are fading with both short and wide scratches and some abrasion visible (10x OM). (f) Iron Age-style soap used in the cleaning of vessel 3631. (g) After cleaning vessel 3631 with water, soap and a piece of linen cloth, production traces have slightly worn away. Where the top layer is eroded, the temper is clearly visible (7.5x OM). (h) Wear traces on experimental vessel 3631, after cleaning with water, soap and a pig's bristle brush. The temper is laid bare, and production traces have erased. In this location wide circular scratches are visible (7.5x OM) (f = © S. Pointer, others = © Laboratory for Material Culture Studies Leiden University).

Zone 4: bundle of grass

Of all sections, the surface cleaned with grass is altered the least. The manufacturing traces are partly worn away, and only a few light scratches can be distinguished. On 3506 some wider, curved scratches are present (Fig. 10e). Overall, the surface of vessel 3505 and a large part of the surface of vessel 3506 are smoothed. The ripped-out particles and small holes in the surface visible after cleaning with the pig's bristle or heather brush were not created by cleaning with a bundle of grass.

Cleaning with water, soap, a brush or a cloth (Experiment 3631)

For the experiments above only water was used during the cleaning. We also did one experiment adding soap. We used a soap made by a specialist on historic soaps and cosmetics (Sally Pointer; https://www.sallypointer.com/). It was made of equal parts of beef and pork fat and a lye produced with the ashes of beech, oak and ash, aged before use (Fig. 10f). The soap was diluted in water, and the vessel (a replica of HB-VB-002) was immersed in this and cleaned. The pot was divided into two zones, one was cleaned with a piece of linen cloth (60 min) and one with a brush of pig's bristle (60 min). The soap seemed to impregnate the vessel wall leaving a greasy sheen and making the bowl slightly water repellent. The soap also seems to have left a thin layer of residue that we could not remove. This slightly obscures the traces. In the section where the piece of cloth is used for cleaning, the smoothing traces of production have somewhat worn away, but are still detectable. The temper, however, became more clearly visible, and short and wide scratches can be seen on the surface (Fig. 10g). Cleaning with a pig's bristle brush leaves traces similar to the linen cloth: the temper is laid bare and production traces wear away where small scratches become discernible (Fig. 10h). When we compare these traces to the vessel cleaned without soap, the traces are less well developed. It seems the soap served as a sort of lubricant, protecting the vessel from damage. We did not observe the removal of the clay surface or ripped out particles of temper after cleaning with soap either. As no experiments were done on dirty vessels, we cannot give any information on whether the soap facilitates cleaning.

Leaving soap in a vessel for 2.5 months (Experiment 3632)

The soap mentioned above (experiment 3631) was put into a small vessel, covered and left for 2.5 months to simulate storing soap. The pH of the soap is 11. There were no visual changes in the vessel surface during this period. After cleaning, soap was still present in the pores and lower areas of the pot, but the surface of the pot was unchanged, no traces of wear being visible. Whereas washing with soap left a fatty residue on the vessel surfaces (see above), this was not the case with storing soap.

Handling

Some of the locally made vessels from the Heuneburg displayed considerable craftsmanship and would have required time, care and skills to produce. For this


a
b
2 mm
c
2 mm
d
2 mm
e
f
1 mm
g
2 mm
h

Figure 11 (opposite page): (a) Shoving experimental vessel 3592 on a dried clay surface. (b) The resulting heavily abraded surface with relatively rough and irregular character and removed particles of temper (taken at 16x original magnification (OM)). (c) Light wear on the edge of the used zone produced thereby (7.5x OM). (d) Long and wide scratches on the edge of the used zone of 3627 after shoving on a dried clay surface (7.5x OM). (e) Shoving vessel 3593 on a wooden surface. (f) The resulting relatively long and narrow or short and wide scratches (25x OM). (g) Idem (16x OM). (h) Bumping vessels 3600a and 3600b against each other (© Laboratory for Material Culture Studies Leiden University).

reason, we would expect them to display a lot of handling traces as evidence of long-term use. Experiments were therefore done with shoving pots around on different surfaces (clay floor and wooden plank). We assumed that the vessels would have been stored as well, sometimes bumping into each other while being moved around or taken off their storage space. We also explored the effect of stacking pots on top of each other, emulating a situation in which the vessels were stored in a restricted space like a shelve.

Shoving a pot on clay surface (Experiments 3592 and 3627)

To mimic handling vessels around the hearth or inside the house on a dried clay floor, two experimental pots were shoved around on a dried clay slab (Fig. 11a). Vessel 3592 was shoved in a more systematic way, whereas experiment 3627 was executed in a more realistic fashion, pretending to pick up the pot and placing it on the floor, as well as shoving the pot towards and away from the user. Both experiments resulted in a heavily abraded surface with a relatively rough character and irregular topography. Temper particles became visible and were also removed from the surface (Fig. 11b). On experimental vessel 3592, on the edge of the abraded area, scratches in the reflective original top layer are still visible, representing the start of the wear (Fig. 11c). On experimental bowl 3627 many long and wide scratches are visible on the abraded surface and its edges (Fig. 11d). The abraded patch is also larger, and the edge of the patch is less well defined, indicating there is definitely a difference in traces between the two ways of conducting this experiment.

Shoving a pot on a wooden surface (Experiment 3593)

This pot was shoved around on an oak wood surface to mimic use on a wooden table or storage area (Fig. 11e). The pot was shoved around for 60 min. The top layer of the surface is lightly worn away, but the shoving results in a more polished rather than abraded surface. There is light polish visible in combination with two kinds of scratches: relatively long and thin ones, and ones that are slightly shorter and much wider (Fig. 11f.g). The scratches are multidirectional.

Bumping pots against each other (Experiments 3600a and 3600b)

These pots were bumped into each other for 60 min as if placing them together for food preparation or storage (Fig. 11h). The widest parts of the vessels touched during use. On the surface of the pots severe abrasion is visible (Fig. 12a). Temper particles have become exposed, and in some locations the temper has been flattened. Some short and wide scratches are visible, mainly on the edge of the zone that is damaged by use.

Stacking pots on top of each other (Experiments 3626 and 3629)

These two pots were stacked on top of each other, with vessel 3629 repeatedly being placed on top of vessel 3626 for 60 min (Fig. 12b). On the rim of vessel 3626 only lightly developed traces are visible, with some abrasion of the rim and short, mainly perpendicularly oriented scratches (Fig. 12c.d). On the bottom of vessel 3629 more scratches are visible. These are long and of medium width with a random distribution (Fig. 12e).

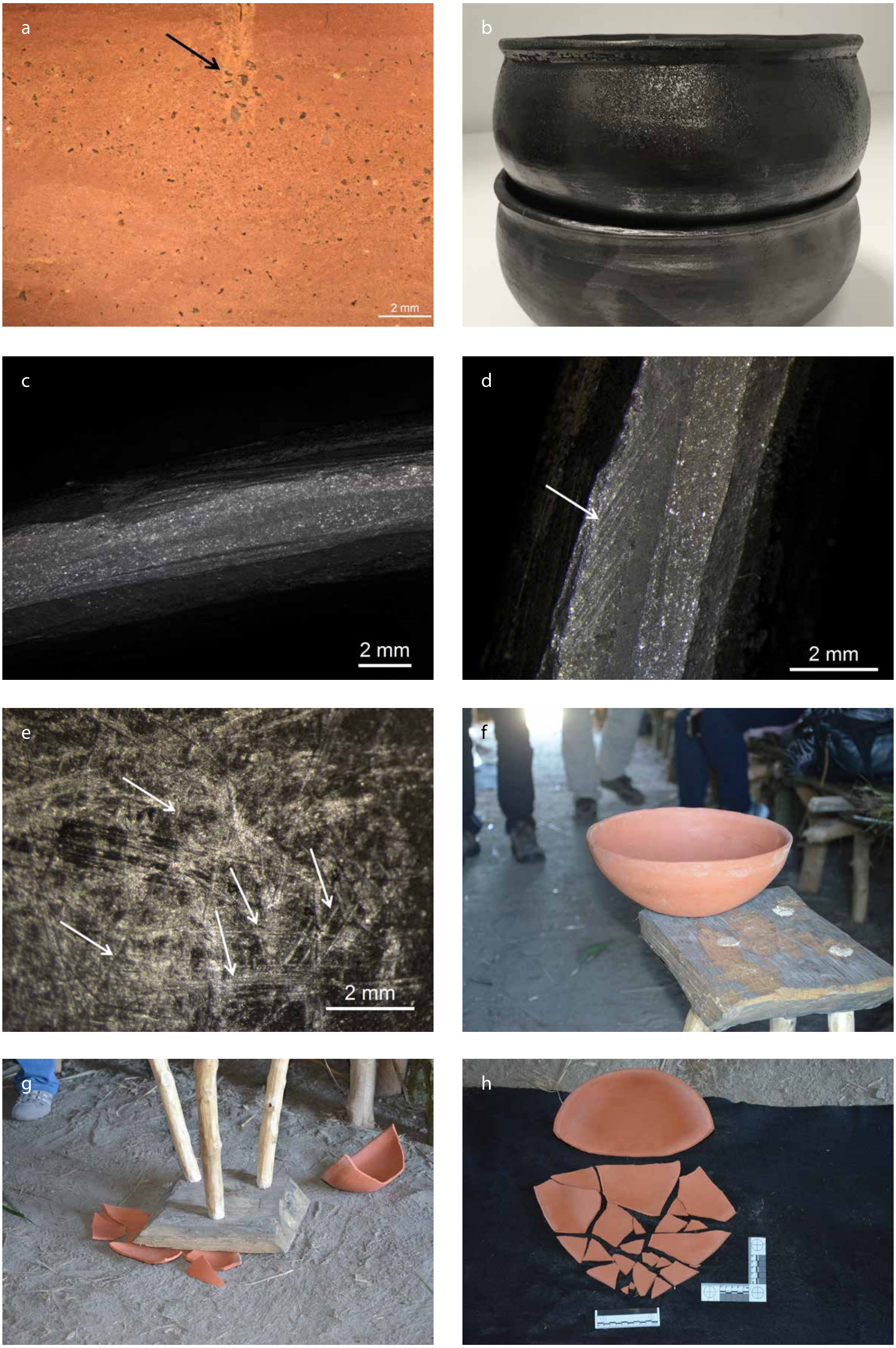
a
2 mm
b
c
2 mm
d
2 mm
e
2 mm
f
g
h

Figure 12 (opposite page): (a) Abrasion with visible scratches and sometimes flattened surface on experimental vessel 3600a after bumping against vessel 3600b (taken at 7.5x original magnification (OM)). (b) Stacking vessels 3626 (below) and 3629 (top). (c) The rim of vessel 3626 before the stacking experiment with vessel 3629 (7.5x OM). (d) Lightly developed traces on the rim of vessel 3626 after use, some abrasion with short scratches after stacking with vessel 3629 (12.5x OM). (e) Long scratches of medium width and a random distribution on 3629 after stacking with vessel 3626 (12.5x OM). (f) Vessel 3352 is placed on a wooden stool for the breaking accident. (g) Vessel 3352 after breaking. The stool fell onto one half of the pot, breaking it into numerous sherds. (h) The sherds created in the accidental breaking of vessel 3352 (© Laboratory for Material Culture Studies Leiden University).

Breaking pots "accidentally"

Obviously while using and handling pots, accidents can happen that cause the vessel to break. A total of seven pots were broken in different ways. It should be stressed that initially we only intended to break the pots in the laboratory, in order to obtain sherds (some with, some without experimental use-wear traces) that could be subjected to various post-depositional and post-excavation processes. However, in the context of the final BEFIM team meeting we decided to make this an experiment in which BEFIM team members could re-enact accidents that could potentially occur with pottery. It should be stressed that no exact measurements of sherd size and distribution were made and that this should be seen as an exploratory experiment that needs to be designed and repeated in a more systematic fashion. The seven pots included two vessels that were used to mix wine and herbs (experiments 3352 and 3768), two pots that were shoved around on a clay surface (experiments 3627 and 3592), two unused vessels (experiments 3769 and 3771), one of which was impregnated with beeswax (experiment 3769) and one that was used to scoop wine with a metal ladle (experiment 3350).

Experiment 3352, originally used for mixing wine and herbs with a wooden spoon, was put on a wooden stool without contents (Fig. 12f). One of us tripped over it, and the pot fell on the loam floor, breaking in half. The stool fell on one of the halves, completely flattening the large sherd and breaking it into a series of small triangular sherds (Fig. 12g.h) that occur frequently in the archaeological context of the Heuneburg assemblage (Mötsch, pers. comm.). For example, HB-VB-048 displays a very similar fracture pattern (van Gijn/Verbaas, this volume, fig. 18a)

Experiment 3768, also originally used to stir wine and herbs in, was filled to the rim with water and put just beside the fire to heat its contents (Fig. 13a). The pot fell out of the hands of the experimenter just before being in place, breaking on the stones of the hearth (Fig. 13b). A couple of really large sherds were visible, and a lot of small sherds and tiny pottery fragments fell into the ashes (Fig. 13c). It should be noted that small parts of the rim are often present in the archaeological evidence, often with a point, as is the case with HB-VB-023. Interestingly, this sherd from the Heuneburg displays signs of repair (van Gijn/Verbaas, this volume, fig. 17c.d). Many of the rim sherds, however, display severe crushing, probably due to the impact of the hearth stones.

Experimental vessel 3627, originally shoved around on a clay surface for 60 min, was put on a table and pushed off accidentally onto the loam floor. It was empty. The first time it did not break. The second time it broke into only a limited number of sherds, and again, half of the pot was still complete (Fig. 13d). No crushing of sherds was visible.

Experiment 3592, previously shoved around on a clay surface for 60 min, was filled with water and dropped straight down from the hands of the experimenter onto the loam floor (Fig. 13e). It landed on its bottom. In a burst the sherds were spread over quite a distance, more than a meter from the location of impact. All produced bottom sherds are very small, whereas the rim sherds are much larger (Fig. 13e.f). One longitudinal rim sherd has a very similar shape to a rim sherd from the Heuneburg,

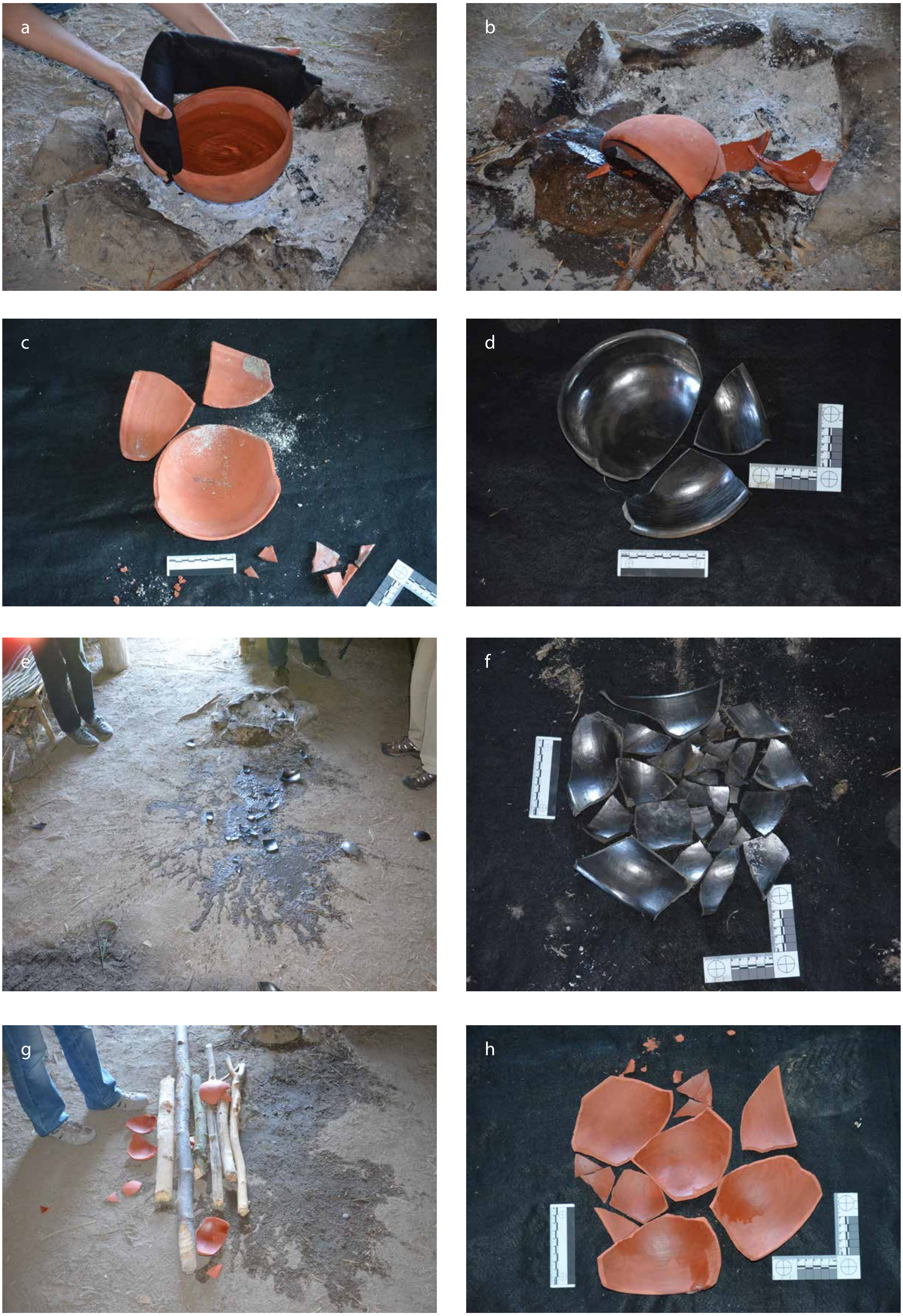
a
b
c
d
e
f
g
h

Figure 13 (opposite page): (a) Breaking experimental vessel 3768 by dropping it onto the edge of the hearth while filled with water. (b) Vessel 3768 after breaking on the stones of the hearth. (c) The sherds resulting from this. (d) The sherds created in the re-enacted "accidental" breaking of vessel 3627. (e) Vessel 3592 filled with water and dropped straight onto the loam floor, after breaking. (f) The sherds created thereby. (g) Vessel 3769 carried around and dropped onto a pathway of wooden beams, after breaking. (h) The sherds thus produced (© Laboratory for Material Culture Studies Leiden University).

HB-VB-026 (van Gijn/Verbaas, this volume, fig. 7b). The wide distribution of especially the smaller sherds may have archaeological implications: these may have been left behind or shoved towards the walls of houses, whereas larger sherds may have been picked up and cleared away outside the house. Experimental vessel 3769 was impregnated with beeswax but had otherwise not been used. In an empty state, it fell on a pathway of wooden beams (Fig. 13g). Where the pot hit the wood, lots of splinters developed, something that was not the case for the vessels that fell on the loam floor. There is also a much larger degree of fragmentation than with the empty pots that fell on loam, with an enormous size differentiation of the sherds (Fig. 13h).

Experiment 3771 consisted of an unused vessel selected because of its distinctive rim shape. It was dropped straight down onto the loam floor, without any contents. It did not shatter until the seventh time we dropped it. The sound of the pot began to change after the fourth drop, indicating that cracks were already developing. The pot was probably too light to shatter and the loam floor too soft. When it finally did break, it was noted that the shape of the fragments was very different from what we see in the Heuneburg assemblages (Fig. 14a) (Mötsch, pers. comm.), suggesting that dropping an empty pot in this way rarely occurred in the past.

Experiment 3350, originally used for scooping wine with a copper spoon, was placed on the edge of the hearth. When lifting it, the vessel was accidentally dropped onto the stones surrounding the hearth causing it to break into three large fragments (Fig. 14b.c).

Although these experiments were not done systematically, some of the insights suggest that it is worth pursuing this kind of experiments further. Fragmentation is usually taken for granted and its causes are rarely investigated. However, it seems that the pattern of fragmentation can be used to a certain extent to reconstruct the circumstances under which a vessel broke. The contents of the pots (that is, whether or not they contained liquids), the material on which they fall (hearth stones, wood, loam floor) or whether or not they were crushed by something falling on top (like a stool) seem to be the three most important variables for the resulting fragmentation pattern. Empty pots appear to break less easily, and when they do break, they produce fewer fragments. Pots filled with water, showed opposite behavior, breaking easily and producing many fragments widely scattered. The latter can probably be explained by the impulse of the falling liquid exerting homogeneous pressure onto the vessel wall. Not unexpectedly, the harder the surface the vessels landed on, the higher the degree of fragmentation as well. When pots fell straight down, bottom sherds were much more fragmented than rim sherds, especially when the pot was filled with liquids (cf. Fig. 13f). Last, the experiment with the stool falling on top of part of the pot, caused a size differentiation between the part of the vessel that was crushed and the part that was not (cf. Fig. 12h). After breaking, the vessels sherds were selected for performing some exploratory experiments with post-depositional and (post-)excavation processes that could potentially modify the experimental use-wear traces.

Post-depositional modifications

The premise of inferring use from microwear research relies on the condition that the traces seen on the object were caused by the use of the artefact. However, in the archaeological record there is often a large time frame after the deposition of

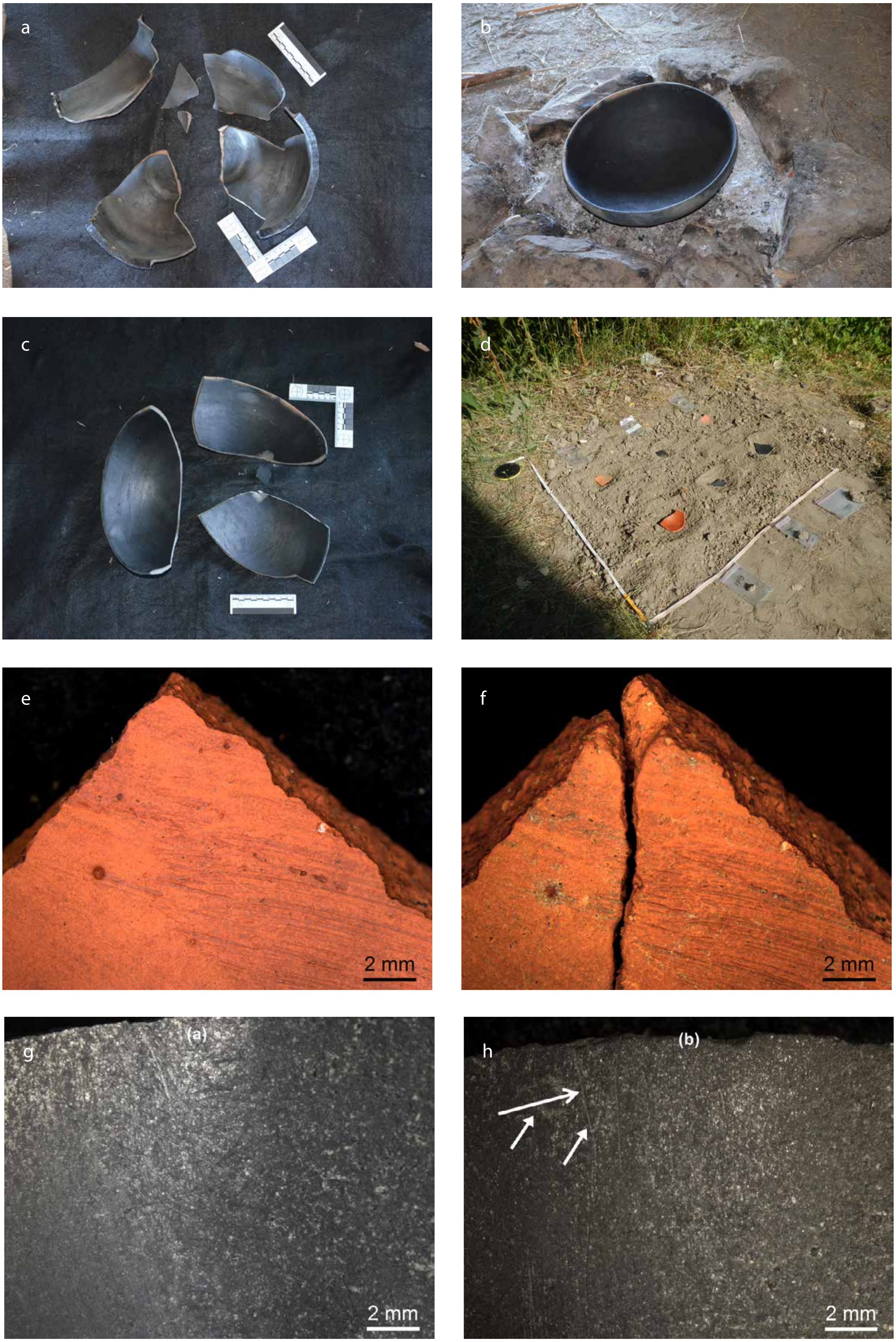
a
b
c
d
e
2 mm
f
2 mm
g
(a)
2 mm
h
(b)
2 mm

Figure 14 (opposite page): (a) Fragmented experimental vessel 3771 that was carried around and fell onto the dried clay floor of the house. (b) Vessel 3550 is placed by the fire for the re-enacting of the accidental breaking. (c) Vessel 3550 broke in three large sherds. (d) The sherds buried at a depth of 3 cm. (e-f) Sherd 3769.4, buried 3 cm below surface, showing a fresh break (taken at 7.5x original magnification (OM)). (e) Before trampling. (f) After trampling. (g) Sherd 3592.1, buried 3 cm below surface, before trampling, showing fine scratches (7.5x OM). (h) Sherd 3592.1, buried 3 cm below surface, after trampling, showing newly developed scratches (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

the artefact, during which a large variety of processes can affect the artefact and cause existing traces of wear to be modified or even to disappear (e. g. Skibo et al. 1997; Skibo/Schiffer 1987). It is therefore important to study the effects of these post-depositional processes as well, in order to differentiate them from use-wear. We decided to do a very preliminary study to examine the effects of burying and trampling, two processes that are likely to have occurred to most of the sherds we encounter in archaeological contexts. It should be stressed, however, that a systematic exploration of the effects of post-depositional processes on sherds was impossible within the scope of the BEFIM project.

Twelve sherds from pots broken during the breaking experiment were selected (Feisrami 2018; Spithoven 2018). Prior to burial, the sherds were scanned for the presence of traces of manufacture and use with a stereoscope at a magnification of 0.75x. Traces observed were subsequently analyzed at magnifications of 3.2x and 6.0x. In order to test whether depth of burying has any influence on the effects of burial and trampling, it was decided to bury half of the sherds close to the surface, 3 cm deep, and the other half relatively deep at 40 cm. The sherds were buried with their inside up in a square of 1 m x 1.5 m of sandy clay. The position of the sherds was drawn and photographed (Fig. 14d).

The trampling experiment was performed by two experimenters, weighing 48 kg and 70 kg, who took 86 and 94 steps per minute respectively. Steps per minute was calculated by counting the number of steps for a duration of 3 min. This was done four times at different moments during the trampling experiment. The experimenters wore soft soled moccasins. During the first 22 min the experimenters walked in circles, but because this made them nauseous, a zig-zag and eight-shaped track was adopted for the remaining duration of the experiment. The sherds at 3 cm depth were trampled for 2.5 h, while the sherds at 40 cm depth were trampled for 5 h in total.

During the experiment several sherds broke. Three sherds (two fragments of 3350.6 and one of 3769.4) were moved to such an extent that they got outside the grid. This occurred after 1 h for one of the sherds and after 1.5 h for the other two sherds. These three sherds were placed back into the grid to ensure that all sherds were trampled sufficiently to be compatible in terms of wear development. After 2.5 h of trampling the position of the sherds buried at 3 cm was documented and they were removed. The sherds buried at 40 cm depth were trampled for another 2.5 h before extraction. Their position was drawn and photographed as well. The sherds buried 3 cm deep were displaced substantially, whereas the sherds buried at 40 cm stayed in the same locations. None of the sherds buried at 40 cm deep broke, while four out of six upper sherds broke during the experiment. After trampling, the sherds and the use-wear on them were investigated with a stereomicroscope at low magnifications. The results, however, vary between sherds, with no pattern discernible, and therefore no final conclusions can be drawn. We plan to do more research into this matter in the future, using the sherds we still have available after the breaking experiments. Some general remarks can already be made at this stage of research. Most post-depositional modifications developed on the sherds buried 3 cm deep. Most prominent is the newly created wear on the sherds. The sherds are often broken, and their edges show tiny edge removals (nibbling) and slight rounding (Fig. 14e.f). New, deep scratches appeared on the surface (Fig. 14g.h), and there is a

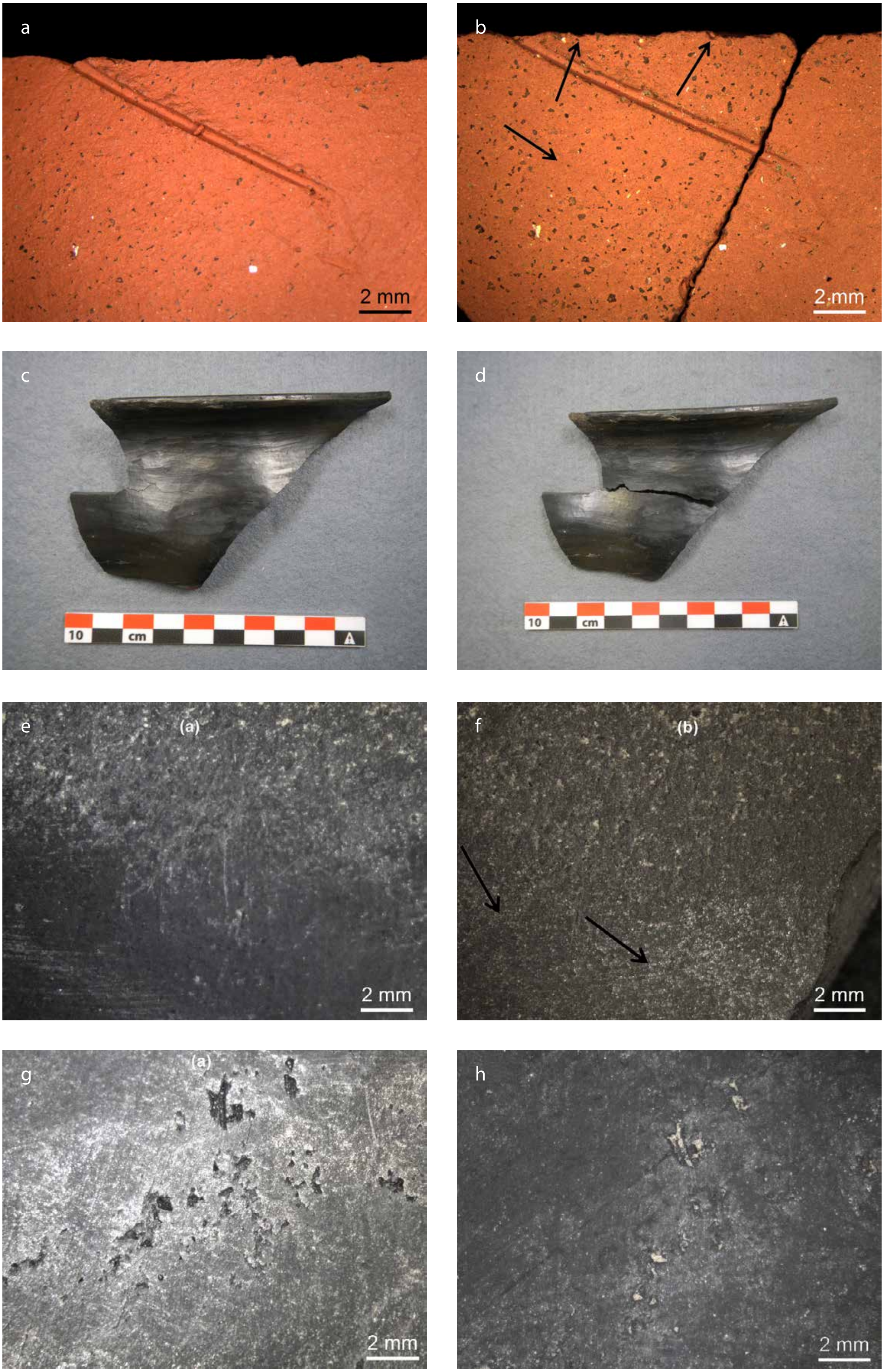
a
2 mm
b
2 mm
c
10
cm
d
10
cm
e
(a)
2 mm
f
(b)
2 mm
g
(a)
2 mm
h
2 mm

Figure 15 (opposite page): (a) Sherd 3769.3, buried 3 cm below the surface, before trampling, showing some temper (taken at 7.5x original magnification (OM)). (b) Idem after trampling, with some of the clay skin worn away, exposing more temper particles and nibbling of the edge (7.5x OM). (c) Sherd 3771.3 before trampling, showing the luster from polishing. (d) Idem after trampling, showing the luster to be matter, and the break caused by the pressure. (e-h) Changes in the use-wear seen on sherd 3592.1, shoved on a clay surface. (e-f) Levelling and smoothing of the wear traces present. (e) Before trampling (7.5x OM). (f) After trampling (7.5x OM). (g) Scratches before trampling (7.5x OM). (h) Scratches have disappeared after trampling (7.5x OM). (© Laboratory for Material Culture Studies Leiden University).

general abrasion of the smooth clay skin, exposing the temper (Fig. 15a.b). This also removed the luster from the sherds, and they no longer look fresh, but a little more like archaeological sherds (Fig. 15c.d).

The abrasion and degradation of the surface of course also affect the use-wear present on sherds. In general, it can be stated that the use-wear existing before burying was leveled and smoothened, as is visible e. g. on sherd 3592.1 (Fig. 15e.f). The use-wear became less prominent and slightly less well recognizable, especially where use-wear traces were only lightly developed to begin with. In some cases, scratches disappeared or became otherwise invisible (Fig. 15g.h).

There was an apparent change in the beeswax residues present on sherds from depths of both 3 cm and 40 cm. In general, the amount of residue decreased, even nearly disappearing in some cases. The amount of wax present on the sherds buried at 40 cm depth was reduced, the wax on the sherds buried at 3 cm depth did not only decrease, but sand also got stuck to the wax.

Combining the observed changes in microwear and the breakage of sherds, it seems that the depth of burial has significant influence on the preservation of sherds. Fractures only occurred at shallow depths, and changes in microwear were most severe at shallow depths as well. However, the differences between burial depths are less important for the preservation of beeswax residues. At both levels loss of residue was reported, and there was no clear relation between the degree of loss and the depth. When investigating ancient residues, it seems that archaeologists should be mindful that they are only studying a fragment of the residue that was deposited.

Excavation and post-excavation damage

Although the intention of an excavation is to recover the archaeological record in as complete a fashion as possible, the choice of methods and techniques introduce a certain bias that modifies the archaeological record. To test whether standard modern excavation techniques impact microwear research, a total of six sherds from six pots (experiments 3350, 3352, 3768, 3592, 3771 and 3769) were given to the commercial archaeological firm Archol to be processed as if they were finds from the field (see Fig. 16 for an overview of their workflow).

Archol buried the sherds in a pit in the site of Udenhout, covered the sherds with silty sand and left them for 5.5 h before digging them up by shovel and hand. The finds were put in plastic bags along with a find tag and then placed in a wheelbarrow in a plastic tub together with other finds, including prehistoric ceramics and a brick. The wheelbarrow was then brought to a container and the contents were deposited in a crate, into which more finds were added the following days. This crate full of various finds was transported to Leiden by car two days later. The next day the sherds were washed with cold water and a toothbrush. They were subsequently left to dry in plastic baskets put on a metal rack. A week later the finds were sorted, counted, weighed and put into a clean find bag with a tag. The sherds were put in a box, which was brought to the Laboratory for Material Culture Studies where they were analyzed. The analysis showed that there were slight changes in microwear on the sherds. The silvery surface treatment of experiment 3592 had dulled a little

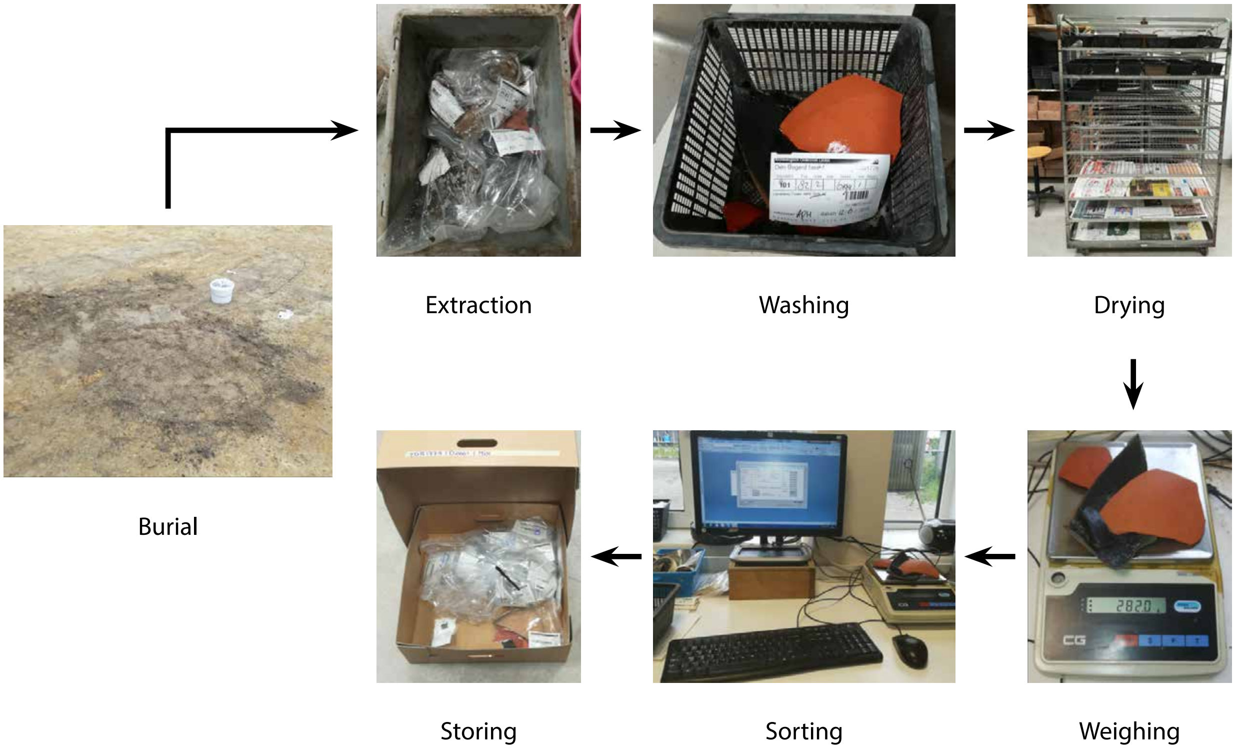

Figure 16: The workflow of the experimental sherds given to the contract archaeology company Archol for processing as archaeological sherds in order to create excavation and post-excavation damage (© Archol, Leiden).

and the waxy surface of experiment 3769 appeared thinner (Fig. 17a.b). The sherds showed some extra scratches, probably from contact with other sherds. The traces identified as use-related prior to the excavation had not changed significantly and were all still clearly visible. The contact with other sherds had also caused a transfer of residues between sherds. In one case (sherd 3592), a beeswax-like residue was found on a sherd that had no beeswax previously (Fig. 17c). The beeswax probably rubbed off sherd 3769. On sherd 3769 a black residue was visible in the scratches in the wax surface. These probably originate from other sherds in the sample that had a predominantly black texture.

There are no apparent changes that can be the result of cleaning with a toothbrush. This, however, does not indicate that cleaning with a toothbrush does not leave any traces of wear. The Archol archaeologists handling the sherds said that the sherds felt harder and shinier than the sherds they normally recovered from Iron Age excavations. As these experimental sherds were only in the soil for a couple of hours, they may not have been as vulnerable to the later processing techniques as archaeological ceramics are.

However, there were clear changes on the edges of the sherds. The fractured edges were significantly abraded, more irregular and occasionally rounded (Fig. 17d.e). The degree of abrasion varied between sherds and within sherds as well, although all sherds exhibited edge abrasion. The experimental setup does not allow for quantification of the level of abrasion. The beeswax surface treatment disappeared from the edge of sherd 3769 (Fig. 17f).

The excavation techniques commonly used nowadays seem to have little effect on microwear, but the edges of sherds and residues are affected. The abrasion of edges is undesirable for the preservation of the artefacts, but does not significantly affect down-the-line analysis. However, the transfer of residues is potentially problematic, as residues are often used to infer the use of an artefact. This highlights the importance of minimizing contact between artefacts during excavation.

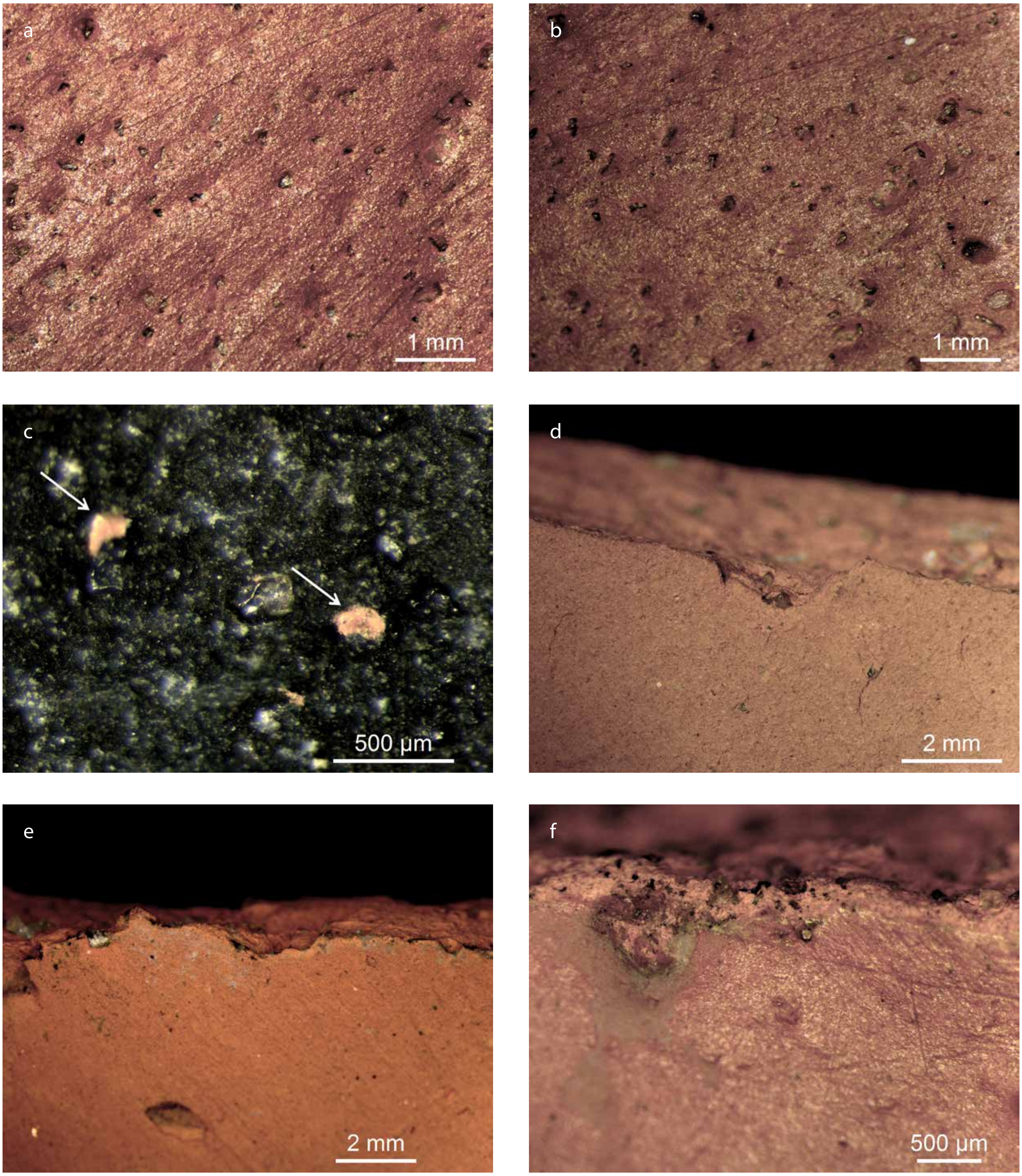

Figure 17: (a) The surface of experimental sherd 3769.3 before finds processing by Archol (taken at 20x original magnification (OM)). (b) Idem after finds processing by Archol. The wax layer has thinned, and black inclusions are more obvious after processing (20x OM). (c) Orange residue on a sherd of 3592 observed after find processing by archaeologists. Its waxy appearance suggests it may have rubbed off the sherd from 3769, which was covered in beeswax (60x OM). (d) The edges of experimental sherd 3352.1 before excavation and find processing by Archol (12.5x OM). (e) Idem after excavation and find processing by Archol. The edge has become more abraded, irregular and lightly rounded (10x OM). (f) The wax on the edge of experimental sherd 3769.3 has disappeared during excavation and post-excavation treatment by Archol, probably due to the toothbrush used to clean the sherds (32x OM) (© Laboratory for Material Culture Studies Leiden University).

Conclusions

When asked to partake in the BEFIM project in order to study the function of a selection of Early Celtic pottery vessels from the Heuneburg and Mont Lassois, conducting an experimental program was a first priority. Use-wear or microwear analysis of tools and objects relies on a comparison of experimentally obtained traces of wear and those seen archaeologically. If such traces are similar, we can infer a similar function, so basically this is an analogy. Every functional inference is therefore an interpretation, with a high probability if the traces are matching very closely (cf. van Gijn, this volume). Covering as many variables as possible in our experiments extends our reference collection and therefore our interpretive potential.

However, we were a bit optimistic in thinking this experimental endeavor through. Although we have ample experience with experimental reference collections for other contact materials such as flint, stone or bone, experimenting with pottery vessels is quite a different undertaking. Every experiment requires a ceramic vessel, which needs to be as close as possible in terms of paste, temper and firing temperatures to the archaeological counterparts to be studied. This requires a lot more work than making a series of flint scrapers for hide working experiments. Our expert potter Loe Jacobs made dozens of pots (Jacobs, this volume), but to control for all the possible variables in manufacture in terms of paste, temper, shaping technique, method and temperature of firing and of course morphology of the vessel, was way beyond our means. The central research questions of the BEFIM project also required quite a large number of experiments to be done, in order to address the role of vessels in Celtic consumption patterns. Like with the manufacturing stage, it was impossible to cover all the possible combinations of relevant motions, contents and duration of the use experiment. As a consequence, we were not able to repeat experiments, a definite prerequisite of a scientific experimental program (e. g. Lammers-Keijsers 2005, 23; Mathieu 2002, 8). The present article should therefore be seen as pilot study, intended to explore the inferential limits and possibilities of a microwear analysis of vessels. Much work needs still to be done!

The shortcomings of the present experiments are manifold. Some experiments should probably have been carried out longer or shorter, but we adhered as much as possible to the standard duration of 60 min per experiment (except for the storage experiments), to allow compatibility of this variable. However, this meant that for example an experiment with drinking, did not cause much visible wear as the contact material, our lips, are very soft and do not cause discernable traces very quickly. In contrast, shoving vessels around on a loam floor, created heavily developed wear traces in a short time. Clearly duration of the experiment is as much a factor as the abrasiveness and hardness of the contact material involved. Second, as mentioned above, we could not test the gamut of different technological features such as the kind of temper used or firing temperature, across the same experimental activity. We would then have needed hundreds of vessels at our disposal. The variability in ceramics in terms of materials and manufacturing is much greater than with other raw materials: flint for example can vary in grainsize, which is of influence on the way wear traces develop, but its variability by far does not match the enormous variation possible between ceramic surfaces.

Yet, despite the important limitations of the experiments presented in this article, some things became apparent, and preliminary conclusions can be drawn. First of all it became clear quite quickly that the temper, finish and firing of the pots all influence the development and character of wear traces that result from different activities. The calcite temper chemically reacted with the acidic wine, ultimately dissolving and causing inclusion loss and fine pitting. This seems to be a use-wear feature that can be used to discern vessels that may have contained acidic substances like wine. The preparation of honey wine (mead) also caused tiny pitting and some inclusion loss in the vessel surface (Groat, this volume), suggesting that this pitting may indeed be associated to alcohol.

Some activities related to the preparation of food and beverages, such as stirring, seem to cause considerable damage, although not to the extent that was sometimes seen on the archaeological vessels (van Gijn/Verbaas, this volume; Verbaas/van Gijn-Vix, this volume). The traces encompassed scratches with a predominantly circular directionality and the abrasion and removal of the clay skin of the vessel, thereby exposing, removing and sometimes flattening the temper particles. The size and angularity of the (calcite) temper affected the kind of scratches that resulted from stirring, with more numerous and deeper scratches resulting the larger the temper fragments.

Our experiments with consumption - using ladles, spoons or simply drinking - did not produce clear cut patterns in the resulting wear traces. In general, utensils that came into contact with the rims caused some damage, in the form of abrasion of the rim, scratches, rounding and sometimes, in the case of an iron spoon, "nibbling". Generally, the harder the material the utensil was made from, the more pronounced the traces of wear, but the copper ladle e. g. did not produce discernable traces, yet the wooden one did. Motions related to storing - applying and removing lids or covers - in some cases led to quite characteristic traces on the rim, including perpendicularly oriented striations and abrasion. Traces from stacking pottery on top of each other cannot be clearly distinguished from covering pots with pottery lids. Yet, covering traces on the rims do look different from the traces inflicted by ladles, with the first causing a flattening of the rim.

We also experimented with different ways of cleaning. Some cleaning tools left hardly any traces, others much more substantial ones. In general, the resulting traces, including both striations and abrasion, are located higher on the vessel wall than those from stirring. They also have a less regular directionality than the striations obtained by stirring, the latter displaying a predominantly circular pattern. Stirring traces are also more prominent in the bottom of the vessel, whereas the striations from cleaning are located all over the inner vessel wall, but are more developed on its upper parts. This latter observation may of course be the result of the way we clean today, based on our assumptions and embodied gestures.

Handling the pots caused substantial damage, especially the shoving around of vessels in an attempt to replicate putting them on tables, on the floor, on shelves or into chests. These traces are, of course, situated on the bottom of vessels and are very characteristic. If found on archaeological sherds we interpreted them as a sign of long-term use of the vessel. Pottery must also have "bumped" into each other, especially during storage, or while preparing food and drinks. These traces are quite distinctive, located on the external wall at the widest perimeter of the vessel. If we do not know the place of an archaeological sherd in the vessel profile, it may, however, not always be possible to distinguish such "impact traces" from traces the vessel (or sherds thereof) develop after deposition or during post-excavation procedures. Nevertheless, color differences may suggest whether these traces are recent or not.

In general, it can be said that use-wear analysis on archaeological pottery sherds is definitely possible. On our experimental vessels wear traces did develop and were frequently distinctive enough to make meaningful inferences. That said, there is also a large overlap in traces observed. One of the key traces of wear that we observed is abrasion. Pottery is a relatively soft material and, whereas wear traces on other materials tend to be cumulative, leading to well-developed and interpretable polishes, the pottery surface abrades quickly. Although use-wear polishes have been noted on ceramic sherds used as tools (van Gijn/Hofman 2008; Lopez-Varela et al. 2002; Vieugué 2015), polish on complete vessels seldom occurred, at least in our experiments. Only with prolonged contact between a medium-hard to soft, non-abrasive contact materials and a pottery vessel of sufficient resistance (i. e. fired at relatively high temperatures, with small temper particles) can we expect some polish development to take place. For example, we observed polish from possibly human hands that we associated with handling on some finds from Vix-Mont Lassois (Verbaas/van Gijn-Vix, this volume) and the Heuneburg (van Gijn/Verbaas, this volume). Our experiments showed polish development from contact with a wooden spoon and lid, traces that were also observed archaeologically on Mont Lassois and Heuneburg finds.

This lack of well-developed polishes on ceramic surfaces is in contrast to other materials studied and for which polish is instrumental to infer contact material. We have investigated the possibility of inferring contact material based on the traces of wear on the stone temper particles, using a metallographic microscope with magnifications of 200-300x. We have done so for some stone types like quartzite where you can "jump" from one quartz crystal to the next, "following" as it were the distribution and directionality of the polish. This, however, was impossible with the stone temper in our pottery as the particles were not only too small to properly analyze for traces of wear, they are also frequently "torn out" of the clay surface before even developing any polish. Consequently, as polish rarely develops, we focused on the traces related to surface loss: abrasion, rounding, scratches and pitting, features already mentioned by Skibo and others in their analyses of pottery function (e. g. Fanti et al. 2018, 116; Forte et al. 2018, 127-129; Skibo 2013, 120-155; Skibo 2015, 193-194). It also meant that we relied more on the stereomicroscope than on the metallographic one, which was used, but not as much as we had hoped for.

The combination of these traces forms the basis for the interpretation of wear, based on which we often can infer the motion and in some cases the contact material or contents. To do this, the location of the wear traces on the vessel is very important. When abrasion is present in the lower part of the inner vessel, it is assumed to be the result of stirring or scooping motions, when abrasion is visible on the outer rim, it is probably related to covering, consumption or hanging a spoon from the rim. The final interpretation is, similar to such analysis on other materials, based on a combination of the wear attributes as well as the location and distribution of traces.

There were also some pleasant surprises. A somewhat playful experiment with "accidentally" breaking vessels during household activities gave some unexpected, yet promising insights. One observation was that pots with contents broke into many more sherds than those without. The way of falling also seemed to be of influence, with pots falling straight down producing a very different fragmentation pattern than those which for example broke on the edge of a hearth or which fell off a table or stool in a tilted position. Some of the resulting sherds actually showed strong similarities in terms of their fragmentation patterns to ones observed in the archaeological context. We have to note, however, that these experiments are very preliminary, and we cannot draw any firm conclusions as we used pots of different make and shape which we broke in different ways. We therefore did not control any variables. Nevertheless, the results are promising and call for further, more controlled experimentation.

Arriving at post-depositional traces of wear, only a few experiments were possible within the time frame of the project. The burying and subsequent trampling of sherds caused substantial modification of the sherd edges, resulting in not only their fragmentation but also in rounding and nibbling of their edges. The sample was too small to discern the effect of trampling on use-wear traces. This is something we would like to explore further in the future. Of particular importance are the results of the excavation and post-excavation process a sample of sherds was subjected to. Although the excavation itself did not seem to have caused damage (no trowel or shovel marks observed), the subsequent transport, handling and cleaning did. As has been argued before, the obsession of archaeologists with cleaning finds can potentially lead to damage on sherds (van Gijn et al. in BEFIM 1, 91).

In conclusion, we would contend that the reconstruction of vessel biographies is a little more complicated than reconstructing the life history of a flint or bone tool. First of all, and in order to do so, we need complete vessel profiles, as the distribution of wear traces from different activities is very much related to specific zones of the vessel. A wall sherd from the middle of the vessel profile is usually less informative than a rim or bottom sherd. Moreover, it has become very clear that technological features have an impact on the way use-wear traces develop. Especially temper and hardness of the ceramic surface are of influence. This would theoretically mean that every new assemblage would need a completely new experimental program. To some extent, we believe this to be the case but, nevertheless, our experiments have shown that certain aspects of vessel biographies can most likely be reconstructed as they leave distinct traces of wear largely independent of the technological features of the pot such as paste, temper and firing circumstances.

Acknowledgments

These experiments could not have been possible without the enthusiastic participation of a number of MSc students, who wrote their MSc thesis or internship reports on this topic and all of whom are actually co-authors of this article (Dekker, de Koning, Feisrami, Spithoven, Timmer, Vernon). In addition, we would like to thank Geong Kim and Nick Groat for being part of this collective effort. Marleen van Zon of Archol was so kind as to subject a sample of our sherds to the regular excavation and post-excavation treatment of their archaeological company. Eric Mulder, as always, has been indispensable as our laboratory assistant, drawing and photographing finds and keeping track of experiment numbers and documentation. The BEFIM team came together one last time at the Vlaardingencultuur huis, near Rotterdam, to smash some pots as a last farewell ritual of this wonderful project. Last, but not least, we thank Loe Jacobs for making all the vessels that we used for our experiments, several of which, unfortunately, we had to break.

Bibliography

De Koning 2018: N. de Koning, Wear and tear in Early Iron Age Europe. An experimental approach to use-wear analysis on selected assemblages of household ware pottery from the settlements Mont Lassoix and the Heuneburg. Unpublished MSc Thesis, Faculty of Archaeology, Leiden University (Leiden 2018).

Fanti et al. 2018: L. Fanti/L. Drieu/A. Mazuy/T. Blasco/C. Lugliè/M. Régert, The role of pottery in Middle Neolithic societies of western Mediterranean (Sardinia, Italy, 4500-4000 cal BC) revealed through an integrated morphometric, use-wear, biomolecular and isotopic approach. Journal Arch. Scien. 93, 2018, 110-128.

Feisrami 2018: T. Feisrami, Burying and trampling ceramic sherds. An experimental study into the changes of identifiable wear. Internal Report, Faculty of Archaeology, Leiden University (Leiden 2018).

Forte et al. 2018: V. Forte/S. Nunziante Cesaro/L. Medeghini, Cooking traces on Copper Age pottery from central Italy: An integrated approach comprising use wear analysis, spectroscopic analysis and experimental archaeology. Journal Arch. Scien. Report 18, 2018, 121-138.

Groat 2017: N. Groat, Abrasion and Inebriation: Investigating the application of ceramic use-wear analysis for exploring alcohol production at Iron Age Heuneburg, Germany. Unpublished MSc Thesis, Faculty of Archaeology, Leiden University (Leiden 2017).

Keeley 1980: L. H. Keeley, Experimental determination of stone tool uses (Chicago 1980).

Lammers-Keijsers 2005: Y. Lammers-Keijsers, Scientific experiments: A possibility? Processing a general cyclical script for experiments in archaeology. Euro/Rea 2, 2005, 18-24.

Lopez Varela et al. 2002: S. L. López Varela/A. L. van Gijn/L. F. H. C. Jacobs, De-mystifying pottery production in the Maya Lowlands: Detection of traces of use-wear on pottery sherds through microscopic analysis and experimental replication. Journal Arch. Scien. 29, 2002, 1133-1147.

Mathieu 2002: J. R. Mathieu (ed.), Experimental archaeology. Replicating past objects, behaviors and processes. BAR Internat. Ser. 1035 (Oxford 2002).

Mötsch et al. in BEFIM 1: A. Mötsch/M. Rageot/B. Schorer, Organic residues in pottery vessels from selected archaeological features of the Heuneburg. First results of a case study. In: Stockhammer/Fries-Knoblach 2019a, 61-76.

Mötsch et al. in BEFIM 2: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/ S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber /R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen“. Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/P. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/Th. Hoppe/ Ph. W. Stockhammer/C. Spiteri, The dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Saurel in BEFIM 1: M. Saurel, Grandes jarres et fosses allongées. La production de bière à l’âge du Fer en Champagne (France), entre le VII^{e} et le V^{e} siècle av. notre ère. In: Stockhammer/Fries-Knoblach 2019a, 135-152.

Schorer et al. in BEFIM 1: B. Schorer/M. Rageot/A. Mötsch, Vessels from old excavations at the Heuneburg. New evidence for their functional interpretation. In: Stockhammer/Fries-Knoblach 2019a, 47-60.

Skibo 2013: J. M. Skibo, Understanding Pottery Function (New York 2013).

Skibo 2015: J. M. Skibo, Pottery use-alteration analysis in use-wear and residue analysis. In: J. M. Marreiros/J. F. Gibaja Bao/N. Ferreira Bicho (eds), Use-wear and Residue Analysis in Archaeology (New York 2015) 189-198.

Skibo/Schiffer 1987: J. M. Skibo/M. B. Schiffer, The effects of water on processes of ceramic abrasion. Journal Arch. Scien. 14, 1987, 83-96.

Spithoven 2018: M. Spithoven, Burying and trampling experimental Heuneburg ceramic sherds: An experimental study into the changes of identifiable wear. Internal Report, Faculty of Archaeology, Leiden University (Leiden 2018).

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Timmer 2017: T. Timmer, Ceramic experiments related to the BEFIM project. Internal report, Faculty of Archaeology, Leiden University (Leiden 2017).

Van Gijn 1990: A. L. van Gijn, The wear and tear of flint. Principles of functional analysis applied to Dutch Neolithic assemblages. Analecta Praehist. Leidensia 22 (Leiden 1990).

Van Gijn 2006: A. L. van Gijn, Implements of bone and antler: A Mesolithic tradition continued. In: L. P. Louwe Kooijmans/P. F. B. Jongste (eds), Schipluiden. A Neolithic settlement on the Dutch North Sea coast c. 3500 cal BC. Analecta Praehist. Leidensia 37/38 (Leiden 2006) 207-224.

Van Gijn/Hofman 2008: A. L. van Gijn/C. L. Hofman, Were they used as tools? An exploratory functional study of abraded potsherds from two pre-colonial sites on the island of Guadeloupe, northern Lesser Antilles. Caribbean Journal Scien. 44/1, 2008, 21-35.

Van Gijn et al. in BEFIM 1: A. van Gijn/L. Jacobs/N. Groat/N. de Koning/D. Braekmans/A. Verbaas, Studying vessel biographies from the Heuneburg: An experimental approach. In: Stockhammer/Fries-Knoblach 2019a, 77-99.

Vaughan 1985: P. C. Vaughan, Use-wear analysis of flaked stone tools (Tucson 1985).

Vernon 2018: F. Vernon, Microwear analysis of replica Iron Age ceramics for BEFIM. Internal report, Faculty of Archaeology, Leiden University (Leiden 2018).

Vieugué 2015: J. Vieugué, What were the recycled potsherds used for? Use-wear analysis of Early Neolithic ceramic tools from Bulgaria (6100-5600 cal. BC). Journal Arch. Scien. 58, 2015, 89-102.

Author information

Annelou van Gijn, Annemieke Verbaas, Jan Dekker, Terrilya Feisrami, Nicole de Koning, Merel Spithoven, Tessa Timmer and Fiona Vernon
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.l.van.gijn@arch.leidenuniv.nl
a.verbaas@arch.leidenuniv.nl
jan3dekker@gmail.com
terrylia.feisrami.abdurachmat@umail.leidenuniv.nl
nicoledekoning@outlook.com
merel.spithoven@gmail.com
t.n.timmer@umail.leidenuniv.nl
fkvernon@gmail.com

Ceramic permeability experiments

Exploring the role of surface treatment

Annemieke Verbaas & Annelou van Gijn

Summary

It is often assumed that the various ways of surface finish of ceramic vessels, like burnishing, diminish their permeability. In this paper we set up a simple exploratory experiment to test this for a variety of surface treatments. We also included three vessels which were sealed with milk, a milk/honey mixture and beeswax respectively. It turned out that all of the vessels lost their liquid contents rather quickly. Only the vessel sealed with beeswax scored well.

Keywords: *permeability, vessel function, experimental archaeology*

Zusammenfassung

Es wird oft behauptet, dass die verschiedenen Arten der Oberflächenbehandlung von Keramik wie Politur ihre Durchlässigkeit verringerten. Für diesen Aufsatz wurde ein einfaches Forschungsexperiment durchgeführt, mit dem diese Vermutung für unterschiedliche Arten von Oberflächenbehandlung getestet werden konnte. Es wurden auch drei Gefäße untersucht, die mit Milch, einer Milch-Honig-Mischung und Bienenwachs versiegelt waren. Es zeigte sich, dass alle Gefäße ihren Inhalt relativ rasch verloren und nur das Gefäß mit der Bienenwachsversiegelung gut abschnitt.

Schlüsselwörter: *Durchlässigkeit, Gefäßfunktion, experimentelle Archäologie*

Introduction

It is a generally known fact that unglazed pottery is always more or less permeable. It will soak up liquids and "sweat" them out again. Even though this increases the insulation properties of the pot, the adverse effect is that contents are lost. "Permeability refers to the penetration of a fluid (water, air, gases, smoke) from the surface of a vessel into the wall through open pores" (Rice 2015, 316). Permeability is closely related to porosity, namely by the size and frequency of open pores in the fabric. It is often postulated that different surface finishes like burnishing can diminish this permeability (Rice 2015, 317). Besides surface finishes that can be applied during the production of the pot, there are also different possibilities which are known (or believed) to seal the vessel after production, such as the application of

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 109-119.

beeswax, pine resin or milk (Messing 1957; Mötsch et al. in BEFIM 1 and BEFIM 2; Rageot et al. 2019a; 2019b; Auler 2020). However, the relationship between surface finish and permeability has, as far as we know, never been systematically tested[1]. This paper discusses the results of a first attempt at a systematic experiment to investigate the effect of different types of surface finish on permeability.

Experiment design

Loe Jacobs made 15 ceramic vessels (Jacobs, this volume) with the same fabric, shape and capacity (Fig. 1). For all pots either the inside or outside surface was left smoothed, while the other surface had a different surface finish. As a reference two pots had both a smoothed in- and outside surface. An overview of surface finishes can be found in Tab. 1-3 (see below). Due to time constraints we could only carry out these experiments with one set of pots. Ideally, we should of course have used multiple pots with the same combination of surface finishes. The following therefore should be regarded as a pilot project.

As we were aiming to use a standardized vessel shape suitable for the research question of this experiment, we did not exactly replicate one of the Heuneburg or Mont Lassois vessels. Instead we designed, together with Loe Jacobs, a simple, open-shaped pot that could contain approximately 1 l of water (Fig. 1). Jacobs used the so-called "paste 2", tempered with 20 to 25 % of a mixture of mainly quartz grains, some feldspar, some basalt and some muscovite ≤ 500 µm (0.5 mm) in size (Jacobs, this volume and pers. comm.). All pots were hand-made using a coiling technique and were fired in the same way (except for the two pots that were (partly) fired under reducing circumstances). More information on shaping, surface treatment and firing can be found in Jacobs (this volume).

For the secondary sealing beeswax, milk and a mixture of milk and honey were used[2]. To apply these substances the pot was heated to 100° C in a conventional oven. The sealant was molten in the case of the beeswax or heated in the case of the milk and the milk/honey mixture, and subsequently poured into the pot. The sealant was swirled around the pot so that the entire surface was covered by the liquid. This was done until the pot was cold enough to hold without pot holders. The vessel was then rested upside down so that excessive sealant could drip out. In total three pots were sealed (Tab. 1-3 below).

When all pots were finished, they were placed in the same, more or less stable environment[3]. They were put on plastic strips so that their bottoms were not fully resting on a flat surface allowing evaporation over their entire surface (Fig. 2). To ensure that all loss of contents was due to evaporation through the wall or the open top surface of the pots, we first made sure that all vessels were saturated before we started the experiment. We also wanted to measure the amount of water the different pots could soak up. We therefore first weighed the vessels when empty and then filled them with 1 l of water. They were subsequently left to sit for 24 h to saturate and then emptied and weighed to measure how much water had been soaked up by the vessel walls.

The vessels were then prepared for the experiment, filled with 1 l of water and weighed in order to measure exactly how much water had been added, and the water

---

[1] After the experiments were finished, an experiment with the sealing of amphoras with different sealants was published (Auler 2020).

[2] A pure, unrefined beeswax and honey were used. The milk was a full fat, fresh raw milk.

[3] The pots were placed in a small laboratory space with central heating and an air refreshing system in place. During office hours the room is heated to approximately 22° C, outside office hours the heating is switched off. Humidity of the air was not measured.

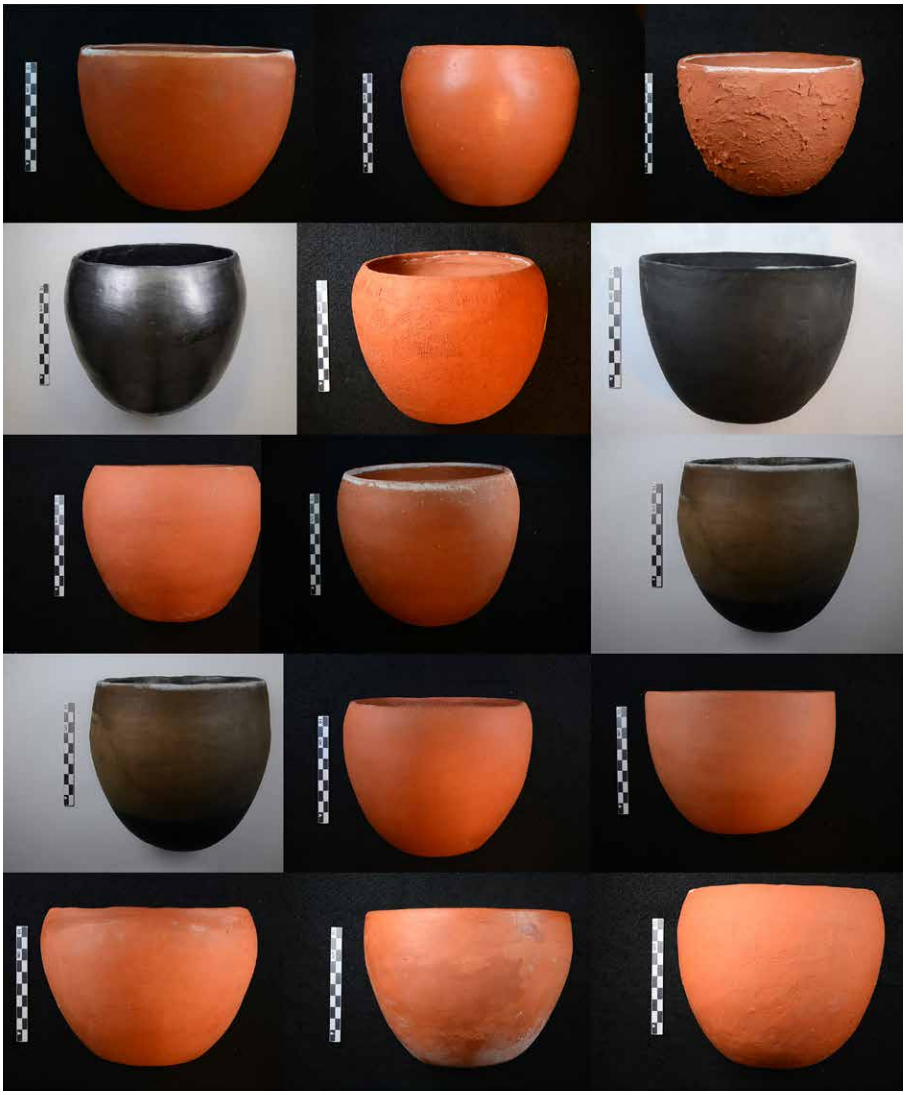

Figure 1: Overview of the pots used in the experiments. Top left is no. 1, bottom right is no. 15, pots are numbered from left to right (see Tab. 3 for an overview of surface finishing per vessel (© Laboratory for Material Culture Studies Leiden University).

Figure 2: The pots in the experimental set-up (© Laboratory for Material Culture Studies Leiden University).

Inside finish	**Outside finish**	**Extra comments**	**24**	**48**	**120**	**144**	**168**	**192**	**288**
Beeswax	smooth		2 %	3 %	10 %	11 %	13 %	15 %	22 %
Burnished	smooth		6 %	11 %	33 %	39 %	44 %	50 %	76 %
Smooth	scraped		6 %	11 %	34 %	39 %	45 %	52 %	80 %
Graphitized	smooth	reduced	6 %	12 %	34 %		44 %	50 %	75 %
Smooth	graphitized		6 %	12 %	36 %	41 %	47 %	54 %	84 %
Smooth	smooth		6 %	12 %	36 %	42 %	48 %	55 %	86 %
Milk/honey	smooth		6 %	12 %	34 %	39 %	44 %	50 %	76 %
Smooth	polished		6 %	13 %	38 %	44 %	50 %	57 %	83 %
Milk	smooth		7 %	13 %	37 %	43 %	49 %	56 %	86 %
Graphitized	smooth	inside reduced, outside neutral	7 %	14 %	42 %	48 %	55 %	63 %	98 %
Polished	smooth		7 %	14 %	41 %	47 %	54 %	62 %	94 %
Smooth	smooth	reduced	7 %	14 %	43 %	49 %	56 %	64 %	97 %
Smooth	slap and pat		7 %	15 %	43 %	50 %	56 %	64 %	97 %
Scraping	smooth		8 %	15 %	43 %	50 %	56 %	64 %	92 %
Smooth	smooth		9 %	17 %	56 %	64 %	71 %	80 %	108 %

Table 1: Percentages of water loss per vessel per time interval (hours) of experiment series 1.

level was documented from the top of the pot. After these measurements no more water was added, and the vessels were left in place uncovered. At more or less regular intervals[4] (see Tab. 1 and 2 below for details) we weighed the pots and measured the water level to see how much water had evaporated. We continued this experiment until most pots were empty. We then left the pots to dry for a week and measured the weight of the empty pots to see whether there was a change in their weight[5].

The entire experiment was repeated, and we added a glass measuring cup with a content of 1 l of water to see how much water evaporated from the water surface, as glass is considered to be impermeable. The top surface of the glass jar was approximately half the size of the one of the ceramic vessels.

Discussion on control of variables and experiment design

It is custom with archaeological experiments to control all variables that influence the outcome of the experiment (Outram 2008). This, however, is not always possible, and not all variables need to be controlled to answer a particular research question. Two important variables that we did not control or measure are the temperature and humidity of the room the experiment took place in. We carefully considered this, but as we were looking into the relative porosity of the vessels compared to each other and not the absolute porosity of the vessels, we decided that controlling or measuring these variables was unnecessary. As long as all pots are continuously in the same environment, we are measuring their relative porosity. A second point of discussion was whether we were going to cover the pots or not. To measure the absolute porosity of the pottery this would of course be necessary, as one would want to exclude evaporation through the water surface. We actually considered sealing the pots, but we could not come up with a sealing option that would fully seal the top of the pot, could easily be removed and replaced for measurements and, at the same time, did not cover the top part of the pot wall. We therefore decided to leave the pots uncovered. The third point of debate was how to carefully measure the loss of contents of the pot. In the end we decided on both weighing the vessel with contents

---

[4] We did not measure e. g. during weekends, therefore the intervals were not fully regular.

[5] This was only done for experiment series 1.

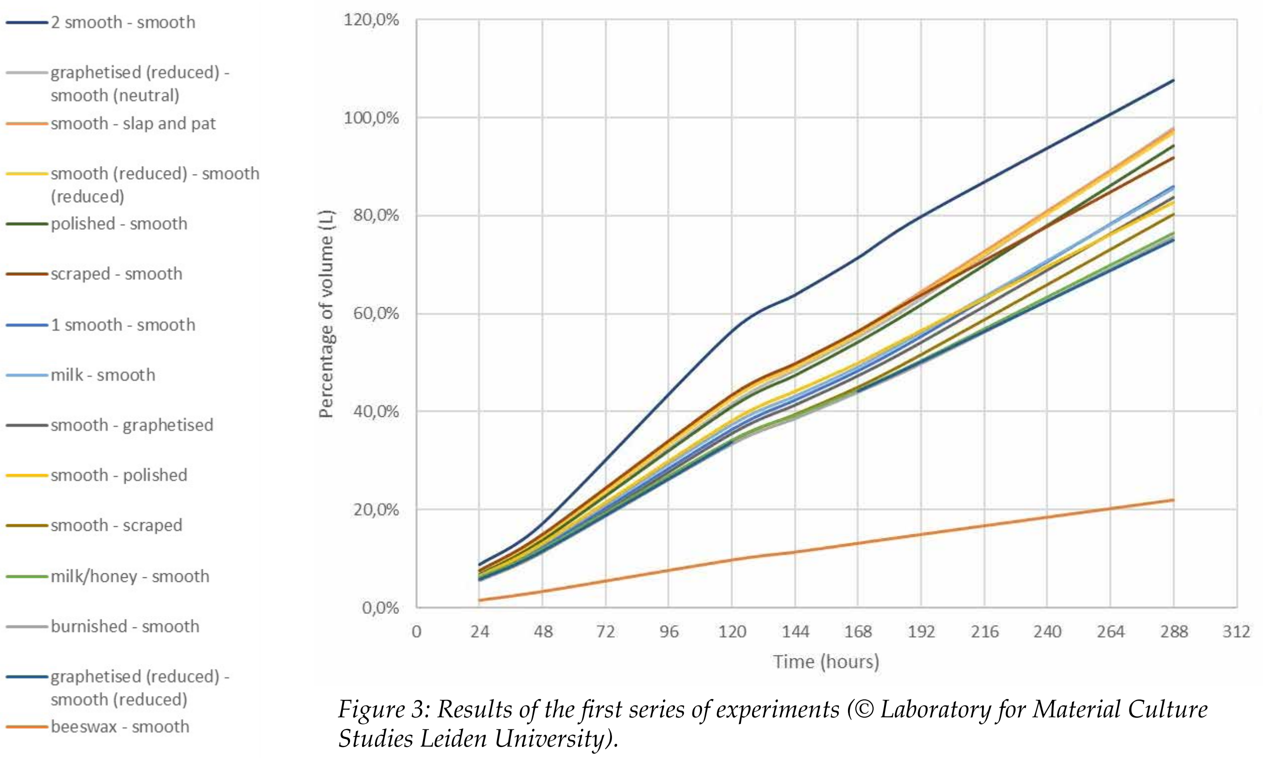

Figure 3: Results of the first series of experiments (© Laboratory for Material Culture Studies Leiden University).

and also documenting the water level. The measurements of the water level were of course much less accurate than weighing, but as this procedure was not very time consuming, we decided to do so anyway. However, in the end we did not use the measurements of the water level in our analysis.

Results

The complete results of both experiments can be found in Appendix I (see end of paper). The results per experimental series are displayed in Tab. 1 with Fig. 3 and Tab. 2 with Fig. 4 respectively. In the tables the percentage of water loss (from 1 l) is calculated for every vessel.

The results are placed in rising sequence of water loss with the vessels sealed with beeswax losing the least water and thus being the least permeable. It is also clear that the two series of experiments do not fully compare. While for both experimental series the pot sealed with beeswax and the burnished/smoothed pots were least permeable, the permeability of the other vessels varies between the two experiments. There is, however, a large gap visible between the vessel sealed with beeswax (and the glass beaker) and all the other pots. Other surface finishes only seem to have a minor impact on the permeability of pots.

Some of the percentages in Tab. 1 and 2 are above 100 %. This can be explained by the fact that the vessels were saturated with water before the measurements of water evaporation began. When all water from the pot had disappeared, the water inside the ceramic fabric also evaporated. After the first series of experiment we also weighed the pots after they were completely dry (Tab. 3). We saw that all pots had gained weight (except for the pot sealed with beeswax). This weight gain was probably due to minerals from the water being left behind in the ceramic fabric. This can possibly also partly explain the difference in results between the first and second series of experiments as these minerals may help to seal the fabric. If we compare the vessel sealed with beeswax with the glass jar, we see that the two compare very well,

Inside finish	Outside finish	Extra comments	24	120	144	168	192	264	278	336
Glass jar	glass jar		1 %	5 %	6 %	7 %	8 %	12 %	13 %	16 %
Beeswax	smooth		2 %	8 %	10 %	12 %	14 %	20 %	22 %	26 %
Burnished	smooth		4 %	17 %	21 %	25 %	28 %	41 %	45 %	53 %
Smooth	scraped		5 %	22 %	26 %	31 %	34 %	51 %	56 %	65 %
Graphitized	smooth	reduced	5 %	24 %	29 %	34 %	39 %	58 %	64 %	74 %
Smooth	graphitized		5 %	24 %	31 %	36 %	41 %	62 %	70 %	83 %
Smooth	smooth		5 %	25 %	32 %	37 %	42 %	64 %	71 %	84 %
Milk/honey	smooth		5 %	25 %	30 %	35 %	39 %	58 %	64 %	73 %
Smooth	polished		5 %	25 %	32 %	37 %	42 %	61 %	69 %	80 %
Milk	smooth		6 %	26 %	33 %	38 %	44 %	65 %	73 %	86 %
Graphitized	smooth	inside reduced, outside neutral	6 %	28 %	36 %	42 %	48 %	72 %	82 %	96 %
Polished	smooth		6 %	29 %	36 %	42 %	48 %	72 %	80 %	93 %
Smooth	smooth	reduced	6 %	30 %	38 %	44 %	50 %	76 %	86 %	100 %
Smooth	slap and pat		7 %	31 %	38 %	44 %	50 %	76 %	85 %	101 %
Scraping	smooth		7 %	32 %	41 %	48 %	54 %	80 %	90 %	105 %
Smooth	smooth		7 %	33 %	42 %	49 %	56 %	85 %	96 %	107 %

Table 2: Percentages of water loss per pot per time interval (hours) of experiment series 2.

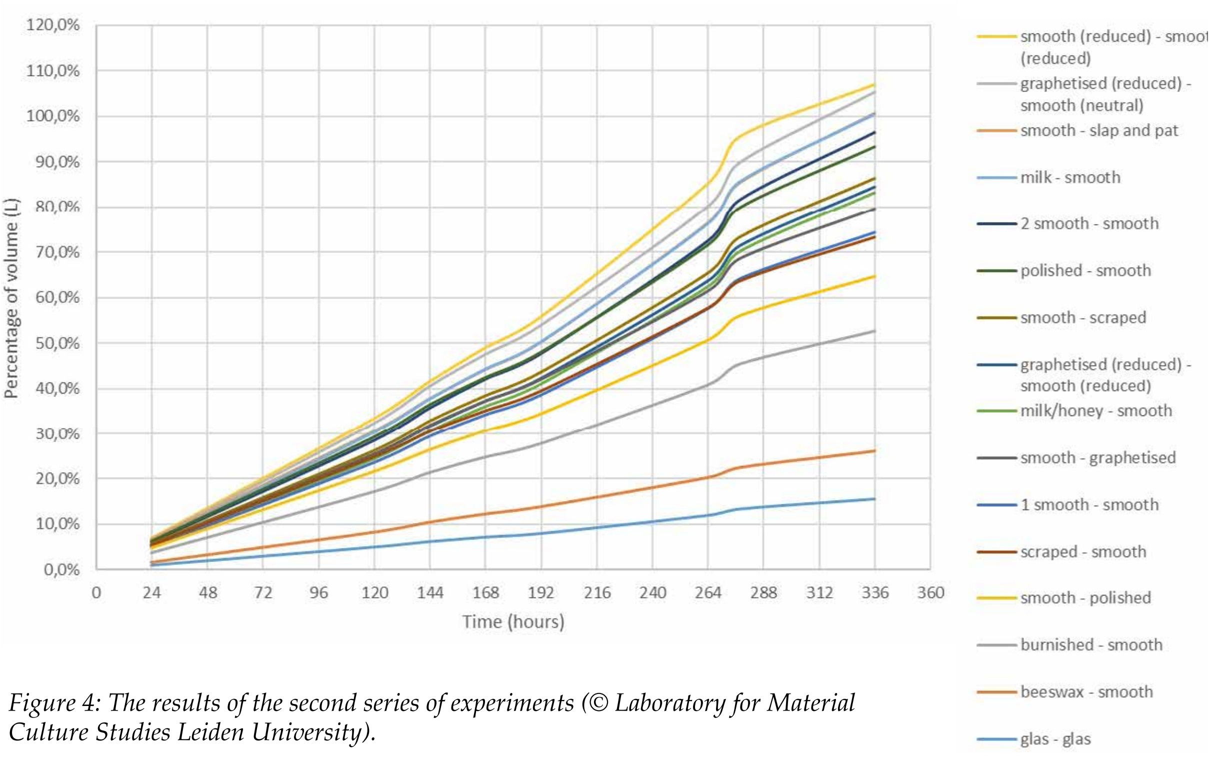

Figure 4: The results of the second series of experiments (© Laboratory for Material Culture Studies Leiden University).

Table 3: Weight of the vessels before and after experiment series 1.

No.	Inside finish	Outside finish	Weight before experiment (g)	Weight after experiment (g)	Weight gain (g)
1	Smooth	smooth	634	636	3
2	Smooth	polished	718	722	5
3	Smooth	slap and pat	628	630	2
4	Smooth	graphitized	725	728	3
5	Smooth	scraped	662	666	4
6	Smooth (reduced)	smooth (reduced)	595	596	1
7	Burnished	smooth	691	696	5
8	Polished	smooth	653	656	3
9	Graphitized (reduced)	smooth (neutral)	709	712	3
10	Graphitized (reduced)	smooth (reduced)	506	508	2
11	Scraping	smooth	634	638	4
12	Beeswax	smooth	502	502	0
13	Milk	smooth	627	628	2
14	Milk/honey	smooth	568	570	2
15	Smooth	smooth	693	696	3

especially if one takes the smaller top opening of the glass jar into account (which gives a smaller water surface to evaporate from). This shows that beeswax truly seals the pot.

Points of improvement for this experiment

The experiment was executed with only one vessel for every surface finish (in-/outside). For a better overview at least five pots per combination should be used. It is very possible that vessels contain flaws like hairline fractures, accidentally larger pores or pockets of air that influence permeability. By using several pots of the same combination of surface finish, the effect of these invisible but influential features will equal out between the consecutive experiments.

The experiment should also be repeated more than once, as was done here. As the vessels probably absorb minerals from the fluids placed inside, this may also affect permeability. It is of course possible to use demineralized water for the experiments, which is something we should probably have done but did not think of initially. It may also be informative to know whether repeated use will help to seal the pot. To test this, it would be better to run a longer sequence of experiments. There are of course many more secondary surface treatments possible than were used here. We can also safely assume that other fluids than just water were present in the vessels. Some may have decreased the permeability of the vessel like milk or cereal based products. Traces of such substances have in fact been found in many of the vessels from the Heuneburg and Mont Lassois (Rageot et al. 2019a; 2019b). For this experiment we decided to limit ourselves to these three secondary sealants, and we applied them only once. However, repeated application of e. g. milk may increase the sealing properties, and this should be tested further. Nevertheless, our experiments form a starting point for more extensive experiments in this field in the future.

Conclusion

The main conclusion for this experiment is that the different surface finishes hardly seem to affect the permeability of a pot. The only exception was the vessel sealed with beeswax, which proved far less permeable. Even if there were some minor differences in permeability between the various surface finishes, the interpretation of this observation is complicated by the fact that the results also differ between the two series of experiments conducted. This would suggest that there are more variables at play which were not controlled in this experiment, but caused permeability variations. This needs to be tested in a set-up where more pots with the same surface finish are used. If the absolute porosity of the pots is investigated, the temperature and the humidity of the laboratory needs to be controlled.

Despite the limitations of the present experiment, we would tentatively postulate that the application of different surface finishes may well have had another (or additional) reason than reducing the permeability of a vessel. The fact that the vessel sealed with beeswax proved to be far less likely to lose its liquid contents through its vessel walls is relevant in the context of the BEFIM project. This project addresses the drinking habits of the Early Celtic communities in Central Europe (Stockhammer/Fries-Knoblach 2019a; 2019b). Organic residue analysis performed on samples from the Heuneburg and Mont Lassois ceramic assemblages have revealed a high frequency of signatures for beeswax (Rageot et al. 2019a; 2019b). Obviously, other explanations can be proposed for the presence of such traces, like serving mixtures containing honey with remnants of honeycomb. However, the fact that beeswax signatures were present in especially bowls at both of these sites may suggest that these vessels were prepared to contain liquids for a longer time, by reducing the permeability of the vessels.

Acknowledgments

We want to thank Loe Jacobs for the production of the vessels used in these experiments and his knowledge regarding different surface finishes. Eric Mulder did all the measurements and helped in devising the measurement techniques and taking photographs. Jan Dekker assisted with making the graphs and tables.

Bibliography

Auler 2020: R. Auler, Antiker Weinausbau in Amphoren: Grundlegende Versuche zur Abdichtung von Weinamphoren (Dressel 1). Marburger Beitr. Antike Handels-, Wirtschafts- u. Sozialgesch. 37, 2020, 192-223.

Messing 1957: S. D. Messing, Further comments on resin-coated pottery: Ethiopia. American Anthr. 59, 1957, 134.

Mötsch et al. in BEFIM 1: A. Mötsch/M. Rageot/B. Schorer, Organic residues in pottery vessels from selected archaeological features of the Heuneburg. First results of a case study. In: Stockhammer/Fries-Knoblach 2019a, 61-76.

Mötsch et al. in BEFIM 2: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen“. Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Outram 2008: A. K. Outram, Introduction to experimental archaeology. World Arch. 40/1, 2008, 1-6.

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/P. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/ Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, The Dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Rice 2015: P. M. Rice, Pottery analysis. A sourcebook ²(Chicago, London 2015).

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Author information

Annemieke Verbaas and Annelou van Gijn
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.verbaas@arch.leidenuniv.nl
a.l.van.gijn@arch.leidenuniv.nl

Appendix 1: The complete results of both series of experiments (na = not applicable).

		Hours after filling		**series 1**	0		24		48	
			Date (2018)		**06/11**		**07/11**		**08/11**	
No	**Inside finish**	**Outside finish**	**Weight empty pot (g)**	**Weight soaked pot (g)**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**
1	smooth	smooth	633.5	722	1710	5.7	1650	5.1	1586	4.8
2	smooth	polished	717.5	816	1804	5.1	1740	4.6	1672	4.3
3	smooth	slap and pat	628	718	1706	6.9	1634	6.2	1558	5.8
4	smooth	graphitized	725.1	822	1814	5	1756	4.5	1696	4
5	smooth	scraped	661.8	754	1742	6.3	1686	5.8	1628	5.2
6	smooth reduced	smooth (reduced) 736° C	595	678	1674	7	1602	6.3	1532	5.1
7	burnished	smoothed	691.4	784	1774	5.4	1718	5	1660	4.6
8	polished	smooth	652.6	738	1728	5.2	1660	4.8	1590	4.2
9	graphitized	smooth (in reduced / out neutral)	708.9	802	1790	5	1724	4.4	1652	3.9
10	graphitized	smooth (comp reduced)	505.9	574	1568	6.1	1510	5.8	1452	5.4
11	scraping	smooth	634	724	1714	6	1638	5.4	1564	4.8
12	beeswax	smooth	502.1	506	1502	6.2	1486	6.1	1468	6
13	milk	smooth	626.5	696	1690	6.4	1624	5.9	1560	5.6
14	milk / honey	smooth	568.4	640	1626	6.9	1564	6.4	1506	6
15	smooth	smooth	692.9	790	1780	5.6	1692	5	1608	4.4
16	glas	glas	na	na	na	na	na	na	na	na

		Hours after filling	**series 2**		0		24		120	
			27/11		**28/11**		**29/11**		**03/12**	
No	**Inside finish**	**Outside finish**	**Pot + water (g)**	**Weight soaked pot (g)**	**Pot + water (g)**	**336 h cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**
1	smooth	smooth	1634	724	1718	5.8	1658	5.4	1434	3.8
2	smooth	polished	1718	816	1812	5.3	1764	5	1596	3.8
3	smooth	slap and pat	1628	718	1716	7.1	1648	6.5	1410	4.8
4	smooth	graphitized	1720	822	1818	5.1	1764	4.8	1564	3.4
5	smooth	scraped	1666	756	1756	6.4	1700	6.1	1494	4.7
6	smooth reduced	smooth (reduced) 736° C	1596	678	1674	7.1	1604	6.5	1340	4.8
7	burnished	smoothed	1690	780	1776	5.5	1738	5.3	1604	4.4
8	polished	smooth	1650	738	1736	5.4	1674	5	1444	3.4
9	graphitized	smooth (in reduced / out neutral)	1708	804	1802	5.2	1734	4.6	1478	2.7
10	graphitized	smooth (comp reduced)	1506	576	1568	6.1	1516	6	1314	4.6
11	scraping	smooth	1628	724	1724	6	1670	5.8	1476	4.4
12	beeswax	smooth	1504	506	1502	6.2	1486	6.1	1420	5.8
13	milk	smooth	1624	704	1700	6.2	1638	6	1398	4.4
14	milk / honey	smooth	1564	646	1642	6.8	1592	6.5	1398	5.3
15	smooth	smooth	1688	790	1784	5.6	1734	5.3	1548	4
16	glas	glas	1282	288	1286	6.5	1276	6.4	1236	6

120		144		168		192		288		
12/11		**13/11**		**14/11**		**15/11**		**19/11**		
Pot + water (g)	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Empty pot after one week (g)**
1346	3.1	1286	2.6	1226	2.2	1156	1.8	850	-1	636
1422	2.4	1362	2	1304	1.6	1238	1	976	na	722
1278	3.8	1210	3.2	1142	2.8	1062	2.1	732	na	630
1458	2.5	1400	2.1	1340	1.7	1272	1.1	976	na	728
1402	3.9	1348	3.3	1292	3.1	1226	2.5	940	na	666
1248	3.8	1184	3.5	1116	3	1036	2.4	706	-0.1	596
1440	3.1	1388	2.8	1334	2.4	1276	1.9	1018	-0.5	696
1318	2.4	1254	1.9	1186	1.4	1110	0.7	786	na	656
1374	1.9	1306	1.4	1238	0.8	1160	0.1	812	na	712
1230	3.9	14180	3.5	1126	3.1	1066	2.6	818	0.5	508
1280	2.9	1216	2.4	1150	1.9	1076	1.3	796	na	638
1404	5.5	1388	5.4	1370	5.4	1352	5.2	1282	4.8	502
1316	3.8	1258	3.5	1198	3.1	1128	2.6	834	1.1	628
1284	4.3	1234	4.1	1182	3.8	1122	3.2	862	1	570
1216	1.5	1142	1	1066	0.2	982	-0.6	704	na	696
1246	6.1	1238	5.8	1228	5.7	1216	5.6	1172	5.2	288

144		168		192		264		278		336	
04/12		**05/12**		**06/12**		**10/12**		**11/12**		**13/12**	
Pot + water (g)	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**	**Pot + water (g)**	**cm**
1362	3.2	1298	2.6	1242	2.3	994	0.2	902	0.1	754	na
1548	3.2	1506	2.9	1468	2.6	1306	1.3	1252	0.8	1166	0.1
1338	4.3	1274	3.7	1214	3.2	952	1.2	862	0.2	710	na
1500	2.9	1446	2.4	1398	2.1	1204	0.6	1132	-0.1	1022	na
1428	4.3	1372	3.8	1320	3.3	1102	1.4	1022	0.7	892	na
1258	4.3	1184	3.6	1116	3.1	822	0.3	718	na	604	na
1562	4.1	1528	3.7	1498	3.4	1368	2.2	1322	2	1250	1.3
1372	2.8	1312	2.3	1256	1.8	1020	0.8	936	na	802	na
1396	2.1	1326	1.5	1262	1	1000	0	902	na	748	na
1252	4.3	1196	3.8	1146	3.3	932	1.7	854	1	724	na
1420	4	1374	3.6	1330	3.2	1148	1.9	1088	1.1	992	0.5
1398	5.5	1380	5.4	1364	5.2	1300	49	1278	4.7	1242	4.5
1324	3.9	1258	3.5	1198	3.1	938	1	844	0.1	696	na
1336	4.9	1282	4.5	1232	4.1	1018	2.5	940	1.9	810	0.7
1490	3.6	1442	3.2	1398	2.9	1208	1.5	1142	0.8	1040	0.1
1224	5.8	1214	5.7	1206	5.6	1166	5.1	1152	4.8	1130	4.5

Microwear studies of pottery from the Iron Age site of the Heuneburg (Germany)

Annelou van Gijn & Annemieke Verbaas

Summary

In the context of the BEFIM project ("Meanings and Functions of Mediterranean Imports in Early Central Europe") led by Philipp W. Stockhammer, the life history of (drinking) vessels from the Early Iron Age hillfort of the Heuneburg was examined, studying how they were produced and used. In order to do so, we set up an extensive experimental program of dozens of experiments directed at a better understanding of the production and use of this pottery. The traces we observed on the experimental vessels by means of microwear analysis formed the basis for our interpretation of the archaeological ware from the Heuneburg. These displayed evidence for stirring, mixing and the consumption of substances, as well as for cleaning, extensive handling and storage. Many of the ceramic vessels must have had a long use life. Traces of pitting were interpreted as the result of an acidic alcoholic substance, providing additional evidence for the contents that these vessels may have contained.

Keywords: *Early Celtic pottery, vessel function, microwear analysis, drinking habits, Heuneburg*

Zusammenfassung

Im Kontext des Forschungsprojekts BEFIM (Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa) unter der Leitung von Philipp W. Stockhammer wurde die Biographie von (Trink)Gefäßen aus der früheisenzeitlichen Höhensiedlung der Heuneburg im Hinblick auf Herstellung und Gebrauch untersucht. Zu diesem Zweck erstellten wir ein umfangreiches Programm aus Dutzenden von Experimenten zum besseren Verständnis, wie diese Keramik gemacht und benutzt wurde. Die Spuren, die wir auf nachgetöpferten Gefäßen mithilfe von Gebrauchsspurenanalysen beobachteten, bilden die Grundlage unserer Interpretation der archäologischen Keramik von der Heuneburg. Sie zeigte Belege für Umrühren, Mischen und den Verzehr von Substanzen ebenso wie für Reinigung, intensive Handhabung und Aufbewahrung. Viele Keramikgefäße müssen über lange Jahre gebraucht worden sein. Spuren von Abplatzungen (*pitting*) wurden als Folge einer säurehaltigen alkoholischen Substanz gedeutet, was zusätzliche Hinweise auf die einstigen Inhalte der Gefäße liefert.

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 121-150.

Schlüsselwörter: *Frühkeltische Keramik, Gefäßfunktion, Gebrauchsspurenanalyse, Trinksitten, Heuneburg*

Introduction

The BEFIM project (*Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa*), which ran from 2015-2018, was focused on a better understanding of Celtic drinking patterns during the 7th-5th cent. BC (Stockhammer in BEFIM 1). Both locally made pottery and imported ware from Greece have been found at the Heuneburg (Mötsch et al. in BEFIM 1 and BEFIM 2; Schorer et al. in BEFIM 1; for an overview of pottery types see Jacobs, this volume). Feasting was supposed to have been an important part of life in the princely Celtic sites of Central Europe, and the import of feasting dishes from the Mediterranean was seen as an attempt to emulate such practices by the Celtic elite (Krausse et al. 2016; Fernandez-Götz, 2014, 2018). Were these import vessels used in the same way as in Southern Europe, where they were associated with grape wine consumption? Or were these imported vessels used in a different way, e. g. to drink beer or honey wine, indicating a transformation from one cultural context to another (Stockhammer 2016; Stockhammer in BEFIM 1)? Some of the locally made pottery, especially so-called tableware, is extremely finely made and almost looks as if it was intended to be copies of the Southern Alpine originals. What was their role in Celtic feasting practices? Were these locally made vessels used in a different way from the imported ones? The BEFIM project, directed by Philipp W. Stockhammer (Institut für Vor- und Frühgeschichtliche Archäologie und Provinzialrömische Archäologie, Ludwig-Maximilians-Universität, Munich, Germany, and Max Planck Institute for the Science of Human History, Jena, Germany) set out to address exactly these questions, involving a multidisciplinary team of researchers. The main sites studied in this project were the Heuneburg (Krausse 2016) and the Mont Lassois (Bardel 2009; Chaume/Mordant 2011).

The project entailed a holistic study encompassing a detailed typological and contextual analysis (Stockhammer in BEFIM 1), organic residue analysis (ORA) (Rageot et al. 2019a; 2019b; Mötsch et al. in BEFIM 2; Spiteri et al. in BEFIM 2) and microwear analysis (van Gijn et al. in BEFIM 1; van Gijn et al., this volume) in order to understand the functions of all of these vessels. Organic residue studies obviously give the most detailed and direct evidence of the contents of vessels, whereas the microwear study tells us more about the human gestures that were connected to pots, the intensity of their use and only rarely about their contents. Both approaches have their shortcomings and inferential limits (see for microwear van Gijn 2014 and for organic residue analysis Rageot et al. 2019a; 2019b; Spiteri et al. in BEFIM 2), but they do complement each other and at times support each other's results (Verbaas/van Gijn-Vix, this volume). The combination of approaches could shed light on the biography of the vessels and their entanglements with humans (Gosden/Marshall 1999; Hahn/Weiss 2013; van Gijn 2012). In this chapter the finds from the Celtic so-called *Fürstensitz* or princely seat of the Heuneburg are addressed. Those from the Mont Lassois are discussed elsewhere (Verbaas/van Gijn-Vix, this volume).

Sample and methods of analysis

The sample from the Heuneburg excavations was taken by Angela Mötsch (then Landesamt für Denkmalpflege beim Regierungspräsidium Stuttgart, Dienstsitz Esslingen, Germany, now Max Planck Institute for the Science of Human History, Jena, Germany) and Birgit Schorer (then Landesmuseum Württemberg, Stuttgart,

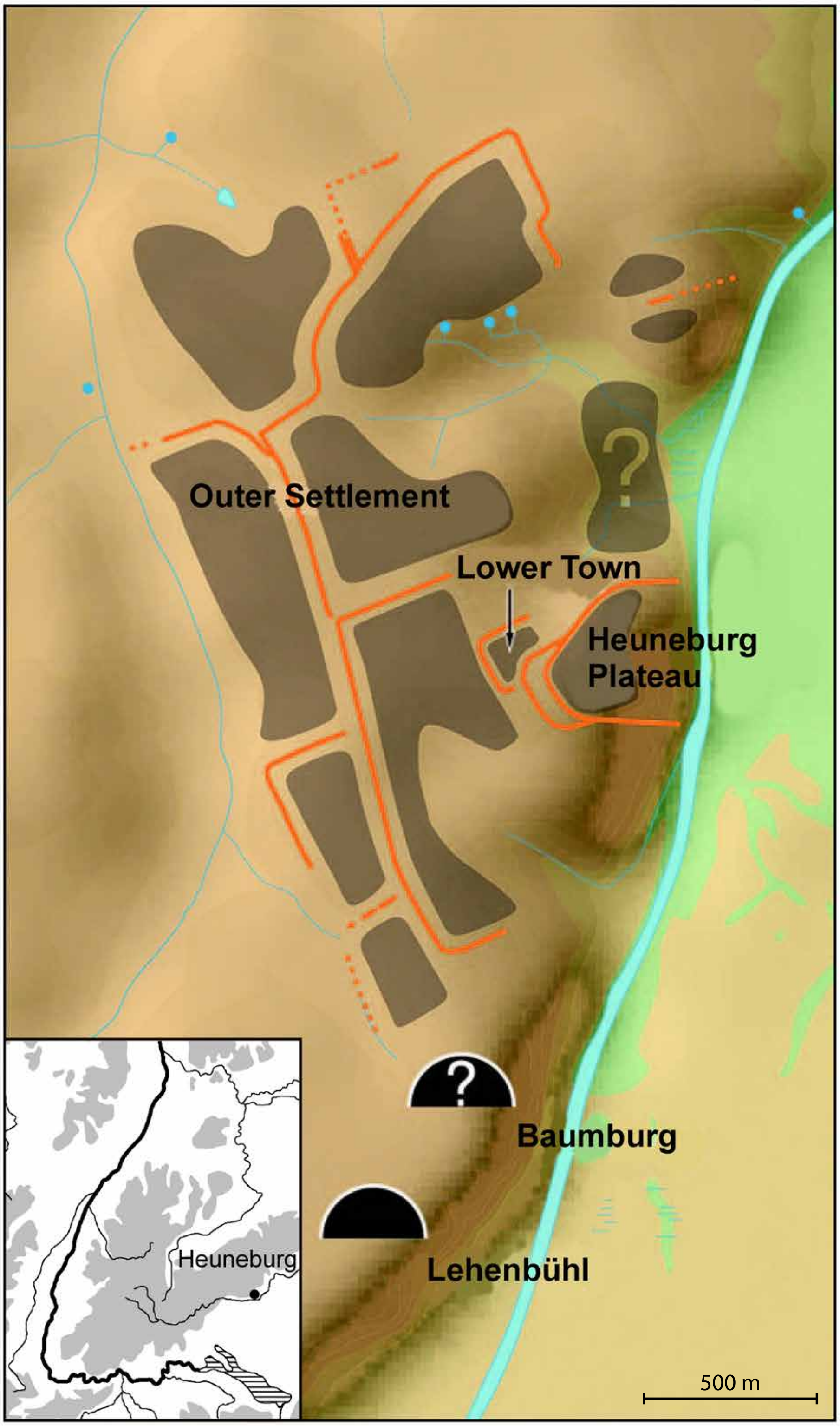

Figure 1: Situation and map of the Heuneburg in later Ha D1 with the location of the three different sampled excavation areas, two princely barrows to the south and the ditch system structuring the settlement (adapted from Mötsch et al. in BEFIM 2, 120 fig. 2b © Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, after S. Kurz).

now Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Dienstsitz Esslingen, Germany). They selected the sherds on the basis of their possible role for preparing, consuming and storing beverages (Mötsch et al. in BEFIM 1 and BEFIM 2; Schorer et al. in BEFIM 1). The selection included bowls of various sizes and diameters, cups, flasks, beakers, goblets, cone-necked vessels and pots. A total of 112 finds, most of them sherds, were analyzed for the presence of microwear. The sherds came from the Lower Town Settlement (*Vorburg*, HB-VB series), the Outer Settlement (*Außensiedlung*, HB-AS series) and the Plateau (*Plateau*, HB-PL series) (Fig. 1). The original selection made by Mötsch and Schorer included sherds from 132 vessels, 125 locally made and only seven imported. Unfortunately, not all finds selected by Mötsch and Schorer could be studied for the presence of wear traces as some samples were unavailable or could not be transported to the Leiden Laboratory for Material Culture Studies. For further details on the excavations at the Heuneburg and contextual information the reader is referred to other papers (Mötsch et al. in BEFIM 1 and BEFIM 2 incl. references; Rageot et al. 2019b).

Microwear is a method that was developed in the latter half of the 20th cent. and fitted very well with the new way of looking at material culture ('The Material Turn') in which the biography or life history of objects and their entanglements with humans is center piece. Archaeological objects are not just seen as static entities with spatial-temporal connotations, but also as having agency of their own, being very much part and parcel of daily human life (e. g. Hodder 2012; Hahn/Weiss 2013). Microwear analysis provides data on the use of objects, how they were handled and how they were treated during the course of their life (e. g. van Gijn 2012; 2014; Marreiros et al. 2015b). Objects develop traces of wear during their life history, and pottery is no exception (van Gijn/Hofman 2008; Skibo 2013; 2015). The methodology and the inferential limits of microwear analysis, especially regarding the use-wear analysis of pottery, are extensively discussed elsewhere (van Gijn et al., this volume; van Gijn et al. in BEFIM 1).

On the basis of the traces observed, their location, distribution, topography and morphology, we are often able to infer the motion and the contact material a tool was involved in (van Gijn 1990). However, microwear analysis was initially developed for flint, bone and stone tools. "Motions" in relation to the use of vessels is obviously a little ambiguous as it includes gestures as well as all sorts of accidental "contacts". For example, when two pots repeatedly touch each other in a cramped storage space the motion is referred to as "bumping" and the contact material is "pottery". Another example are the rim sherds with transversely oriented fine scratches that seem to point to the presence of a bent ladle hanging from the rim of the vessel. The motion in this case is "hanging spoon" and the contact material is e. g. "metal" when we see a likeness of traces to an experiment that involved a metal spoon.

We defined the following "motions": stirring, battering, covering, pitting, cleaning, scraping/cleaning, bumping, handling, shoving, handling/bumping, hanging spoon, repair, multiple and unsure. The traces on which these interpretations are based, will be referred to in the descriptions of use-wear seen on individual sherds given below. The contact materials the traces of which could be discerned included: acidic substance, cloth, wooden spoon, pottery, metal, rope and tar, medium material, hard material, coarse material, and unsure/diverse.

As to the equipment used, the sherds were first examined with stereomicroscopes (Leica M80 and Wild M3Z) at magnifications between 10x and 100x to detect the presence of traces of use and their spatial distribution. All sherds with micropolish were subsequently studied by means of an incident light or metallographic microscope (Leica DM6000, DM1750 and DM2700) with magnifications up to 500x. All sherds were drawn, and traces observed were marked on registration sheets, including, where relevant, those attributed to manufacturing. Photos were taken with Leica cameras MC120HD and DFC450 on the microscopes and an integrated Leica Application Suite program.

The first round of examination was done with the naked eye, together with expert potter Loe Jacobs (Jacobs, this volume) to obtain an overview of the manufacturing traces present. We specifically were attentive to the kind of fabric and temper and the shaping techniques used. These observations formed the basis for the replication of the vessels by Jacobs (Jacobs, this volume), which were subsequently used in the experimental program (van Gijn et al., this volume). Studying the traces of manufacture is also essential in order to be able to distinguish them from traces of wear. We had to learn for the types of fabrics that were inferred for the Heuneburg how e. g. traces from scraping the inner wall of the vessel to smoothen it differed from traces of stirring with a spoon. Additionally, the initial examination of the sherds provided us with a broad overview of possible gestures that were represented by these sherds. This overview defined the range of experiments we subsequently conducted with the replicas made by Jacobs (van Gijn et al., this volume).

Apart from the inferential limits inherent in microwear analysis in general, and that of pottery in particular, there were also some external restrictive factors that influenced the final result. The Heuneburg finds were present in the Leiden Laboratory for Material Culture Studies for a short time only, which made it impossible to come back to some of the more problematic specimens. This explains to some extent the relatively large category of "unsure" for inferred contact material and motion. The Heuneburg sample was also studied before we conducted our experimental program as these sherds formed the departure point and basis for the reproduction of the vessels (Jacobs, this volume) as well as for the design of the subsequent use experiments (van Gijn et al., this volume). Although we documented the archaeological sherds in as much detail as possible taking a substantial number of photographs, it would have been better to have had a second look at them and compare the traces on them in detail to those that developed on the experimental vessels. Such a dialectic between experiments and archaeological objects is considered best practice in microwear studies.

Another restrictive factor in the analysis was the fact that quite a large number of finds concerned body sherds. It was therefore not always easy to interpret e. g. the scratches observed: were these due to cleaning or stirring? Our experiments showed that the location and distribution of the traces is highly informative about the action involved (van Gijn et al. in BEFIM 1; van Gijn et al., this volume). The type of sherd, bottom, body or rim, also defines the kind of inferences we are able to make: traces from shoving pots around are logically visible on bottom sherds only. Similarly, a body sherd will not show traces from an overhanging ladle like we see on some of the rim sherds. So, the fact that we studied only a few complete pot profiles severely limited the detail of inference possible (cf. van Gijn et al., this volume). It also restricted the possibilities for the reconstruction of vessel biographies.

Finally, the investigated finds had been catalogued, repaired, refitted, drawn and handled a lot. We therefore encountered not only a lot of glue to stick together broken vessel fragments, but also remnants of tape and very large registration numbers, sometimes of several different registration series. The restoration that several of the vessels had undergone, however useful for museum display, at times severely hampered the visibility and interpretability of wear traces (Fig. 2a). One of the worst habits we encountered the detrimental effects of is the use of chalk to highlight elevations on

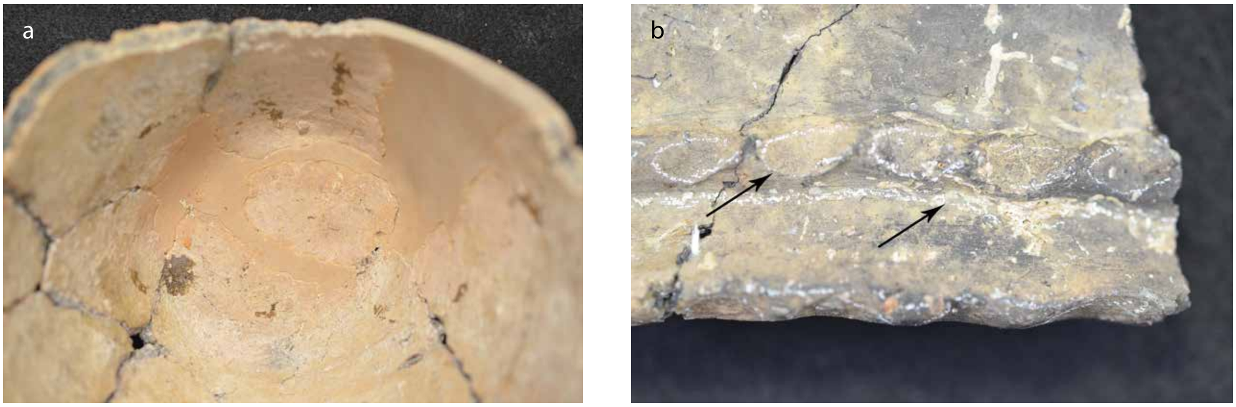

Figure 2: Post-excavation treatments that leave substantial traces on the finds. (a) Restoration of vessels sometimes severely impedes the visibility and interpretability of wear traces (HB-VB-027). (b) Chalk remains seen on HB-VB-014, covering the outlines of the decoration (© Laboratory for Material Culture Studies Leiden University).

finds, a practice that occurs very often for lithics to improve the visibility of retouch, but which we occasionally encountered on the Heuneburg finds as well (Fig. 2b). It is so problematic, because it is very difficult to remove and actually also has an abrasive effect on the ceramic surface.

General results

It turned out that, unfortunately, many sherds were not interpretable due to post-depositional surface modifications (n = 9) or because they were really too small to allow for the interpretation of the traces we may have been observing. As argued elsewhere (van Gijn et al., this volume) the distribution of the traces along the vessel profile constitutes an important clue as to the gestures that caused these traces. In addition, quite a number of sherds did not display interpretable traces of wear (n = 32). It should be stressed that this does not necessarily mean that the vessels these sherds belonged to were not used. As discussed elsewhere (van Gijn et al., this volume), not all activities leave traces of wear very quickly, if at all. This is not just the case with pottery, but also with objects or tools made of other materials like flint (van den Dries/van Gijn 1997). Moreover, it may also be that the relative absence

Figure 3: Find HB-VB-010, an open bowl from Befund 1819, an oven. (a) Overview of the sherd. (b) Scratches and exposed temper in the bottom of vessel. (c) Rounded rim and slight transverse scratches from contact with a ladle (© a = A. Mötsch, b, c = Laboratory for Material Culture Studies Leiden University).

of traces of wear may also be due to a practice of sealing the pots on the inside with beeswax, in order to prevent percolation and evaporation of the fluids inside. Experiments have shown such a sealing to be highly effective against the loss of fluids (Verbaas/van Gijn- Permeability, this volume). The beeswax may at the same time have protected the inner surface from stirring or pounding damage. ORA has demonstrated that a number of vessels had beeswax signatures, often in combination with other substances (Rageot et al. 2019b; Mötsch et al. in BEFIM 2).

All in all, 71 of the 112 finds examined displayed traces of use. Because several finds showed a combination of two or more types of traces, the 71 vessels with use-wear traces produced 120 locations of use. A total of 36 vessels were studied for both the presence of residues (Mötsch et al. 2019 in BEFIM 1 and BEFIM 2; Schorer et al. in BEFIM 1; Rageot et al. 2019b) and for traces of wear.

A range of motions and contact materials could be inferred. Traces of stirring, battering, cleaning, handling and shoving predominate, but various other "motions" were represented as well. The number of contact materials inferred was much less varied: only in a limited number of cases was it possible to interpret the contact material involved: wood, acidic substance, metal, cloth and pottery are the most specific inferences.

In the following, the results from the microwear analysis will be discussed for each of the three different contexts: the Lower Town Settlement (*Vorburg*, HB-VB series),

Figure 4: Find HB-VB-014, a wide-mouthed pot from Befund 1819, an oven. (a) Overview of the sherd. (b) Manufacturing scratches from scraping, still visible in the inside. (c) Rounded rim (© a = A. Mötsch, b, c = Laboratory for Material Culture Studies Leiden University).

the Outer Settlement-Old Excavation (*Außensiedlung*, HB-AS series) and the Plateau (*Plateau*, HB-PL series). Where available, mention will be made of the results of the organic residue analysis (Schorer et al. in BEFIM 1; Mötsch et al. in BEFIM 2; Rageot et al. 2019b). The samples came from three different locations and dated to different periods of time (Ha D1 to D3). The majority of our samples came from the Lower Town Settlement (*Vorburg*, HB-VB series) (n = 70). From the Outer Settlement a total of 27 sherds (*Außensiedlung*, HB-AS series) were examined, but from the Plateau (*Plateau*, HB-PL series) a mere 15.

The Lower Town (*Vorburg*, HB-VB series)

Starting with the Lower Town, 70 sherds were examined, all local pottery most of which hand-made. Only four finds (HB-VB-001; HB-VB-003; HB-VB-030; HB-VB-066) were wheel-thrown, HB-VB-051 was possibly so. Of the total of 70 sherds, 47 showed traces of use, six finds were not interpretable and 17 finds did not display traces of use. The 47 sherds with wear traces produced 86 locations with such traces. On 21 sherds only one location with traces was detected, on 17 sherds two locations of use were present, and seven sherds had three locations. Two finds had four and six used zones respectively, making the number of used locations 86. Tab. 1 depicts the results.

As the sample from the Lower Town Settlement constitutes the largest one, the range of contact materials and motions is the most diverse of the three locations. In the following the results will be discussed following the different find contexts (*Befund)* from the 2004-2008 excavations (Bofinger 2005; 2006; Bofinger/Goldner-Bofinger 2008; Kurz 2006; 2012a; 2012b). Only find contexts with secure dating and coming from a circumscribed feature or find layer are discussed below. Other finds from the Lower Town from less interesting contexts, but with an interesting biography will be presented in a separate paragraph on the life history of these vessels.

Context/Befund 1819 and 1870 (Ha D1)

From a vaulted oven excavated in sector 16 (*Befund* 1819) (Mötsch et al. in BEFIM 1 and BEFIM 2; Rageot et al. 2019b) and the living floor (*Befund* 1870) surrounding it, several vessels were selected for study. Both contexts are dated to period Ha D1 (Mötsch et al. in BEFIM 2). From the oven (*Befund* 1819), an open bowl (HB-VB-010) (Fig. 3a) and a wide-mouthed pot (HB-VB-014) were studied for both microwear and ORA. HB-VB-010 displays evidence on the outside bottom for having been

Table 1: Results of the microwear analysis of the Lower Town (Vorburg), cross tabulation of inferred contact material and motion, per location.

Contact material	**Stirring**	**Battering**	**Covering**	**Pitting**	**Cleaning**	**Scraping/ cleaning**	**Bumping**	**Handling**	**Shoving**	**Handling/ bumping**	**Hanging spoon**	**Repair**	**Multiple**	**Unsure**	**Total**
Acidic substance	-	-	-	7	-	-	-	-	-	-	-	-	-	-	7
Cloth	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Wooden spoon	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pottery	-	-	2	-	-	-	3	-	-	1	-	-	-	-	6
Metal	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Rope and tar	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Medium material	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Coarse material	4	-	-	-	-	-	-	-	2	-	-	-	-	-	6
Unsure/diverse	8	2	4	-	3	-	1	12	9	-	7	-	2	13	61
Total	**13**	**2**	**7**	**7**	**3**	**1**	**4**	**12**	**11**	**1**	**9**	**1**	**2**	**13**	**86**

shoved around on a coarse surface. The inside of this vessel is very worn and shows multiple, multidirectional fine and medium long scratches, probably attributable to stirring (Fig. 3b). There is also one location in the bottom where the clay surface is very rough and the mineral temper has been exposed (Fig. 3b). The rim is rounded and the inside of the rim displays a slight polish and fine scratches that were interpreted as being the result of a spoon that rested against the inner rim on a regular basis (Fig. 3c). The outside bottom of the vessel is very much worn, and the skin of the pot has largely disappeared as a result of storage and handling. Organic residue analysis showed there to be traces of animal fat (probably heated milk or a heated milk product), beeswax, plant wax and millet in this pot (Mötsch et al. in BEFIM 2, Kat. 103; Rageot et al. 2019b). The decorated pot HB-VB-014 (Fig. 4a) still displays the smoothing traces from manufacturing (Fig. 4b). The pot has a rounded rim, traces that were interpreted as being related to an overhanging ladle of unknown material (Fig. 4c). There is also some possible pitting on the inside, possibly related to an acidic substance and/or fermentation (see Groat, this volume for more details). However, ORA only pointed to traces of animal fat (probably heated milk or a heated milk product) (Mötsch et al. in BEFIM 2, Kat. 102; Rageot et al. 2019b). Both HB-VB-010 and HB-VB-014 display

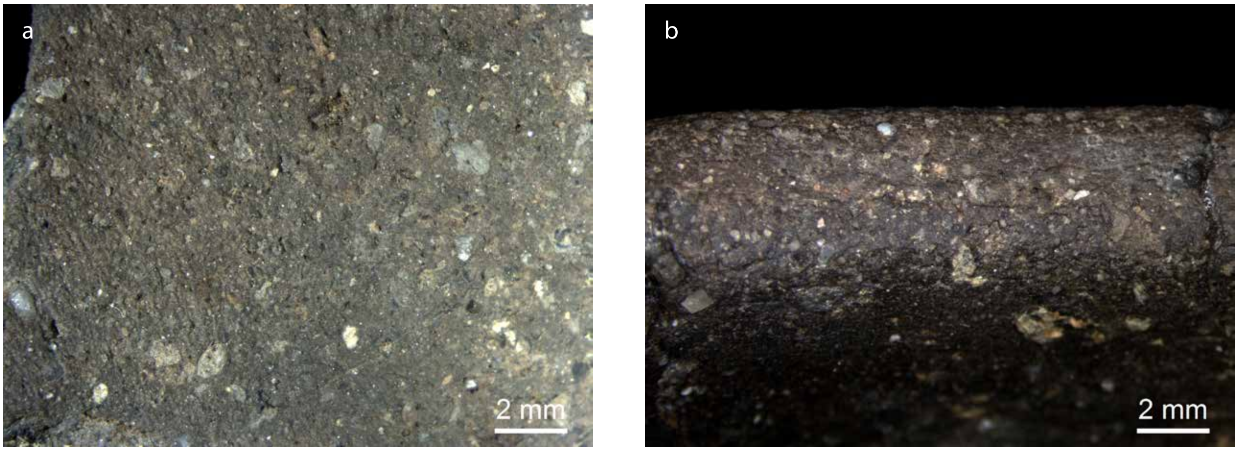

Figure 5: Bowl HB-VB-011. (a) Scratches, probably from stirring, and exposed temper. (b) Heavily rounded rim with fine scratches only visible under higher magnifications and interpreted as being the result of a ladle hanging over it (© Laboratory for Material Culture Studies Leiden University).

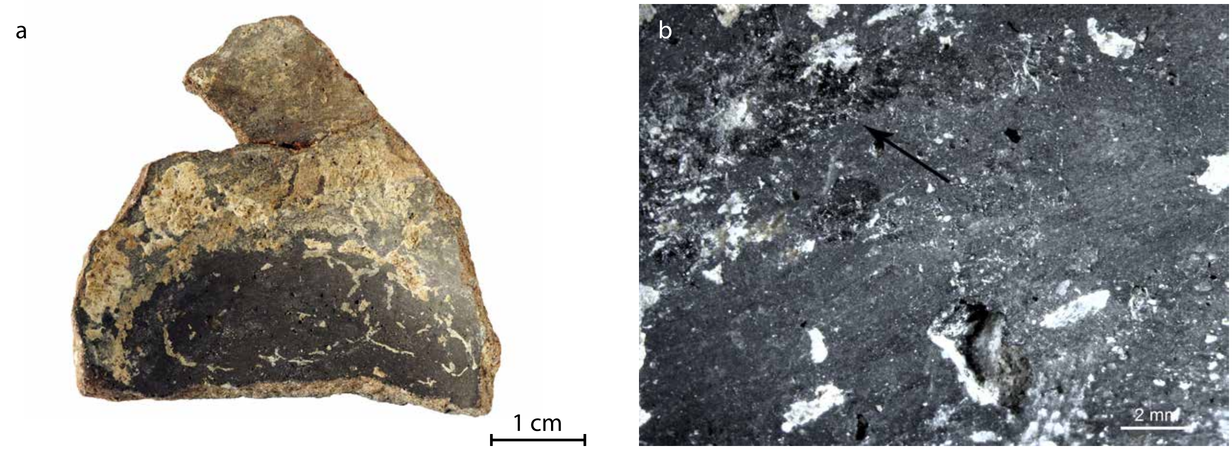

Figure 6: Cone-necked vessel fragment (HB-VB-016). (a) Overview. (b) Residue covering the inside of the sherd (© a = A. Mötsch, b = Laboratory for Material Culture Studies Leiden University).

encrustations and black residue both inside and outside, possibly from their proximity to fire and to heating of the milk or milk products. Milk is widely used to seal pottery, something that is also reported from e. g. Ethiopia (Messing 1957, 134).

Four finds were studied from the living floor (*Befund* 1870): HB-VB-011, a large bowl with a diameter of 26 cm, two cone-necked vessel sherds (HB-VB-016 and HB-VB-017, possibly belonging to the same vessel) and a sherd of a big pot, possibly a storage jar (HB-VB-021). Bowl HB-VB-011 (Fig. 5a) has a heavily worn inside bottom with evidence for stirring as well as a polished and facetted rim, the latter probably related to a ladle hanging over it (Fig. 5b). Rageot found traces of animal fat and millet in this vessel (Mötsch et al. in BEFIM 2, Kat. 105; Rageot et al. 2019b). The two sherds of the cone-necked vessels (HB-VB-016; HB-VB-017) (Fig. 6a) were tempered with rather coarse quartz fragments. Their insides were largely covered with a film of residue (Fig. 6b) which, to a large extent, inhibited observing the presence of any wear traces of e. g. stirring that may have been present. Both finds were body sherds, so no information was available on the wear traces of the rim. We had postulated that the residue looked a bit like milk, a substance sometimes used to seal pottery (see above). However, organic residue analysis has shown traces of a fatty substance of plant origin, millet and possibly plant wax (Mötsch et al. in BEFIM 2, Kat. 106-107; Rageot et al. 2019b). On the inside of the possible storage jar HB-VB-021 the presence of pitting and craters may point to the former presence of an acidic substance stored in this vessel. Rageot et al. (2019b; Mötsch et al. 2019 in BEFIM 2, Kat. 104) found signatures of animal fat, probably milk or a milk product.

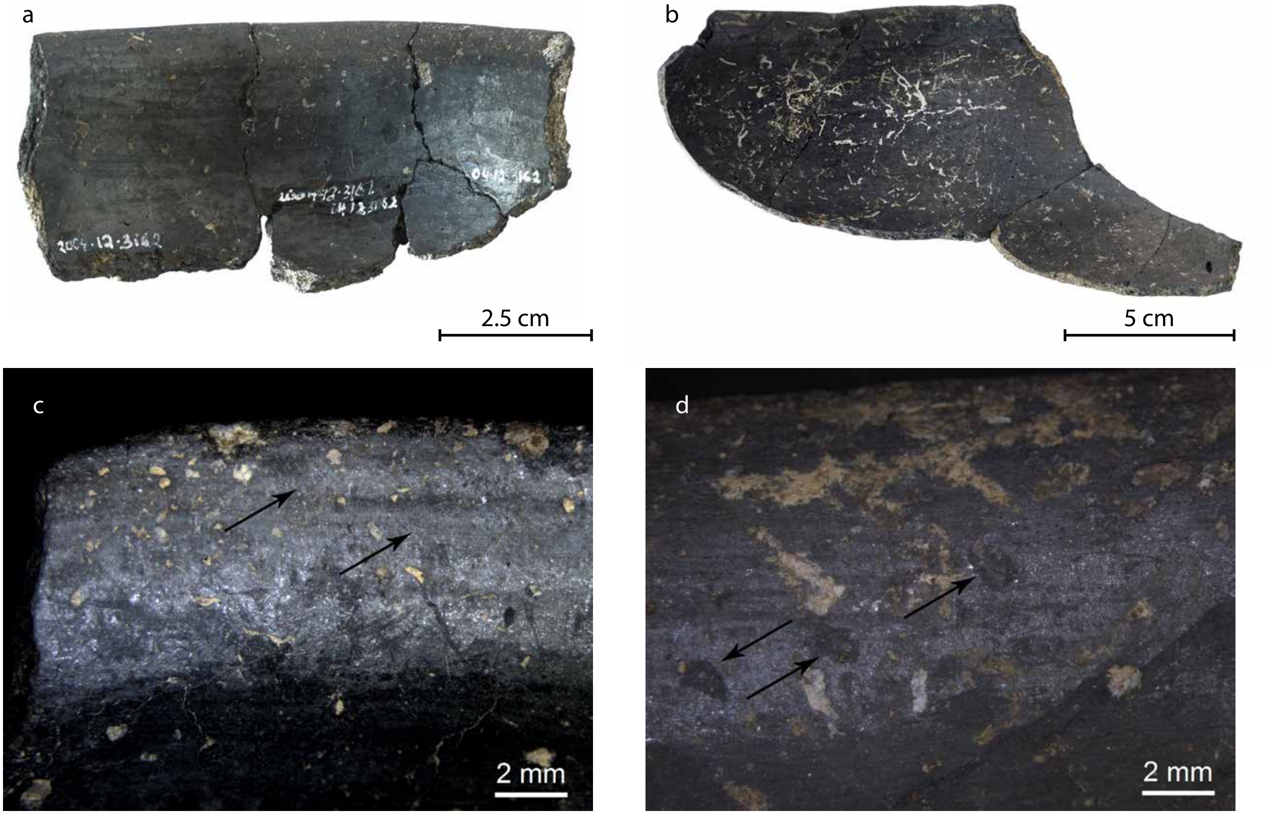

Figure 7: Bowls HB-VB-022 and HB-VB-026. (a-b) Overview of both sherds. (c) Polish and fine scratches on the internal rim of HB-VB-022 possibly due to contact with a metal ladle. (d) Pitting seen on the inside top of HB-VB-026, possibly due to contact with an acidic substance (© a, b = A. Mötsch, c, d = Laboratory for Material Culture Studies Leiden University).

Context/Befund 1159 (Ha D1/D2)

From *Befund* 1159, also dating to Ha D1, an occupation layer that was no longer *in situ* and had slid down the rampart (Mötsch et al. in BEFIM 2), a total of 13 sherds was studied. This included four from cone-necked vessels (HB-VB-067; HB-VB-68; HB-VB-69; HB-VB-070), one from a beaker with a graphitized rim (HB-VB-041), two from graphitized bowls (HB-VB-022; HB-VB-026), one from another bowl (HB-VB-025) and five from pots (HB-VB-012; HB-VB-013; HB-VB-027; HB-VB-028; HB-VB-071). Graphitized bowls HB-VB-022 and HB-VB-026 (Fig. 7a.b) are both finely made with a coiling technique, extremely thin and still displaying extensive traces of production on the inside, notably from scraping the clay. Bowl HB-VB-022 has a worn rim with fine scratches perpendicular to the rim with a bright metallic polish. The entire rim is slightly abraded. Most likely these traces are due to the use of a ladle, possibly made of metal (Fig. 7c). ORA showed traces of animal fat (milk or milk products), beeswax and a fruit product (probably grape wine) on HB-VB-022 (Mötsch et al. in BEFIM 2, Kat. 94). We did not observe pitting or craters that may point to the presence of an acidic substance.

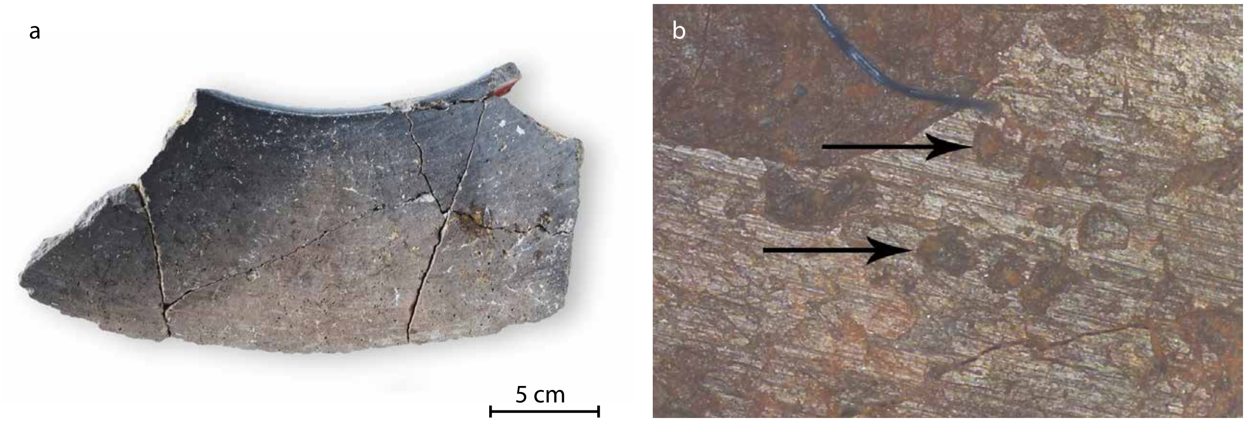

Figure 8: Cone-necked vessel fragment HB-VB-067. (a) Overview. (b) Pitting and cratering seen on the inside of HB-VB-067 indicating contact with an acidic substance (made by metallographic microscope, 100x original magnification; © a = A. Mötsch, b = Laboratory for Material Culture Studies Leiden University).

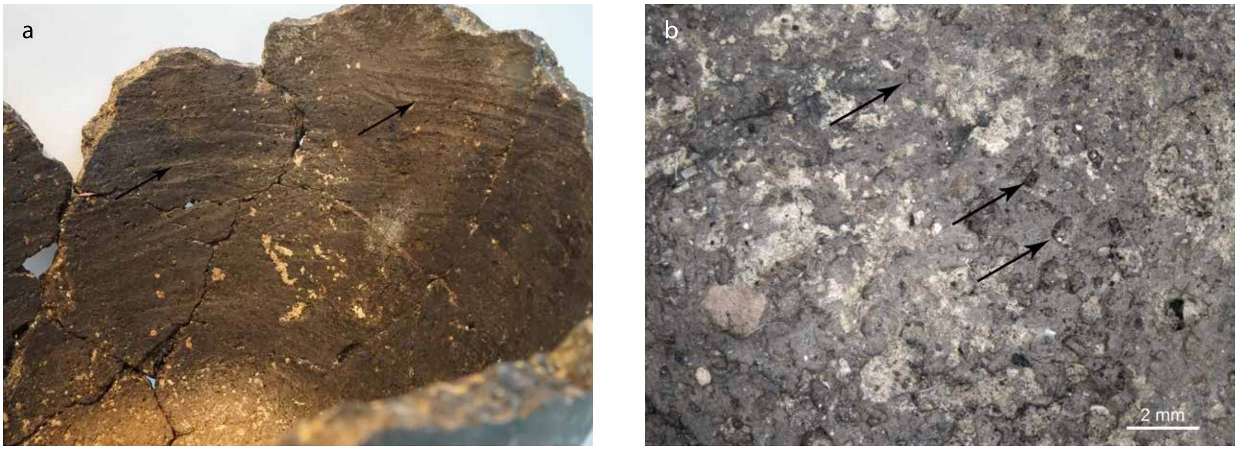

Figure 9: Pot HB-VB-012. (a) Scraping traces from the production stage still visible on the interior. (b) Pitting and cratering on the inside, possibly from contact with an acidic substance (© Laboratory for Material Culture Studies Leiden University).

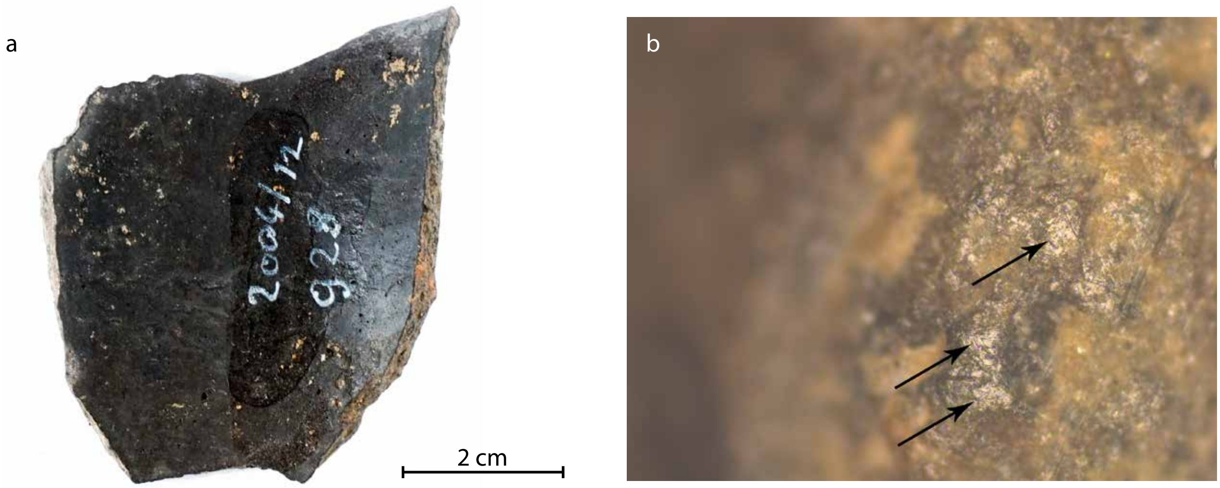

Figure 10: Rim and neck of bottle HB-VB-053. (a) Overview. (b) Polish on the inner bottle neck indicating some sort of stopper (made by metallographic microscope, 100x original magnification; © a = A. Mötsch, b = Laboratory for Material Culture Studies Leiden University).

Bowl HB-VB-026 has a heavily abraded rim, with several bigger and smaller flakes removed, indicating prolonged use. HB-VB-026 also displays pitting and some craters on the vessel walls, a wear feature that we associate with contact with an acidic substance (Groat, this volume; van Gijn et al., this volume). HB-VB-026 has traces of animal fat (heated milk or milk product), plant wax, millet and fruit products (probably grape wine) (Mötsch et al. in BEFIM 2, Kat. 96; Rageot et al. 2019b). This coincides with the microwear analysis that showed pitting from an acidic substance on this sherd (Fig. 7d).

As to the other vessels from *Befund* 1159, the beaker (HB-VB-041) has traces from battering and rubbing on the inside as well as scratches which could be due to forceful stirring and pressing when mixing different substances. The rim shows quite substantial wear as well, again from contact with something hard, resulting in small flakes and battering traces. Organic residue analysis showed traces of a fruit product (probably grape wine), from beeswax as well as from plant wax (Mötsch et al. in BEFIM 2, Kat. 97; Rageot et al. 2019b).

Of the four cone-necked vessels from *Befund* 1159 (HB-VB-067; HB-VB-068; HB-VB-069; HB-VB-070), the function of one (HB-VB-068) was not interpretable and one did not display wear traces (HB-VB-070). Two display pitting and craters (HB-VB-067; HB-VB-069) (Fig. 8a). Of these, only on HB-VB-067 was the extent of the pitting sufficient to infer an acidic substance (Fig. 8b). HB-VB-069 showed a large flake on the rim, next to which the rim is battered. The inside displays vague pitting possibly due to contact with an acidic substance. ORA of HB-VB-069 showed traces of animal fat, possibly beeswax and plant wax and possibly a fruit product of unknown origin (Mötsch et al. in BEFIM 2, Kat. 98; Rageot et al. 2019b). All four finds still bear evidence of their manufacturing process, which included scraping and burnishing of the vessel interior and applying a red slip to the outside. The latter has largely disappeared due to the extensive handling all of these cone-necked vessels were subjected to, probably related to serving. HB-VB-070 displayed extensive production traces from scraping the inside of the vessel with a serrated tool, possibly with an imported cockle shell of 3-4 cm width (Jacobs, pers. comm.).

Five pots (*Töpfe*) also came from this find context. The first one, HB-VB-012, is a coarsely made pot with the scraping and smoothing traces from manufacturing still very clearly visible (Fig. 9a). It displays craters and pits, with the mineral temper

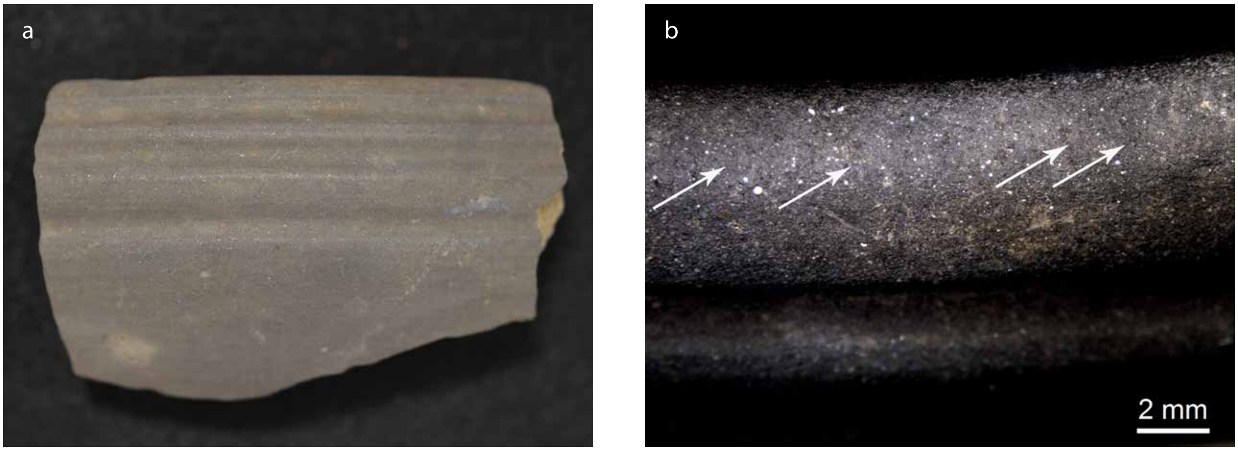

Figure 11: Bowl HB-VB-030. (a) Overview. (b) Extensive rounding of the rim (© Laboratory for Material Culture Studies Leiden University).

dissolved from the bottom to the very top of the vessel (Fig. 9b). These features may point to an acidic substance having been contained in this pot, possibly a fermented beverage (cf. Groat, this volume), but ORA only produced traces of fat (Rageot et al. 2019b; Mötsch et al. in BEFIM 2, Kat. 90). Unfortunately, the rim was absent, so it was impossible to see whether this pot was used for storage (in which case there may have been evidence for a lid), or for serving (resulting e. g. in traces from ladling). The second find, HB-VB-013, was made of a slightly finer paste than HB-VB-012 and included part of the rim. The rim was rounded on both the inside and the outside, and most likely this was due to a ladle hung on it for serving.

Three of the pots (*Töpfe*) were classified as coarse pottery (*Grobkeramik*). Vessel HB-VB-027 had a "slap and pat" outside and a very smoothed interior surface (Fig. 2a). It was heavily restored, especially at the bottom, making microwear analysis difficult. There are no signs of stirring or pitting. The character of the vessel, which was fired at relatively low temperature and only partially oxidized, was more suitable for use as a storage vessel for a dry substance (Jacobs, pers. comm.). Others consider this as a type of surface treatment that enlarges the vessel surface, which would have a cooling effect on the vessel's contents (Mötsch, pers. comm.). ORA has shown the presence of animal fat and plant wax (Rageot et al. 2019b; Mötsch et al. in BEFIM 2, Kat. 91). HB-VB-028 was fired shortly in an open fire, at relatively low temperatures, but it is harder than HB-VB-027 and made of a slightly less coarse-grained paste. Traces from scraping and smoothing are still visible on the internal surface. Rageot et al. (2019b) have shown the presence of traces of animal fat (heated milk or milk products) and millet. The third vessel, HB-VB-071, again classified as *Grobkeramik*, had several encrustations on the outside of the vessel. Reconstruction practices on this pot unfortunately made microwear analysis difficult, although some surface roughness was observed (Groat, this volume). The outside bottom was rounded with polish visible on large parts of the edge between vessel wall and bottom. This indicates that the vessel had been shoved around a lot. Again, no traces of stirring or pitting were visible.

Context/Befund 1674 (Ha D3)

From *Befund* 1674 (period HA D3), a former occupation layer, three vessels were selected: a bottle (HB-VB-038), a goblet (HB-VB-039) and a bowl with a "navel", an omphalos (HB-VB-040), all of which were characterized as fine ware (*Feinkeramik*). HB-VB-038, the rim of a bottle, did not display any traces of wear but the surface of the vessel is somewhat coarse and rough, the origin of which could not be assessed due to the very small size of this sherd. HB-VB-039 was not interpretable because the skin of the vessel was *craquelé* causing the irregular removal of the vessel's skin on both the inside and the outside. This caused the mineral temper to be exposed all the way to the top of the vessel, and some temper particles were removed. ORA demonstrated signatures of beeswax, animal fat and millet (Mötsch et al. in BEFIM 2, Kat. 100; Rageot et al. 2019b). The last find from this context is a bowl with an omphalos (HB-VB-040). Interestingly, the traces from creating the omphalos are still clearly visible. It was made by leaving the center of the pot thicker, then turning the vessel around and cutting away the excess clay around the navel in a circular motion. The traces of this are still visible on this sherd (cf. Jacobs, this volume). In addition, there are some fine and thin scratches visible on the bottom, indicating a stirring motion by a rather soft, non-abrasive tool. The upper inner wall of the vessel is also worn and somewhat abraded. The vessel was handled a lot considering that the bottom shows evidence of having been shoved around. The bowl has ORA signatures from a fruit product (Rageot et al. 2019b; Mötsch et al. in BEFIM 2, Kat. 101).

Context/Befund 192 (Ha D3)

Three samples derive from the deposits of a living floor, *Befund* 192: two fragments of small bowls (HB-VB-052; HB-VB-054) and part of the neck of a bottle (HB-VB-053). HB-VB-052 did not display use-wear traces, but the manufacturing traces from scraping and smoothing the inside of the vessel were still visible. Interestingly, HB-VB-052 had signatures of beeswax (Mötsch et al. in BEFIM 2, Kat. 80; Rageot et al. 2019b), possibly suggesting, again, that beeswax may have been a sealant. This not only prevented liquids permeating through the vessel's skin, but may also have protected the original surface of the pot, along with the manufacturing traces present, against damage from stirring or from the effect of e. g. acidic substances. Additionally, signatures from animal fat and plant wax were demonstrated (Mötsch et al. in BEFIM 2, Kat. 80; Rageot et al. 2019b).

Bowl HB-VB-054 was overall slightly worn with no other specific traces visible except for a very small area with battering traces that could possibly be due to post-depositional processes. ORA showed the presence of traces of animal fat and millet (Rageot et al. 2019b; Mötsch et al. in BEFIM 2, Kat. 82). The inside rim of bottle HB-VB-053 (Fig. 10a) was heavily rounded, displaying polish with a downward directionality, indicating the presence of some kind of stopper (Fig. 10b). The vessel was used even after it had got damaged with a flake being taken off the rim. The ridges of the flake negative are worn and rounded, indicating that the bottle was used after this damage occurred. It displayed the same organic residue as HB-VB-054: animal fat (probably milk or a milk product) and millet (Mötsch et al. in BEFIM 2, Kat. 82; Rageot et al. 2019b).

Context/Befund 84 (Ha D3)

From this context, dated to the Ha D3 period (Mötsch et al. in BEFIM 2, 128), three highly micaceous, fluted sherds were analyzed, one of which was wheel-thrown (HB-VB-030, no ORA). HB-VB-029, did not reveal any traces of use, as it was generally too affected by post-depositional processes. ORA has revealed traces of animal fat and possibly of a fruit product (Mötsch et al. in BEFIM 2, Kat. 78; Rageot et al. 2019b). HB-VB-030 (Fig. 11a) has a rounded rim with fine scratches (Fig. 11b) with some use-wear polish visible as well. This vessel must have been handled and used for a considerable amount of time. HB-VB-031 has a lot of thin, parallel scratches on the inside from stirring as well as abrasion. The rim also displays transversely oriented scratches interpreted as coming from a ladle hanging over the rim. This find has produced traces of animal fat, probably milk or a milk product (Mötsch et al. in BEFIM 2, Kat. 79; 120; Rageot et al. 2019b).

Context/Befund 178 (Ha D3)

Five sherds were analyzed from *Befund* 178, probably a sunken-featured building or pit house (*Grubenhaus*) dating to Ha D3. One bottle, HB-VB-034, did not display traces of wear but showed traces of wax, fat and a grape product, as well as from a bacterial fermentation product. A second bottle, HB-VB-056, has a slightly worn rim, possibly related to the bottle having been covered. Bowl HB-VB-032 shows rounding and abrasion of the rim, whereas the other bowl from this context that was studied, HB-VB-033, displayed traces of battering or impact on the inside of the vessel, the origin of which remains unclear. This sherd, too, has traces from handling on the outside body as well as evidence for bumping, probably into other vessels. The inside wall still displays manufacturing traces from scraping and smoothing.

The last find studied from *Befund* 178 was a miniature vessel, HB-VB-057 (Fig. 12a), showing several zones with use-wear traces. Striations are visible on the interior of the rim, possibly from a metal ladle that was leaning on the edge (Fig.12b). The bottom has a greasy, domed polish of unknown origin on the interior surface. There are also striations on the bottom, but they lack the circularity common to a stirring motion. It is more likely that something was crushed inside the vessel, e. g. seeds (Fig. 12c). The rim, as well as the outer body, has evidence for considerable

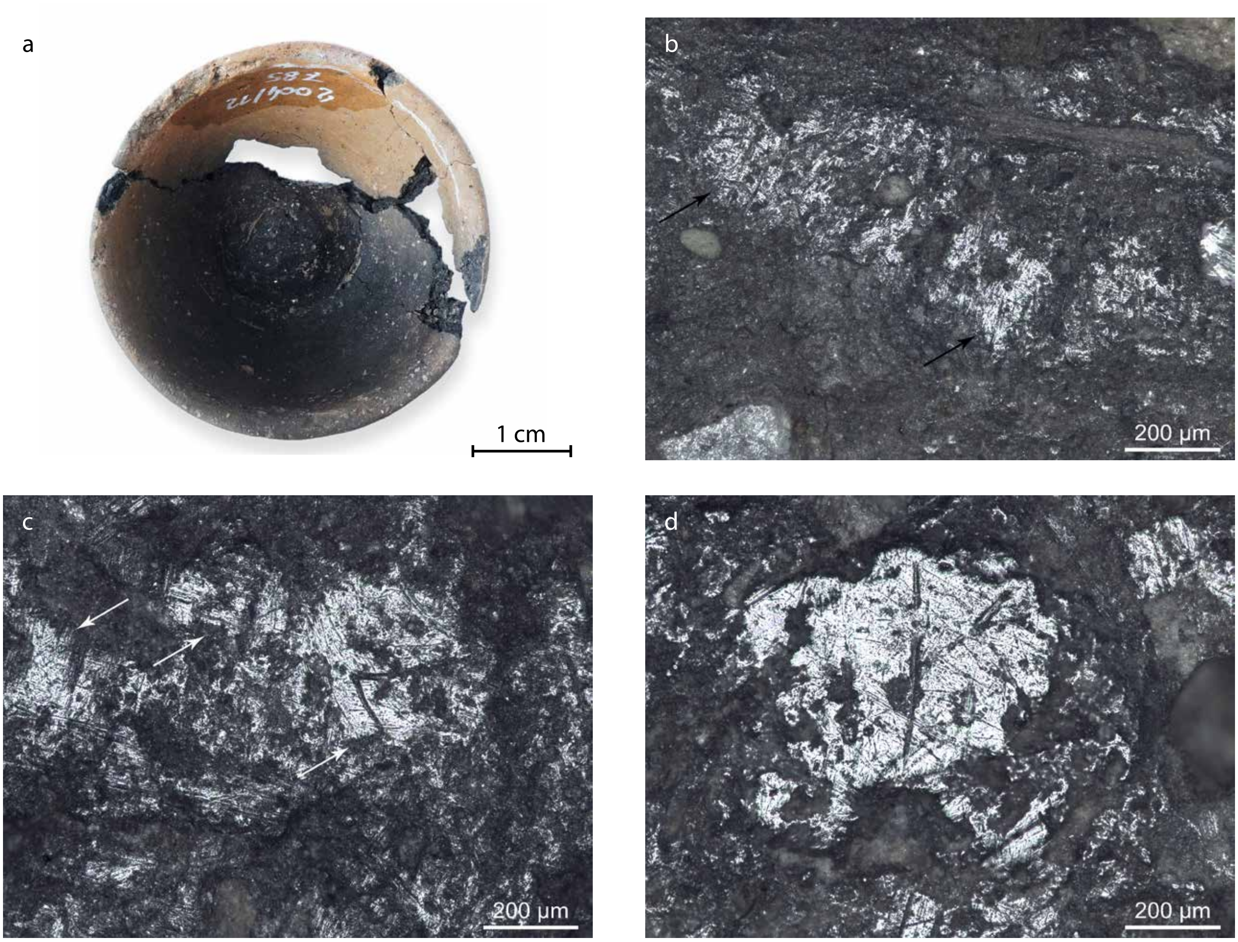

Figure 12: Miniature vessel HB-VB-057. (a) Overview. (b) Polish on the inside of the rim, possibly from a spoon or other utensil leaning against the edge. (c) Greasy polish and striations with variable directionality seen inside vessel bottom, possibly from crushing a hard substance. (d) Polish on the bottom of the vessel. Fig. 12b-d were taken with a metallographic microscope with 100x original magnification (© a = A. Mötsch, b, c = Laboratory for Material Culture Studies Leiden University).

Figure 13: Open bowl HB-VB-002. (a) Overview. (b) Detail of the inner bottom showing attrition and exposed temper. (c) Polish on the bottom of the vessel, indicating considerable shoving around on a hard surface (metallographic picture, 100x original magnification; © a = A. Mötsch, b, c = Laboratory for Material Culture Studies Leiden University).

handling. The outside bottom of the vessel has polish and testifies to much shoving around on a hard surface (Fig. 12d). Unfortunately, this vessel was not sampled for organic residue analysis.

Context/Befund 455 (Ha D3)

Five vessels from this context were studied: three bowls, one bottle and one goblet. Bowl HB-VB-002, low and open in shape, displays a very worn inner bottom and lower belly (Fig. 13a.b). The attrition visible, especially in the lower part of the vessel, has been interpreted as being due to stirring, probably with a wooden spoon (Fig. 13b). The pressure of the spoon was most intense in the lower area of the bowl as scratches gradually diminish in intensity going up the vessel wall. The stirring caused the thin skin (or self-slip) to be removed, exposing the temper underneath. The pot seems intensively used as the exterior of the bottom is very rounded and polished (Fig. 13c), as are the outside rim and shoulder. No ORA was conducted. Bowl HB-VB-035 with an omphalos has a lot of scratches, long and thin on the inside, probably related to the shaping of the omphalos. It may contain traces of a fruit product (Mötsch et al. in BEFIM 2, Kat. 83; Rageot et al. 2019b). The third bowl, HB-VB-037 (Fig. 14a), including a rim and shoulder fragment, displays different traces of use. The external shoulder has battering traces from bumping into other vessels (Fig. 14b). The inside surface shows scratches from stirring and some pitting (Fig. 14c), but no organic residue was detected (Rageot et al. 2019b). The rim is lightly worn. Some of the scratches go all the way up the vessel wall and

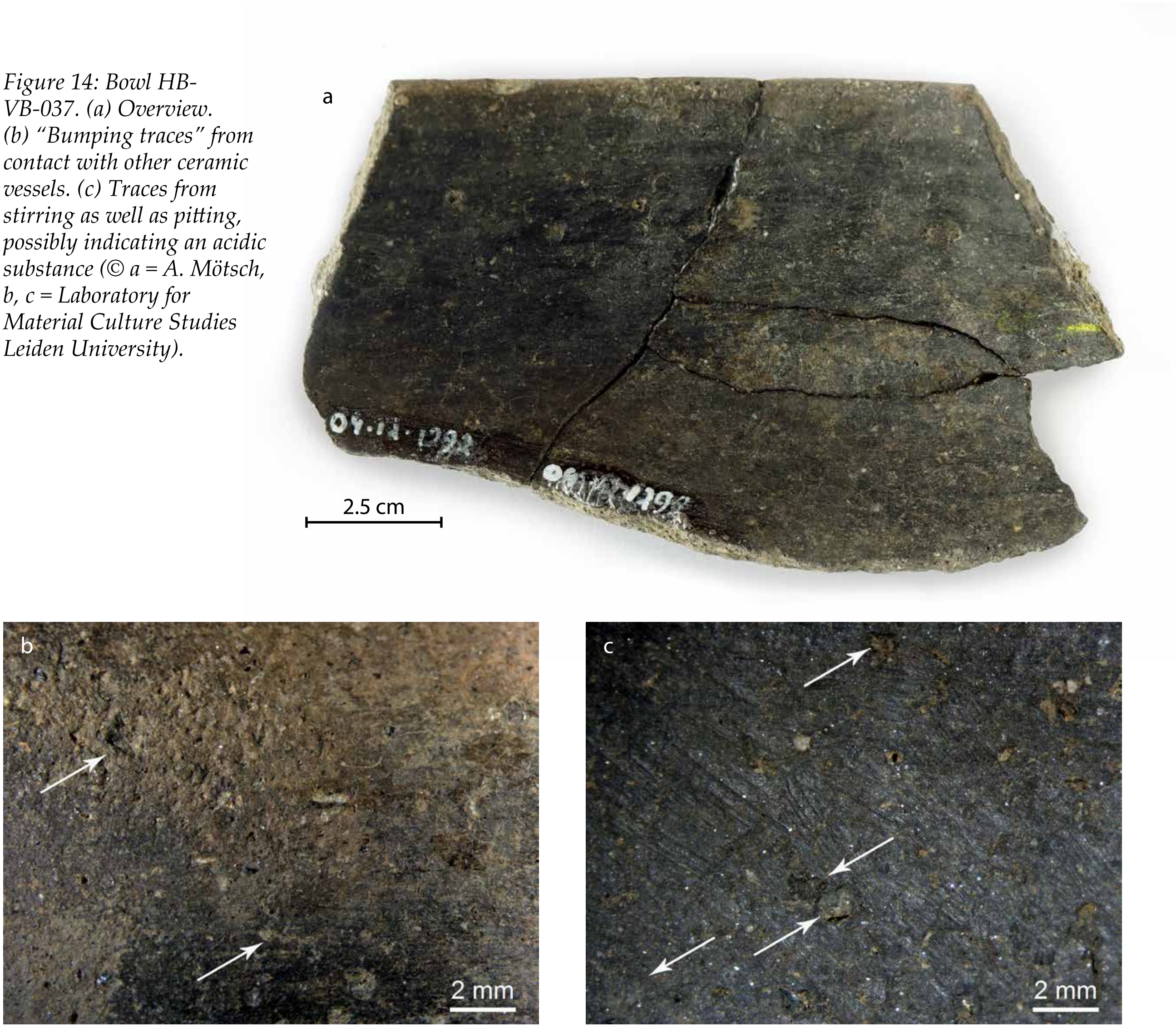

Figure 14: Bowl HB-VB-037. (a) Overview. (b) "Bumping traces" from contact with other ceramic vessels. (c) Traces from stirring as well as pitting, possibly indicating an acidic substance (© a = A. Mötsch, b, c = Laboratory for Material Culture Studies Leiden University).

were interpreted as being related to cleaning. This vessel therefore has been used for a considerable amount of time and was possibly related to preparation, serving and/or drinking of an acidic substance. Find HB-VB-036 is a rim of a goblet which does not reveal much in terms of its past use, except that the edge of the shoulder has some damage suggesting the vessel bumped into other vessels during storage. However, as this constitutes the very edge of the sherd, it cannot be excluded that this was post-depositional damage. Organic residue analysis revealed traces of animal fat, beeswax and possibly a fruit product (Mötsch et al. in BEFIM 2, Kat. 84; Rageot et al. 2019b). Lastly, bottle HB-VB-001 did not display any diagnostic traces of wear, but organic residue analysis revealed traces of a fruit product, probably grape wine (Mötsch et al. in BEFIM 2, Kat. 87; Rageot et al. 2019b).

Outer Settlement, Old Excavation (*Außensiedlung*, HB-AS series)

A total of 27 sherds were analyzed from the Outer Settlement. All of these were characterized as *Feinkeramik* with the exception of HB-AS-034 and HB-AS-035 (Mötsch et al. in BEFIM 2, Kat. 109; 110) which were listed as *Grobkeramik*. None of the finds that we examined were wheel-thrown. Of these, 18 showed traces of wear, six had no traces and three sherds were not interpretable. Twelve of the 18

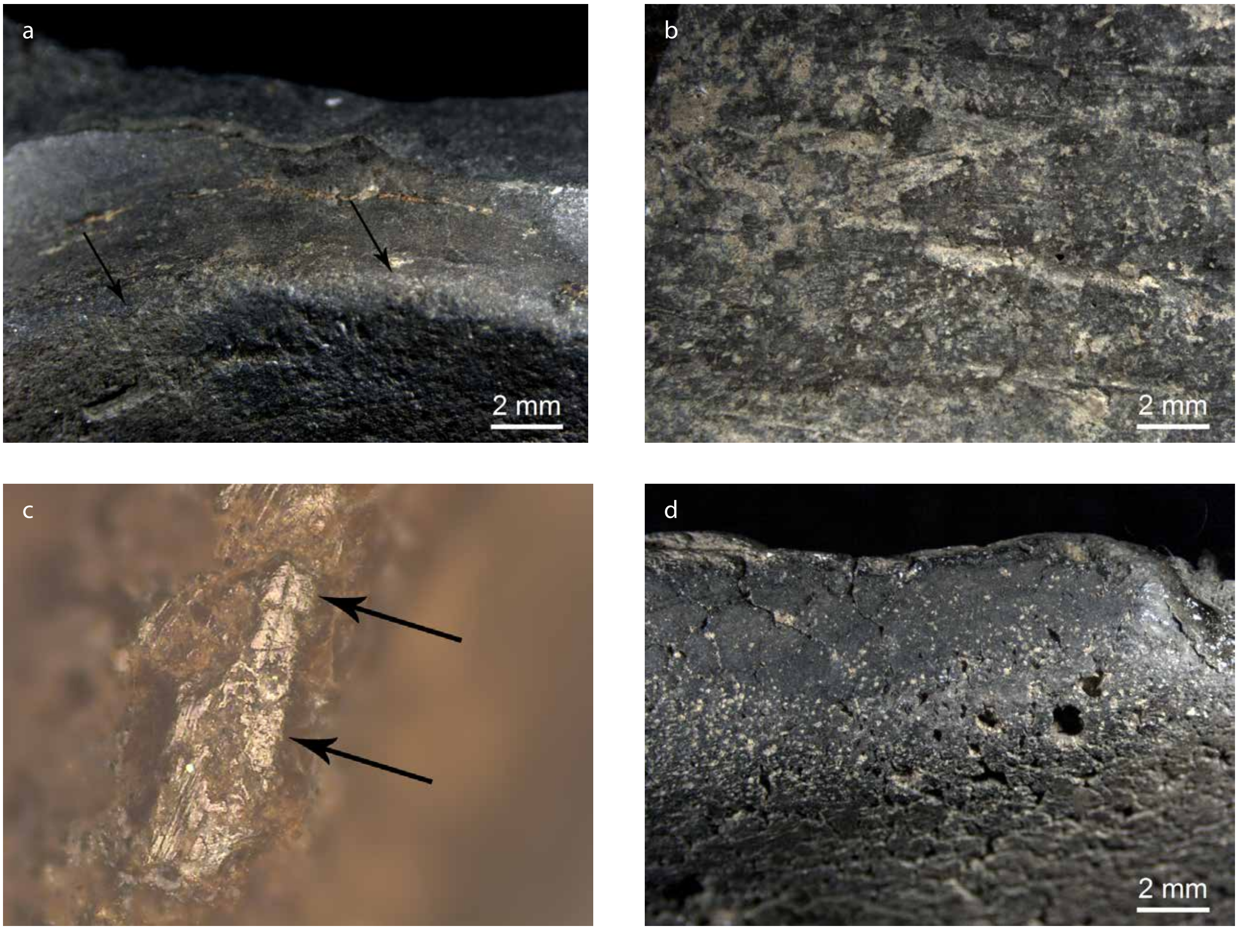

Figure 15: Some used vessels from Heuneburg-Outer Settlement (Außensiedlung). (a) Worn bottom of bowl HB-AS-017. (b) Stirring traces on bottle HB-AS-002. (c) Striations and polish on and just below the rim of HB-AS-027. The polish spot on top with vague directionality is probably related to the use of a spoon for serving (made by metallographic microscope, 100x original magnification). (d) Pitting and abrasion seen on the internal bottom of HB-AS-027 (© Laboratory for Material Culture Studies Leiden University).

used sherds had only one location with wear traces, four had two zones, whereas two sherds had three and four used locations respectively. The total number of used zones therefore amounts to 27, located on 18 sherds. Only in four cases was it possible to infer the contact material (Tab. 2). As the finds derive from a large variety of find contexts, only the most informative ones will be described in detail below, specifying the results from the organic residue analysis wherever this was done.

Most of the finds examined displayed general wear or abrasion. As these finds were excavated between 1950 and 1985 and were handled a lot in museum and research context, their surfaces were not always ideal for microwear analysis. This explains the lack of specific inferences that could be made. However, it is clear that the majority of these vessels were used and handled considerably in the past as well, testifying to their roles in past food and drinking practices at this area of the Heuneburg. It also explains why so many locations with wear showed traces which could not be interpreted in terms of contact material (n = 23), eleven of which also proved insufficiently diagnostic to infer the motion or activity involved. Yet, in a few cases the traces were characteristic enough to go beyond very general or uncertain statements.

One bowl fragment (HB-AS-017) displayed evidence from stirring with an unknown utensil. The outer wall of the vessel shows signs of extensive handling and contact with

Table 2: Results of the microwear analysis of the Outer Settlement (Außensiedlung), cross tabulation of inferred contact material and motion, per location.

Contact material	Stirring	Covering	Bumping	Handling	Shoving	Edge damage	General wear	Unsure	Total
Pottery	-	-	1	-	-	-	-	-	1
Metal	1	-	-	-	-	-	-	-	1
Hard material	-	1	-	-	-	-	-	-	1
Coarse material	-	1	-	-	-	-	-	-	1
Unsure	3	1	-	2	4	1	1	11	23
Total	4	3	1	2	4	1	1	11	27

other pots, e. g. on an overcrowded storage zone where pots would repeatedly touch each other, as well as an abraded bottom rim, indicating that the vessel had been shoved around a lot (Fig. 15a). The base of a painted cist (HB-AS-012; Mötsch et al. in BEFIM 2, Kat. 114) displays a worn bottom, and rounding and smoothing on the transition between body and bottom of the vessel, indicating considerable shoving. Inside there are circular scratches that were related to manufacture rather than use. Two more bottom sherds also display evidence of having been shoved around, probably the result of frequent handling on a table or in a storage area (HB-AS-020; HB-AS-025). Two rim sherds of bowls (HB-AS-018; HB-AS-028) have traces of having been covered by a hard or medium hard material, a cover of wood or maybe pottery. Three sherds (HB-AS-007; HB-AS-016; HB-AS-017) have evidence for stirring, but the material the utensil was made of could not be ascertained.

Only seven finds were subjected to both microwear analysis and ORA. Find HB-AS-002, a bottle, displays scratches along the vessel wall that resemble the scratches obtained experimentally from a metal spoon (Fig. 15b). ORA of this vessel showed traces of beeswax, plant wax, grape products (probably wine) and bacterial fermentation products (Mötsch et al. in BEFIM 2, Kat. 111; Rageot et al. 2019b). Microwear analysis of goblet HB-AS-027 showed abrasion on both the rim and the bottom of this vessel (Fig. 15c.d). The inside surface was *craquelé* and the skin of the vessel removed, exposing the fine fraction of mineral temper. As some fine scratches are visible mainly towards the lower end of the sherd, stirring may have taken place, but a post-depositional cause cannot be excluded. A *craquelé* surface occurs during polishing when the outer skin (usually consisting of finer particles) is drier than the core of the vessel wall, which results in fine cracks (Jacobs, this volume). This causes an instability of the inner surface, which we assume could facilitate the removal of flakes. Organic residue analysis of HB-AS-027 showed traces of beeswax, fat, bacterial fermentation markers and fruit products, possibly grape wine (Mötsch et al. in BEFIM 2, 118; Rageot et al. 2019b).

The second goblet (HB-AS-029) was not considered suitable for microwear analysis as the inner surface also displayed heavy *craquelé* and extensive breaking up of the skin. Signatures of beeswax and fruit products, probably grape wine, were demonstrated by Rageot (Mötsch et al. in BEFIM 2, Kat. 119; Rageot et al. 2019b; Schorer et al. in BEFIM 1, 55). The third goblet (HB-AS-030) has an abraded rim and shows long and thin scratches on the inside wall, with a variable directionality. The inside surface is also *craquelé*. Organic residue analysis revealed traces of beeswax and fruit products, probably grape wine, as well as bacterial fermentation markers (Mötsch et al. in BEFIM 2, Kat. 120). It is remarkable that these three goblets all show the same use-wear features (a *craquelé* surface and extensive flaking and breaking up of the inner surface) in combination with signatures of grape wine. Although it may well be that the flaking, facilitated by the *craquelé* surface, was the result of contact with grape wine, we do not dare to draw this conclusion in view of the poor state of preservation.

One bowl (HB-AS-013) scored on animal fat, plant wax and bacterial fermentation markers (Mötsch et al. in BEFIM 2, Kat. 115; Rageot et al. 2019b). Again, the inner surface shows *craquelé,* but no flaking was seen. Traces of production on the interior of the pot, including scraping and polishing marks, are still visible. The rim is rounded, but this could also be due to post-depositional causes. This is a beautifully made, very thin coiled bowl which must have required a highly experienced potter to make. No traces of use have been observed on this vessel.

Last, two very large, thick walled pots (HB-AS-034; HB-AS-035), described as *Grobkeramik* and tempered with calcite, were analyzed for both wear traces and the presence of organic residue. No clear traces of use were detected, due to the very coarse fabric of these vessels. Both display a lot of rather rough, irregularly shaped pitting which was interpreted as the result of the firing process during which the very coarse calcite temper could have burned out of the vessel walls (cf. Jacobs, this volume). HB-AS-034 has residue from wax, possibly fat, a fruit product (probably grape wine) and bacterial fermentation products (Mötsch et al. in BEFIM 2, Kat. 109; Rageot et al. 2019b). ORA of HB-AS-035 demonstrated the presence of heated animal fat and plant wax (Mötsch et al. in BEFIM 2, Kat. 110; Rageot et al. 2019b), but no traces of use were observed.

Plateau (*Plateau*, HB-PL series)

From the Plateau only 15 finds have been examined for traces of wear, all of them deriving from *Befund* 1002, from the 2015 excavations. They all come from a sunken-featured building (*Grubenhaus*) in the Plateau settlement area, dating to period Ha D1 (settlement periods IVa-IVb) and were part of object/inventory numbers 2008-46-1605 through 2008-46-1623 (Mötsch et al. in BEFIM 2, Kat. 50-66). In total, only six of the 15 examined finds actually displayed wear traces (Tab. 3).

Five of the sherds with traces had only one used zone, one had two. Many of the sherds displayed post-depositional surface modification resulting in a large number of finds that could not be interpreted. The interpretations of vessel use described below constitute the best explanation for the traces we observed, but it cannot be excluded that we mistook some of the post-excavation damage for traces of wear. This is especially the case with the observed wear traces on the rims, as this part of the vessel is most vulnerable to being damaged.

We found evidence for stirring with a utensil which could not be further specified on the inside of a cupped foot, perhaps of a goblet or bowl (HB-PL-009) (Fig. 16a). The outer rim of this foot is somewhat abraded, possibly from being shoved around. Organic residue analysis showed traces of animal fat (milk or milk products, probably heated), beeswax, plant wax and millet (Mötsch et al. in BEFIM 2, Kat. 57; Rageot et al. 2019b). Three rim sherds of bowls had evidence for having been covered with an unknown coarse material, maybe a piece of cloth of hemp or another coarse plant fiber (HB-PL-001; HB-PL-002; HB-PL-019) (Fig. 16b.c). HB-PL-001 scored animal fat (milk or milk product), plant wax and millet, HB-PL-002, as well as

Contact material	**Stirring**	**Covering**	**Bumping**	**Handling**	**Shoving**	**Total**
Hard material	-	-	1	-	-	1
Coarse material	-	3	-	-	-	3
Unsure	1	-	-	1	1	3
Total	1	3	1	1	1	7

Table 3: Results of the microwear analysis of the Plateau, cross tabulation of inferred contact material and motion, per location.

beeswax (Mötsch et al. in BEFIM 2, Kat. 5-6; Rageot et al. 2019b). HB-PL-019 was the only of the 2008-46 series that we looked at for microwear which had signatures of a grape product, probably wine; it also has traces of millet (Mötsch et al. in BEFIM 2, Kat. 66; Rageot et al. 2019b). It concerned a rim/shoulder sherd of a thin, very well-made graphitized bowl. There was also evidence for bumping (HB-PL-006), shoving (HB-PL-009) and handling (HB-PL-014) (Mötsch et al. in BEFIM 2, Kat. 55; 57; 61), indicating that the vessels from this area were also intensively used and handled.

The functional integrity of different vessel types

An important research focus was the relationship between vessel type and the activity they were involved in. Most of the typological classifications of pottery are based on their resemblance to present-day examples of vessel shapes like bowl, vase, cup and so forth. All of these classifications have a functional connotation: their name already suggests that we know how they were used. This is not always the case and there is substantial fluidity between the supposed primary function of a vessel and its actual usage or usages. Bottles, probably intended for storage of beverages, can also be used to drink from directly, whereas cups could not only be used for drinking, but

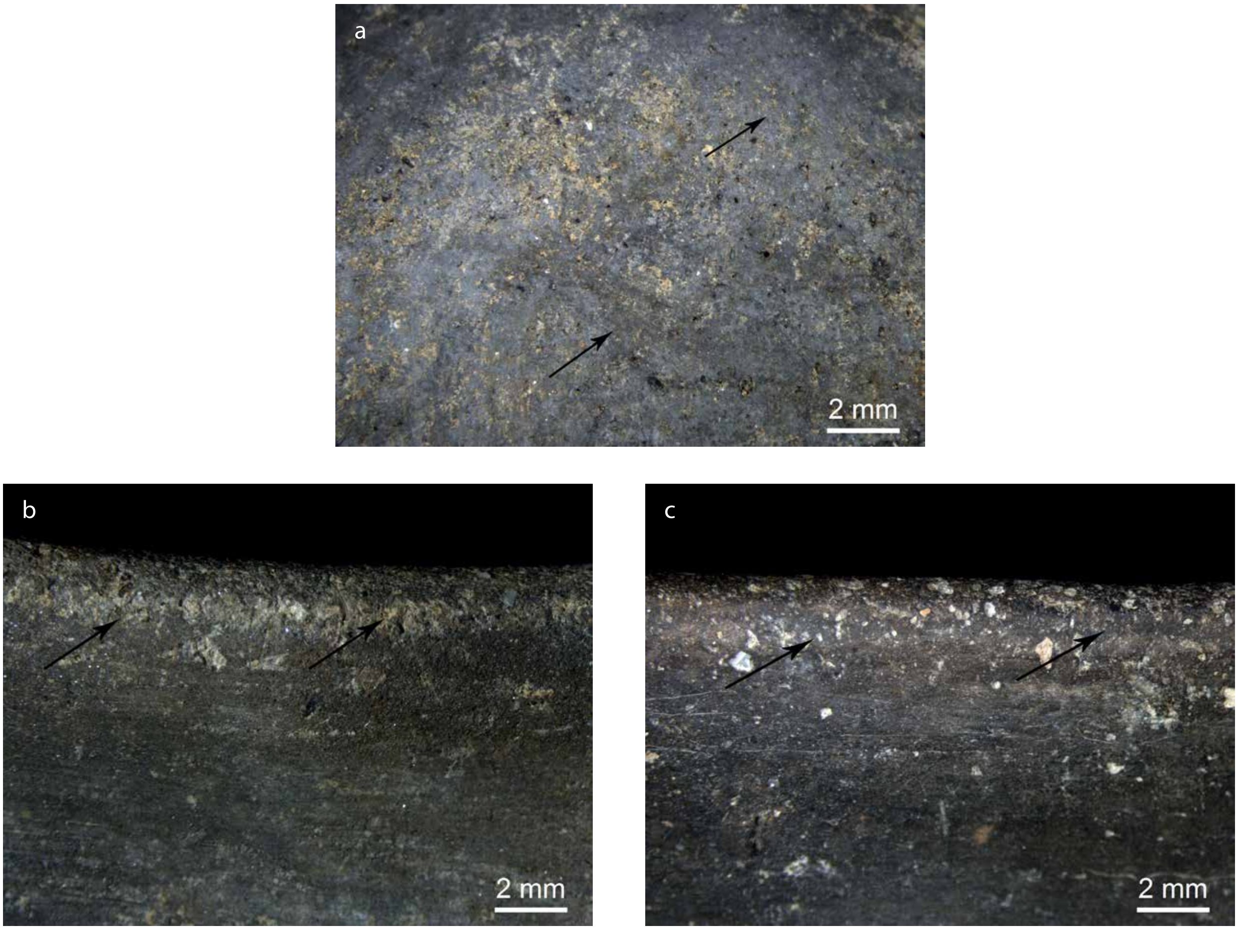

Figure 16: Traces observed on some of the vessels from the Heuneburg Plateau. (a) Inside bottom of cupped foot of a bowl or goblet (HP-PL-009) displaying smoothing of the surface and fine circular scratches indicating a stirring motion. (b) Wear traces from covering on the outside rim of bowl HB-PL-001. (c) Wear traces from a cover of coarse material (like a woven fabric of e. g. hemp) on the outside rim of bowl HB-PL-002 (© Laboratory for Material Culture Studies Leiden University).

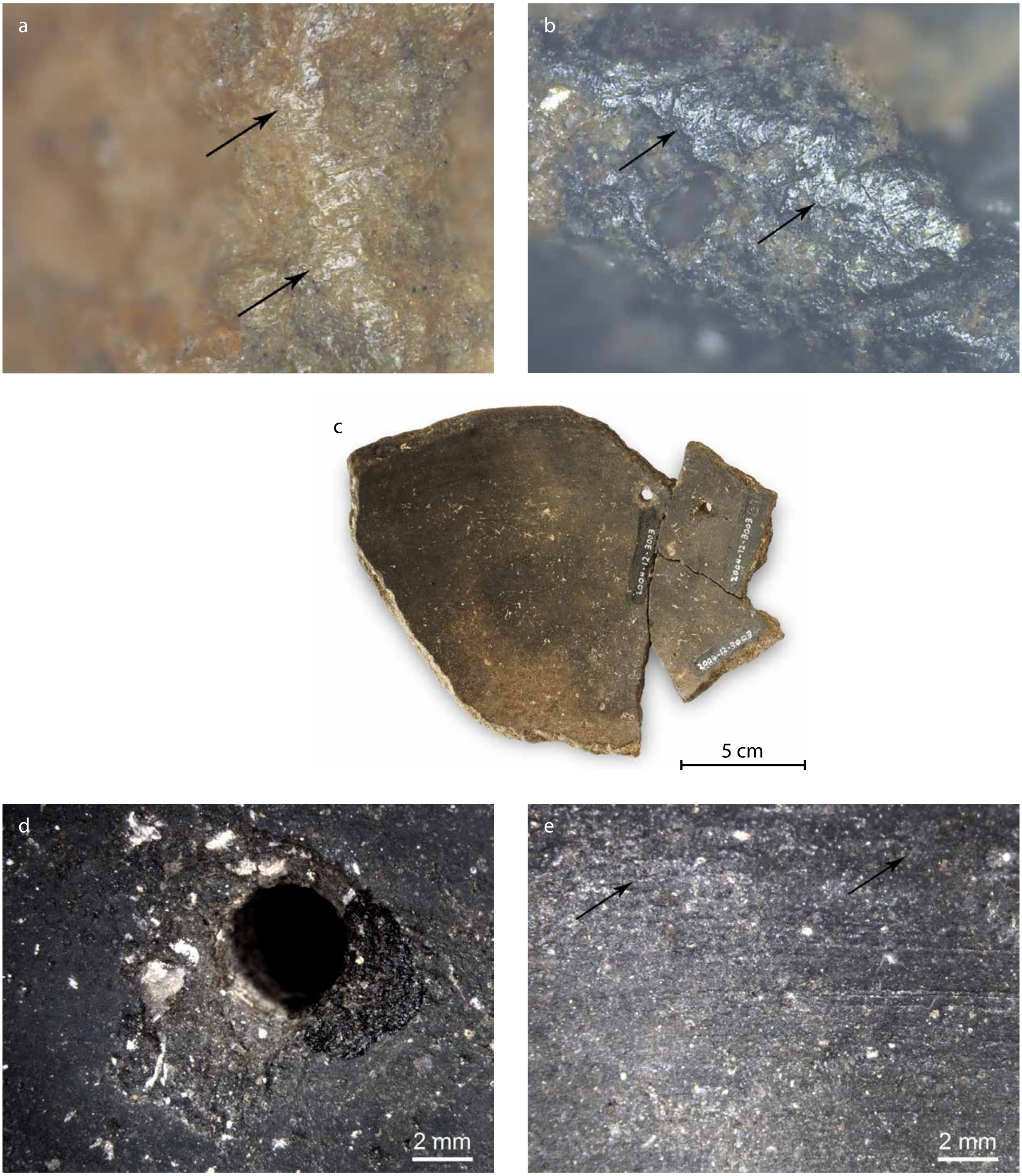

Figure 17: Traces observed on vessels HB-VB-007 and HB-VB-023. (a) Polish from a ladle on the inside of the rim, showing a transverse directionality on HB-VB-007 (made by metallographic microscope, taken at 100x original magnification (OM)). (b) Polish from a ladle on the outside of the rim, showing a transverse directionality on HB-VB-007 (made by metallographic microscope, 100x OM). (c) Repair hole with adhesive on HB-VB-023, overview. (d) Repair hole with adhesive on HB-VB-023, detail. (e) Long thin scratches present only in the upper part of the vessel wall, possibly a result of cleaning seen on HB-VB-023 (© c = A. Mötsch, others = Laboratory for Material Culture Studies Leiden University).

Vessel type	Stirring	Battering	Covering	Pitting	Cleaning	Scraping/ cleaning	Bumping	Handling	Shoving	Handling/ bumping	Hanging spoon	Repair	Multiple	Unsure	Total
Beaker	1	1	-	-	-	-	-	4	-	-	-	-	1	3	10
Bottle	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Bowl	13	-	7	2	2	1	5	8	10	1	6	1	1	6	63
Cone-necked vessel	-	1	-	1	1	-	-	-	-	-	-	-	-	2	5
Cup	1	-	-	-	-	-	-	-	-	-	-	-	-	1	2
Cupped foot of unknown vessel	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2
Cylindrical necked vessel	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Flagon (*Flasche*)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Funnel	-	-	-	-	-	-	-	1	-	-	-	-	-	2	3
Goblet	-	-	-	-	-	-	1	1	-	-	-	-	-	6	8
Miniature vessel	-	-	-	-	-	-	-	1	1	-	1	-	-	1	4
Painted cist	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Pot	-	-	1	2	-	-	-	-	1	-	2	-	-	-	6
Small bowl	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Small pot	-	-	1	1	-	-	-	-	1	-	-	-	-	-	3
Small vessel	-	-	-	-	-	-	-	-	1	-	-	-	-	3	4
Vessel	-	-	-	1	-	-	-	-	-	-	-	-	-	1	2
Total	18	2	13	7	3	1	6	15	16	1	9	1	2	26	120

Table 4: Inferred motion per vessel type (represented are the 120 locations of wear that were observed by means of microwear analysis).

can also serve as a (temporary) storage vessel. In the following the most commonly occurring vessel types in the assemblage studied will be discussed in terms of their functional integrity. The results are displayed in Tab. 4 and 5.

Bowls

The most frequently studied vessel type were bowls (n = 48), which displayed 63 locations of use on 32 bowls. The predominant traces displayed were from stirring (n = 13), shoving (n = 10) and handling (n = 9). On those locations where traces of stirring were observed, it was sometimes possible to infer the kind of stirring tool: it concerned a wooden spoon (n = 1) and spoons of coarse-grained material (n = 4). Some rims (n = 6) showed traces most likely related to a ladle hanging over the edge of the bowl that also made contact with the inside of the vessel (van Gijn et al., this volume). In one case this was probably a metal ladle, in the other cases the material of the ladle could not be inferred. Bowls were obviously heavily used, displaying a variety of traces from consumption, storage and cleaning. In terms of their content, two sherds displayed pitting, perhaps due to an acidic substance. Some of these bowls were covered (n = 7), two locations with a ceramic lid, four with an unknown coarse material, one with hard material and one with an unknown material. Bowls actually also displayed quite a bit of bumping traces, either against each other (n = 5) or against hard objects in general. They were also shoved around (n = 10) and showed signs of abrasion. They were therefore clearly heavily used and handled and seemed to have had an important role in food consumption. They never displayed any evidence for cooking, but obviously that is due to the sampling strategy (see above). The fact that some had signs of having been covered, suggests that they may have played a role in storing as well.

As to the contents of these bowls, there is little evidence from the perspective of microwear traces. In some instances, pitting was observed which is possibly related to an acidic substance like wine, but extensive spalling from fermentation, such as seen

Vessel type	Acidic substance	Cloth	Wooden spoon	Pottery	Metal	Rope and tar	Medium material	Hard material	Coarse material	Unsure/ diverse	Total
Beaker	-	-	-	-	-	-	-	-	-	10	10
Bottle	-	-	-	-	-	-	-	-	-	2	2
Bowl	2	-	1	6	1	1	1	1	10	40	63
Cone necked vessel	1	-	-	-	-	-	-	-	-	4	5
Cup	-	-	-	-	-	-	-	-	-	2	2
Cupped foot of unknown vessel	-	-	-	-	-	-	-	-	-	2	2
Cylindrical necked vessel	-	-	-	-	-	-	-	-	-	1	1
Flagon (*Flasche*)	-	-	-	-	1	-	-	-	-	1	2
Funnel	-	-	-	-	-	-	-	-	-	3	3
Goblet	-	-	-	1	-	-	-	-	-	7	8
Miniature vessel	-	-	-	-	1	-	-	-	-	3	4
Painted cist	-	-	-	-	-	-	-	-	-	1	1
Pot	2	1	-	-	-	-	-	-	-	3	6
Small bowl	-	-	-	-	-	-	-	1	-	1	2
Small pot	1	-	-	-	-	-	-	-	-	2	3
Small vessel	-	-	-	-	-	-	-	-	-	4	4
Vessel	1	-	-	-	-	-	-	-	-	1	2
Total	7	1	1	7	3	1	1	2	10	87	120

Table 5: Inferred contact material per vessel type (represented are the 120 locations of wear that were observed by means of microwear analysis).

on some of the pottery from Vix-Mont Lassois, is largely absent from these bowls (Verbaas/van Gijn-Vix, this volume). Our experiments have shown that sealing this type of pottery fabric with beeswax prevents the evaporation and leaching out of liquids (Verbaas/van Gijn- Permeability, this volume). It may equally have been some sort of protection against the abrasive effect of stirring and/or the attack from acidic substances.

The analysis of the bowls shows them to be highly diverse in terms of observed traces. Food or drinks were stirred in them, possibly mixing different ingredients. Organic residue analysis has similarly shown signatures of a mix of substances in many of the vessels (Mötsch et al. in BEFIM 1 and BEFIM 2; Rageot et al. 2019b; Schorer et al. in BEFIM 1). Obviously, it is not known whether these represent subsequent uses leading to these different signatures, but it may well be that herbs and/or honey were mixed with drinks. The combination of "battering" traces with stirring and pitting suggests that foodstuffs were ground fine inside the vessel in order to mix them with the liquids. The bowls were also used to consume from, as we have traces of the use of ladles or spoons that hung from the rim and were used to transfer and serve the contents of the bowl. Some bowls were also most likely used for storage as we have evidence that some were covered with a lid or with a cover of coarse material, probably plant based (hemp for instance). Last, there is abundant evidence for handling: although some of the traces of handling and bumping may be post-excavation damage (van Gijn et al., this volume), the specific, restricted locations of many of these handling and shoving traces suggest them to be related to intensive and/or long-term use.

The number of finds analyzed for the Outer Settlement and the Plateau was too limited to see whether there were any differences in the form/function relationship between the different areas within the Heuneburg. In any case, a multifunctional role for bowls seems to be visible in the Lower Town Settlement, the Outer Settlement and on the Plateau.

Beakers

A total of ten locations were observed on seven beakers, another type of vessel that is intuitively (and hence typologically) connected with liquids. These showed traces of handling (n = 4), stirring (n = 1) and battering (n = 1). One location showed traces of multiple activities. Contact materials could not be assessed, but the evidence makes clear that beakers were extensively handled and must have had a relatively long use life, just like the bowls.

Cone-necked vessels

One sherd of a cone-necked vessel displayed evidence of pitting, possibly related to it having contained an acidic substance such as wine. This type of vessel is often interpreted as being connected to storage and serving. We also observed traces of cleaning (n = 1) and battering (n = 1) on sherds from this type of vessel.

Other pot types

Traces of pitting, probably related to contact with an acidic substance, were observed on three other sherd locations, all of them classified as "pots". For all other vessel types the numbers were really too small to assess the relationship between vessel type and kind of traces. A number of vessels of different shape, like small bowls and pots, showed evidence for having been covered, which may be related to storage but could also indicate that mixtures of ingredients were left to react/mature. Other types of traces possibly related to drinking habits could be those from stirring, observed on sherds from a cup, a bottle and a cupped foot of a goblet or bowl. Evidence for handling is present on sherds from a goblet, a funnel and a miniature vessel, and the relatively frequent occurrence of locations with traces from shoving pots around (n = 16) similarly suggests frequent use of and interaction with these pots.

Some examples of interesting vessel biographies

Several finds displayed multiple types of traces that shed light on their biography and the way they were handled and used. As the following finds did not come from secure or informative find contexts they were not described above. A few examples of such more detailed biographies are given below in order to show the complexity of use-wear analysis of sherds and pottery.

HB-VB-007 Bowl

This very well-made, thin bowl comes from *Befund* 1374. The vessel was certainly made by coiling. The inside and the outside of the rim show polish and rounding, most probably due to contact with a bent spoon that was hanging from the rim (Fig. 17a.b). The bottom sherd is polished, indicating that this vessel was heavily handled, and shows signs of having been shoved around.

HB-VB-023 Bowl

This bowl fragment from *Befund* 1611, consisting of two body sherds, has a fracture that was repaired with two drilled holes. On one side of one of the perforations, wear traces are visible as well as some black residue, possibly an adhesive (Fig. 17c.d). These perforations certainly were not made to facilitate hanging this pot by a rope, as the characteristic one-sided rounding associated with such an arrangement is lacking. Instead these perforations as well as the adhesive are associated with the repair of the bowl. The top part of the bowl displays long and thin scratches on the inside just below the rim, possibly due to cleaning (Fig. 17e). The lower part of the inner body has a rough and worn surface similar to what is seen on some other bowls and is suggestive of a stirring motion. The outer bottom displays traces of having

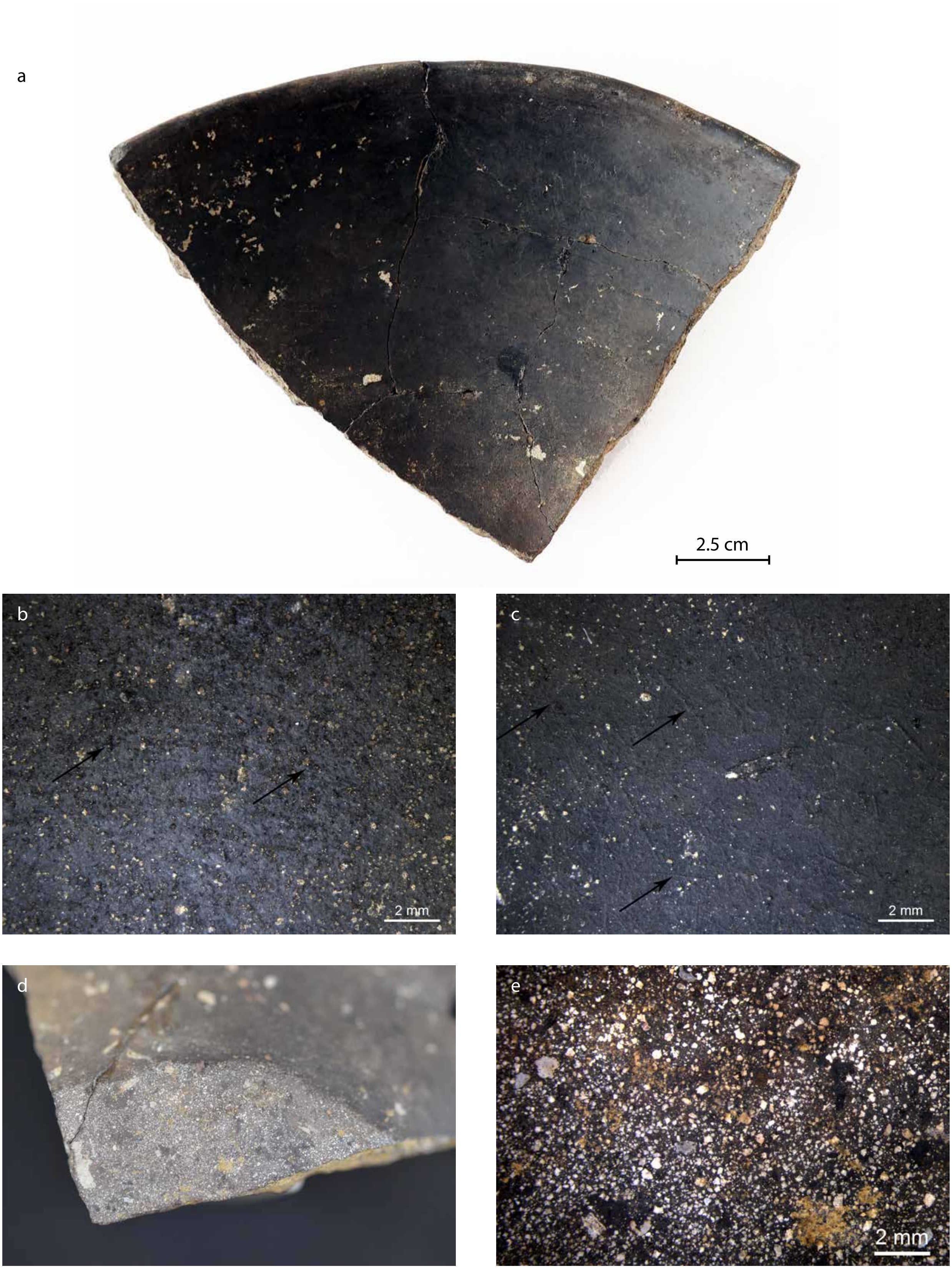

Figure 18: Traces seen on vessel HB-VB-048. (a) Overview of HB-VB-048, part of a bowl. (b) Tiny pitting seen on the inside bottom of the sherd. (c) Short, wide and slightly curving striations with variable direction. (d) Heavily worn outside bottom. (e) Exposed calcite temper from showing the vessel around, seen on bottom of Fig. 18d (© a = A. Mötsch, others = Laboratory for Material Culture Studies Leiden University).

been shoved around as well as some smooth polished areas: both features point to substantial handling of this vessel.

HB-VB-048 Bowl

HB-VB-048 (*Befund* 1693) is a hand-made bowl with a diameter of 23 cm, tempered with very fine calcite (cf. van Gijn et al. in BEFIM 1, 89-90 figs. 22-24) (Fig. 18a). On the interior bottom of the bowl the clay surface has been abraded, dislodging the temper particles, which results in irregularly shaped holes, sometimes referred to as inclusion loss (cf. Groat, this volume) (Fig. 18b). Thin, relatively short, multidirectional scratches can be discerned on the interior surface of the vessel wall (Fig. 18c). These scratches are visible all over the bottom of the bowl, vary in directionality and are probably due to a combination of stirring/spooning and cleaning. The exterior of the bottom is heavily worn, and the calcite temper is exposed (Fig. 18d.e), suggesting that this vessel has been shoved around on a table or in a storage area. The rim displays only lightly developed traces of use, with perpendicularly oriented striations on the inside of the rim. This wear pattern can be caused either by repeatedly resting a spoon or other tool against the rim or, alternatively, by hanging a spoon from the rim.

Conclusion

The microwear analysis of a selection of vessels from different contexts of the Early Iron Age hillfort of the Heuneburg has given us a glimpse of the life history of these vessels, their role in food and drinking practices and how they may have related to feasting practices of the inhabitants of the area. Vessels displayed evidence not only of stirring, mixing and the consumption of substances, but also of cleaning, extensive handling and storage. Many of the ceramic vessels must have had a long use life, considering the extent of the observed wear traces and the fact that one finds evidence for repair. Still, many of these sherds were in the ground for a long time, were excavated and also studied and handled extensively. The damage that resulted from these post-depositional and post-excavation processes made the analysis somewhat problematic. It was not always easy to distinguish secondary damage from damage related to the use life of the vessels. To be on the cautionary side, we did not push our inferences very far, leading to a considerable number of finds that were either not interpretable or with unsure traces.

The ceramic vessels may well have functioned in Celtic feasting practices, as quite a number showed evidence that substances were ladled out of them. It is interesting to note that all of the sherds with evidence for pitting, interpreted as having contained an acidic substance such as wine, come from the Lower Town Settlement. This concurs with the results of the organic residue analysis (Rageot et al. 2019b; Mötsch et al. in BEFIM 1; Schorer et al. in BEFIM 1) which also demonstrated wine consumption to have taken place at the Lower Town and Outer Settlement and not on the Plateau. Due to our sampling strategy only one find, HB-VB-026 from the Lower Town Settlement, showed both the microwear pitting and the grape wine signature. This is a beautiful, locally made vessel that almost seemed to have been made to look like a wheel-thrown pot. In contrast, the Plateau, where supposedly the more elite members of society resided, has produced no vessels with pitting, associated with acidic substances, nor with spalling of the inner surface, a feature that is generally associated with fermentation (Vuković 2009; Arthur 2002; 2003); spalling was seen on vessels from the Plateau Saint-Marcel at Vix-Mont Lassois (Verbaas/van Gijn-Vix, this volume). Our findings indicate that microwear analysis can also tell us a little about the contents of the vessels and not only about the gestures involved. However, it is the combination of organic residue analysis and microwear study that gives the most promising results for a better understanding of pottery function.

Acknowledgments

We would like to thank Maxime Rageot, Angela Mötsch and Birgit Schorer for their advice and their comments on an earlier version of this paper. Taking a first look at the Heuneburg material was done together with Loe Jacobs and Dennis Braekmans, whose insights were indispensable for our subsequent research. Eric Mulder made many of the photographs and was an invaluable help throughout the analysis of the material. Last, Nicholas Groat examined some Heuneburg sherds as part of his Leiden University MSc thesis, the results of which are summarized elsewhere (Groat, this volume).

Bibliography

Arthur 2002: J. W. Arthur, Pottery use-alteration as an indicator of socioeconomic status: The ethnoarchaeological study of the Gamo of Ethiopia. Journal Arch. Method and Theory 9, 2002, 331-335.

Arthur 2003: J. W. Arthur, Brewing beer: Status, wealth and ceramic use alteration among the Gamo of south-western Ethiopia. World Arch. 34/3, 2003, 516-528.

Bardel 2009: D. Bardel, Les vaisseliers céramiques des fouilles anciennes de Vix/le mont Lassois (Côte-d'Or): Bronze final IIIb, Hallstatt D et La Tène C/D. In: B. Chaume (ed.), La céramique hallstattienne de France orientale: Approches typologique et chrono-culturelle. Actes du colloque international de Dijon - 21 et 22 novembre 2006 (Dijon 2009) 69-152.

Bofinger 2005: J. Bofinger, Archäologische Untersuchungen in der Vorburg der Heuneburg: Siedlung und Befestigungssysteme am frühkeltischen Fürstensitz an der oberen Donau, Gde. Herbertingen-Hundersingen, Kreis Sigmaringen. Arch. Ausgr. Baden-Württemberg 2004 (2005) 82-86.

Bofinger 2006: J. Bofinger, Stein für Stein… Überraschende Befunde im Bereich der Befestigungssysteme der Heuneburg-Vorburg, Gde. Herbertingen-Hundersingen, Kreis Sigmaringen. Arch. Ausgr. Baden-Württemberg 2005 (2006) 73-78.

Bofinger/Goldner-Bofinger 2008: J. Bofinger/A. Goldner-Bofinger, Terrassen und Gräben: Siedlungsstrukturen und Befestigungssysteme der Heuneburg-Vorburg. In: D. Krausse (ed.), Frühe Zentralisierungs- und Urbanisierungsprozesse. Zur Genese und Entwicklung frühkeltischer Fürstensitze und ihres territorialen Umlandes. Kolloquium des DFG-Schwerpunktprogramms 1171 in Blaubeuren, 9.-11. Oktober 2006. Forsch. u. Ber. Vor- u. Frühgesch. Baden-Württemberg 101 (Stuttgart 2008) 209-227.

Chaume/Mordant 2011: B. Chaume/C. Mordant (eds), Le complexe aristocratique de Vix: Nouvelles recherches sur l'habitat, le système de fortification et l'énvironnement du mont Lassois (Dijon 2011).

Fernández-Götz 2014: M. Fernández-Götz, Villages and cities in early Europe. Antiquity 88, 2014, 304-307.

Fernández-Götz 2018: M. Fernández-Götz, Urbanization in Iron Age Europe: Trajectories, patterns and social dynamics. Journal Arch. Research 26, 2018, 117-162.

Gosden/Marshall 1999: C. Gosden/Y. Marshall, The cultural biography of objects. World Arch. 31, 1999, 169-178.

Hahn/Weiss 2013: H. P. Hahn/H. Weiss, Introduction: Biographies, travels and itineraries of things. In: H. P. Hahn/H. Weiss (eds), Mobility, meaning & transformations of things. Shifting contexts of material culture through time and space (Oxford 2013) 1-14.

Hodder 2012: I. Hodder, Entangled. An archaeology of the relationships between humans and things (Sussex 2012).

Krausse et al. 2016: D. Krausse/M. Fernández-Götz/L. Hansen/I. Kretschmer, The Heuneburg and the Early Iron Age Princely Seats: First Towns North of the Alps (Budapest 2016).

Kurz 2006: S. Kurz, Relative und absolute Chronologie der Heuneburg. In: Frühe Zentralisierungs- und Urbanisierungsprozesse nördlich der Alpen. Kolloquien und Arbeitsberichte des DFG-SPP 1171. https://publikationen.uni-tuebingen.de/xmlui/handle/10900/44016 (accessed 01/05/2018).

Kurz 2012a: S. Kurz, La Heuneburg: État des dernieres recherches. In: S. Sievers/M. Schönfelder (eds), Die Frage der Protourbanisation in der Eisenzeit. Akten des 34. internationalen Kolloquiums der AFEAF vom 13.-16. Mai 2010 in Aschaffenburg. Kolloquien Vor- u. Frühgesch. 16 (Bonn 2012) 15-27.

Kurz 2012b: S. Kurz, Die Heuneburg an der oberen Donau. Ein Ansatz zur Interpretation eines späthallstattzeitlichen Siedlungszentrums. In: T. Kienlin/A. Zimmermann (eds), Beyond elites: Alternatives to Hierarchical Systems in Modelling Social Formations. International Conference at the Ruhr-Universität Bochum, Germany, October 22-24, 2009. Univforsch. Prähist. Arch. 215/1 (Bonn 2012) 449-459.

Marreiros et al. 2015a: J. M. Marreiros/J. F. Gibaja Bao/N. Ferreira Bicho (eds), Use-wear and Residue Analysis in Archaeology (New York 2015).

Marreiros et al. 2015b: J. M. Marreiros/N. Mazzucco/J. F. Gibaja Bao/N. Ferreira Bicho, Macro and micro evidences from the past: The state of the art of archaeological use-wear studies. In: Marreiros et al. 2015a, 5-26.

Messing 1957: S. D. Messing, Further comments on resin-coated pottery: Ethiopia. American Anthr. 59, 1957, 134.

Mötsch et al. in BEFIM 1: A. Mötsch/M. Rageot/B. Schorer, Organic residues in pottery vessels from selected archaeological features of the Heuneburg. First results of a case study. In: Stockhammer/Fries-Knoblach 2019a, 61-76.

Mötsch et al. in BEFIM 2: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen". Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/P. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, The Dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Schorer et al. in BEFIM 1: B. Schorer/M. Rageot/A. Mötsch, Vessels from old excavations at the Heuneburg. New evidence for their functional interpretation. In: Stockhammer/Fries-Knoblach 2019a, 47-60.

Skibo 2013: J. M. Skibo, Understanding Pottery Function. Manuals in archaeology method, theory and technique (New York 2013).

Skibo 2015: J. M. Skibo, Pottery use-alteration analysis in use-wear and residue analysis. In: Marreiros et al. 2015a, 189-198.

Spiteri et al. in BEFIM 2: C. Spiteri/M. Rageot/St. Buckley, Das Potential von Biomarkern und Isotopenanalysen für die Untersuchung alter organischer Rückstände. In: Ph. W. Stockhammer/Fries-Knoblach 2019b, 21-50.

Stockhammer 2016: Ph. W. Stockhammer, Mensch-Ding-Verflechtungen aus ur- und frühgeschichtlicher Perspektive. In: K. P. Hofmann/T. Meier/D. Mölders/St. Schreiber (eds), Massendinghaltung in der Archäologie. Der *material turn* und die Ur- und Frühgeschichte (Leiden 2016) 345-356.

Stockhammer in BEFIM 1: Ph. W. Stockhammer, BEFIM 1. Neue Perspektiven auf die Kraft interkultureller Kontakte in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019a, 21-28.

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Van den Dries/van Gijn 1997: M. H. van den Dries/A. L. van Gijn, The representativity of experimental usewear traces. In: A. Ramos-Millán/M. A. Bustillo (eds), Siliceous rocks and culture (Granada 1997) 499-513.

Van Gijn 1990: A. L. van Gijn, The wear and tear of flint. Principles of functional analysis applied to Dutch Neolithic assemblages. Analecta Praehist. Leidensia 22 (Leiden 1990).

Van Gijn 2012: A. L. van Gijn, New perspective for microwear analysis. In: C. C. Bakels/H. Kamermans (eds), The end of our fifth decade. Analecta Praehist. Leidensia 43/44 (Leiden 2012) 275-282.

Van Gijn 2014: A. L. van Gijn, Science and interpretation in microwear studies. Journal Arch. Scien. 48, 2014, 166-169.

Van Gijn/Hofman 2008: A. L. van Gijn/C. L. Hofman, Were they used as tools? An exploratory functional study of abraded potsherds from two pre-colonial sites on the island of Guadeloupe, Northern Lesser Antilles. Caribbean Journal Scien. 44/1, 2008, 21-35.

Van Gijn et al. in BEFIM 1: A. van Gijn/L. Jacobs/N. Groat/N. de Koning/D. Braekmans/A. Verbaas, Studying vessel biographies from the Heuneburg: An experimental approach. In: Stockhammer/Fries-Knoblach 2019a, 77-99.

Vuković 2009: J. B. Vuković, Non-abrasive pottery surface attrition: Blagotin evidence. Journal Serbian Arch. Soc. 25, 2009, 25-35.

Author information

Annelou van Gijn and Annemieke Verbaas
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.l.van.gijn@arch.leidenuniv.nl
a.verbaas@arch.leidenuniv.nl

Microwear studies of pottery from the Iron Age site of Vix-Mont Lassois (France)

Annemieke Verbaas & Annelou van Gijn

Summary

The BEFIM project ("Meanings and Functions of Imported Mediterranean Vessels in Early Iron Age Central Europe") led by Philipp W. Stockhammer was aimed at understanding the drinking habits of the early Celts. At the Early Iron Age hillfort of Vix-Mont Lassois many sherds of Attic origin were excavated, raising the question as to what these imported vessels were used for and whether their function differed from that of locally made pottery. Towards this end microwear analysis of the vessels was conducted, focusing on the gestures evidenced by the traces of wear. Experimentally used vessel reconstructions served as a reference for our interpretations of vessel function. Although few of the imported vessels had traces of wear, those that were interpretable were shown to have been caused by drinking fermented beverages. In contrast, the local pottery displayed a more diverse range of functions. They were used for stirring, mixing, storage and the consumption of substances, and they were handled and cleaned extensively. This was especially so with the bowls which turned out to be multifunctional. Many of the ceramic vessels, both of local and foreign manufacture, must have had a long use life. Some of the sherds of the imported amphoras even had a second life as tools in ceramic manufacturing processes. In addition to showing the gestures involved in pottery use, some traces also provided indications of the contents of these vessels: traces of pitting were interpreted as the result of an acidic substance, spalling providing evidence for fermentation processes.

Keywords: *Early Celtic pottery, vessel function, microwear analysis, drinking habits, Vix-Mont Lassois, fermentation*

Zusammenfassung

Das Forschungsprojekt BEFIM (Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa) unter der Leitung von Philipp W. Stockhammer zielte auf ein tieferes Verständnis der Trinksitten früher Kelten. An der früheisenzeitlichen befestigten Höhensiedlung von Vix-Mont Lassois wurden viele Keramikscherben attischer Herkunft ausgegraben, was die Fragen aufwarf, wozu diese Importgefäße dienten und ob ihre Funktion sich von derjenigen einheimischer Keramik unterschied. Um dies zu klären, wurden mikroskopische Gebrauchsspurenanalysen an den Gefäßen durchgeführt,

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 151-169.

wobei der Forschungsschwerpunkt auf den Handbewegungen lag, die durch die Gebrauchsspuren abgebildet sind. Experimentell benutzte Gefäßnachbildungen dienten als Referenzmaterial für die Interpretation der Gefäßfunktion. Obwohl nur wenige Importgefäße Abnutzungsspuren zeigten, gelang es nachzuweisen, dass die interpretierbaren von ihnen durch das Trinken fermentierter Getränke verursacht waren. Im Gegensatz dazu zeigte die einheimische Keramik vielfältigere Funktionen an. Sie diente zum Rühren, Mischen, Lagern und Konsumieren von Substanzen und wurde intensiv benutzt und gereinigt. Dies traf vor allem auf Schüsseln/Schalen zu, die sich als multifunktional erwiesen. Viele der Keramikgefäße, importierte wie einheimische, müssen eine lange Gebrauchsbiographie gehabt haben. Einige Scherben importierter Amphoren hatten sogar ein zweites Leben als Werkzeuge bei der Keramikherstellung. Neben dem Aufzeigen der Handbewegungen beim Keramikgebrauch lieferten einige Spuren auch Anzeichen für den einstigen Inhalt der Gefäße: Spuren von Grübchenbildung wurden als Folge einer sauren Substanz gedeutet, und Abplatzungen lieferten Hinweise auf Fermentationsvorgänge.

Schlüsselwörter: *Frühkeltische Keramik, Gefäßfunktion, Gebrauchsspurenanalyse, Trinksitten, Vix-Mont Lassois, Fermentation*

Introduction

The Early Iron Age hillforts of Central Europe have led to a range of assumptions about the kind of life taking place there. The lavish burials such as Hochdorf and Vix as well as the import of Mediterranean vessels like *amphoreis* and *kylikes*, indicate the existence of an elite who had strong connections with Southern Europe. The import of amphoras and Greek (predominantly Attic) tableware was associated with the consumption of wine, and it was proposed that the elite copied the Greek *symposion*, a type of feast following circumscribed practices during which grape wine was consumed. Much of the research focus has been on the imported goods and objects, presumably related to the elite, and on the role of alcohol in social gatherings and the confirmation and solidification of existing power relations (Arnold 1999; Dietler 1990). Beside the imported vessels, a range of fine vessels were made locally, much of it interpreted as tableware. The objective of the BEFIM project (*Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa*) was to study what the imported vessels were used for: was grape wine consumed from them, as was customary in Southern Europe? In other words, were these imported vessels appropriated along with their associated food ways and consumption practices or were they used for other beverages like beer or mead, indicating a transformation from one cultural context to another (Stockhammer in BEFIM 1)? And what was the role of the local vessels, some of which could be inspired by the Attic ware in terms of their fineness and the craftsmanship put into them. The BEFIM project, directed by Philipp W. Stockhammer (Institut für Vor- und Frühgeschichtliche Archäologie und Provinzialrömische Archäologie, Ludwig-Maximilians-Universität, Munich, Germany and Max Planck Institute for the Science of Human History, Jena, Germany) aimed to answer these questions by means of an interdisciplinary approach. The main sites studied in this project were the Heuneburg (recent summary and bibliography: Krausse et al. 2017) and Mont Lassois (Bardel 2012; Chaume/Mordant 2011).

With the provocative question “What did the Celts drink?” (Stockhammer/Fries-Knoblach 2019a) the BEFIM project set out to go beyond the implicit functional implications of pottery typology, like cup or bowl that were based on untested assumptions and analogies. Combining a detailed typological and contextual analysis with organic residue analysis (ORA) (Rageot et al. 2019a; Mötsch et al. in BEFIM 2) and microwear analysis (van Gijn et al. in BEFIM 1; van Gijn et al., this volume) we hoped to arrive at a more empirically founded interpretation of the function of all of these vessels. Organic residue studies obviously give the most direct evidence for the contents of the vessels, whether they contained e. g. grape wine, animal or plant fat or beeswax. In contrast, microwear analysis of pots, although occasionally evidencing specific contact materials or contents, is more suited to shedding light on the gestures that were connected to the pots and the intensity of their use. However, it is the combination of these three approaches, typomorphology, organic residues and wear traces that gives us insight into the details of vessels' biographies (Gosden/Marshall 1999; van Gijn 2012; Hahn/Weiss 2013). These biographies in turn reveal whether the role of the imported vessels changed from one cultural context to another, from Greece to their destination of the "princely seats" in Early Iron Age Europe, and whether the finely made local ware was indeed an emulation of South European feasting practices.

Sample and methods of analysis

The samples from the Mont Lassois excavations were taken by Angela Mötsch (then Landesamt für Denkmalpflege beim Regierungspräsidium Stuttgart, Dienstsitz Esslingen, Germany, now Max Planck Institute for the Science of Human History, Jena, Germany), Birgit Schorer (then Landesmuseum Würtemberg, Stuttgart, now Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Dienstsitz Esslingen, Germany) and Maxime Rageot (Tübingen University, Germany), in close collaboration with David Bardel (INRAP, France) and Ines Balzer (Deutsches Archäologisches Institut, Abteilung Rom, Italy). The sample examined for use-wear traces differed to some extent from that studied by Rageot et al. (2019a) and Mötsch et al. (in BEFIM 2) in the sense that all of our material came from the old excavations, the VIX-ALT series according to the BEFIM sample numbers. This is the location referred to as Plateau (Fig. 1).

We did not study the samples from Champs de Fossé, Le Breuil and Les Renards. The Vix-ALT finds probably all come from the excavations by Jean Lagorgette in the 1930s (Mötsch et al. in BEFIM 2). There is no information as to their exact find location, but they most likely derive from the North-Easterly slopes of the Saint-Marcel Plateau (for more details see Bardel 2009, 71; 2012, vol. 2, 155). In addition, we were given a small number of sherds beyond the samples selected for organic residue analyses (hereafter ORA) and which are referred to as *Céramique Peintes*. Some other finds are listed as Ech45/Lot18 and Ech 43/A/Lot 16, CAS 1, CAS 14, 89.8953.1 and 80.7846.1. These will be described separately as we do not know their context nor the type of vessel they belong to. The finds were kindly made available to be studied in Leiden by Félicie Fougère (then Musée du Châtillonnais - Trésor de Vix, France). The majority of finds are dated to Ha D2/3. The reader is referred to Balzer (2009), Bardel (2009; 2012) and Mötsch et al. (in BEFIM 2) for further details on the typomorphology of the vessels described below.

Microwear analysis is based on the empirical observation that different activities (i. e. combinations of executed motions and contact materials) result in different types of wear. The method was first developed for flint tools (Keeley 1980; van Gijn 1990), but has also been applied to objects made of a variety of other materials like stone (e. g. Adams 2013; Verbaas/van Gijn 2007), bone and antler (e. g. Maigrot 2005), coral (Kelly/van Gijn 2008), shell (e. g. Cuenca Solana et al. 2011) and ceramic sherds recycled as tools (van Gijn/Hofman 2008; Vieugué 2015). Studying traces of wear offers insights into the biography of an object, not only how it was used, but also how it was handled, (ritually) treated, re-used and deposited (van Gijn 2010; 2012; Marreiros et al. 2015b). Following the pioneering work of Skibo (2013; 2015), more and more attention has lately been paid to the actual use of pottery vessels (Fanti et al. 2018; Forte et al. 2018; Vieugué 2014; van Gijn et al. in BEFIM 1). Microwear (or

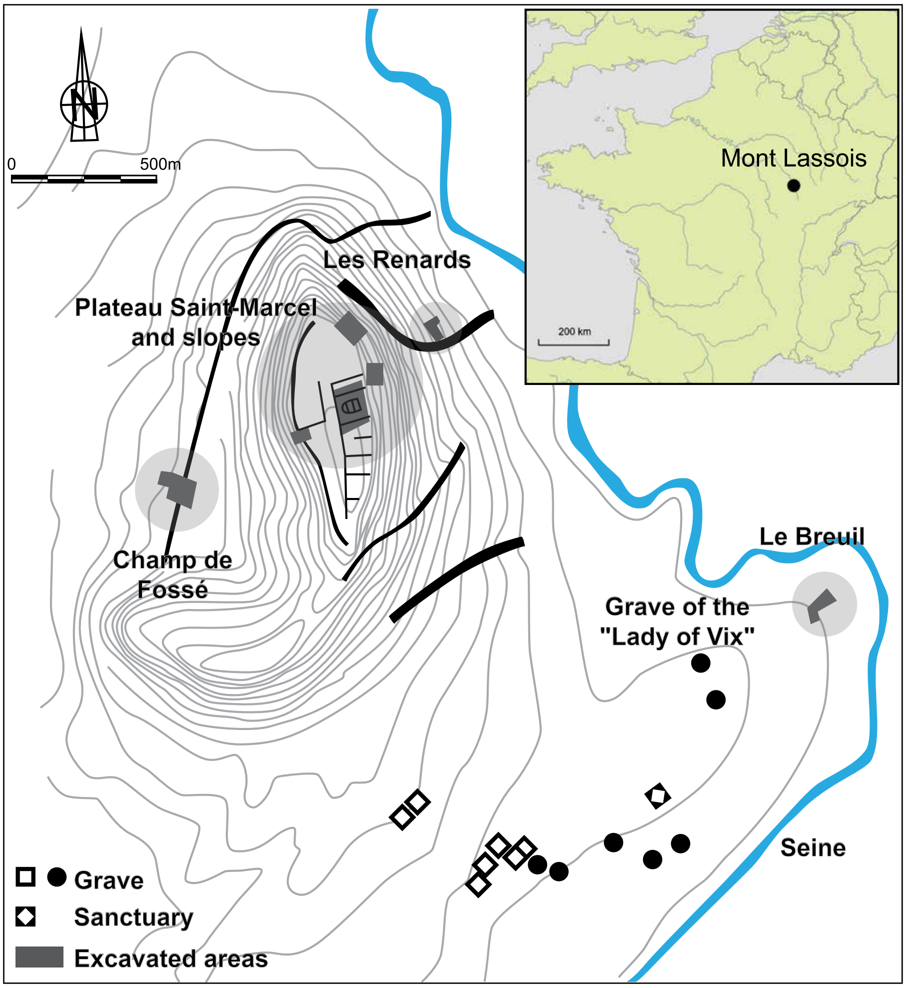

Figure 1: Overview of the excavations at Vix-Mont Lassois with the location of the Plateau Saint-Marcel and the slopes from which the analyzed Vix-ALT series derived (adapted from Mötsch et al. in BEFIM 2, 54 fig. 1 © J. Radosavljevic and Stepmap.de).

use-wear) analysis can contribute to this. The methodology and the inferential limits of microwear analysis, especially regarding the use-wear analysis of vessels, is discussed elsewhere (van Gijn, this volume; van Gijn et al., this volume; van Gijn 2014).

"Motions" in relation to the use of vessels are obviously different from the motions executed by e. g. a flint blade. On ceramic vessels, motions can include gestures like handling, covering, stirring as well as all sorts of accidental "contacts" such as bumping or shoving. Contact materials can also be diverse: other pots, wooden surfaces or spoons. For example, when two pots repeatedly touch each other in a cramped storage space, the motion is referred to as "bumping" and the contact material is "pottery". We therefore defined the following "motions" in sequence of their logical place in the life history of the vessel: stirring, covering, pitting, spalling, cleaning, bumping, handling, shoving, carving, secondary use, unsure. With respect to contact materials we differentiated the following on the basis of the observed traces of wear: acidic substance, fermentation, cloth, wood, pottery, human hand, soft material, hard material, coarse material, and unsure/diverse (Tab. 1).

As to the equipment used, the sherds were first examined by stereomicroscopes Leica M80 and Wild M3Z at magnifications between 10x and 100x to detect the presence and distribution of wear traces. All sherds with microscopic polish were subsequently studied by means of a metallographic microscope (Leica DM6000, DM1700 and DM2700) with magnifications of 100x and 200x. Photos were made with an integrated Leica Application Suite and Leica cameras MC120HD and DFC450 on the microscope.

Table 1: Overview of the motions and contact materials inferred on the vessel samples of local (n = 69), foreign (n = 13) and unknown (n = 6) origin. Note that the frequencies refer to actually used zones, not to number of sherds.

Contact material		**Stirring**	**Covering**	**Pitting**	**Spalling**	**Cleaning**	**Bumping**	**Handling**	**Shoving**	**Carving**	**Unsure**	**Total**
Local	Acidic substance	-	-	7	-	-	-	-	-	-	-	*7*
	Fermentation	-	-	-	6	-	-	-	-	-	-	*6*
	Cloth	-	2	-	-	-	-	-	-	-	-	*2*
	Wood	-	1	-	-	-	-	-	-	-	-	*1*
	Pottery	-	2	-	-	-	4	-	-	-	-	*6*
	Human hand	-	-	-	-	-	-	2	-	-	-	*2*
	Soft material	-	1	-	-	-	-	1	-	-	-	*2*
	Hard material	-	2	-	-	-	-	-	-	-	-	*2*
	Coarse material	-	-	-	-	-	-	-	1	-	-	*1*
	Unsure/diverse	9	5	3	-	1	1	11	5	-	5	*40*
	Subtotal	*9*	*13*	*10*	*6*	*1*	*5*	*14*	*6*	*-*	*5*	*69*
Imported	Fermentation	-	-	-	3	-	-	-	-	-	-	*3*
	Pottery	-	-	-	-	-	1	-	-	3	-	*4*
	Human hand	-	-	-	-	-	-	3	-	-	-	*3*
	Unsure/diverse	-	-	-	-	-	-	1	2	-	-	*3*
	Subtotal	-	-	-	*3*	-	*1*	*4*	*2*	*3*	-	*13*
Unknown	Fermentation	-	-	-	3	-	-	-	-	-	-	*3*
	Unsure/diverse	-	-	-	-	-	-	2	-	-	1	*3*
	Subtotal	-	-	-	*3*	-	-	*2*	-	-	*1*	*6*
Total		9	13	10	12	1	6	20	8	3	6	*88*

Functional inferences were based on:

1. a first visual inspection together with potter Loe Jacobs to understand the manufacturing process and, where relevant, note the traces of production on the sherds;
2. examination by stereomicroscope to obtain an overview of the traces present and their distribution in relation to the vessel fragment (rim, bottom, wall, complete profile) and an interpretation of these traces, where possible;
3. a more detailed inspection of the observed wear traces by means of a metallographic microscope to observe and interpret the characteristics of use-wear polish and related scratches.

All the studied finds were drawn, and traces of use and, where relevant, of manufacture were marked on registration sheets. Interpretation of the function was based on a comparison of the observed traces, their character and their distribution, with those on experimentally used vessels. The latter were made by potter Loe Jacobs (Jacobs, this volume) and used in a variety of ways related to the initial observation of traces on the sample studied from the Heuneburg (Groat, this volume; van Gijn et al., this volume; van Gijn/Verbaas, this volume).

General results

A total of 89 sherds have been analyzed, 48 of which displayed traces of use. Ten displayed no traces and 31 finds were not interpretable. The latter were either too small or too worn to allow a reliable functional inference. In the case of the sherds without traces of wear, we should stress that it does not necessarily mean that these were not used. There are some activities that only leave traces after prolonged use, or we may not have had the part of the vessel with wear traces present.

Several sherds with traces had more than one zone of use: 19 sherds had only one zone of use, 34 finds displayed two used areas, 27 had three used zones and eight sherds had four used zones. The total of used zones is therefore 88, located on 48 sherds. Because not all of the studied sherds that were initially sampled by the BEFIM team were subjected to ORA, only 29 of the samples studied for the presence of use-wear also displayed organic residues. On these 29 sherds 53 zones with use-wear traces were seen.

A range of motions could be inferred from the traces of wear (Tab. 1). There was considerable evidence for handling (n = 20), shoving and bumping (n = 6), covering (n = 13), stirring (n = 9), pitting (n = 10) and spalling (n = 12). Contact materials were more difficult to infer with a substantial number of "unsure" (n = 46) (Tab. 1). For example, the abraded bottoms of some of the sherds and the exposed and polished temper (Fig. 2a) were seen as the result of these vessels having been moved around or shoved across a surface. However, it was not possible to infer the kind of surface these vessels came into contact with, whether it was wood (table, shelf?), loam (floor, hearth?), a combination of these or yet another surface. For the bumping traces, visible as indentations, craters, scratches and general damage on the outer surface, especially along the pot's widest perimeter, this was a little easier to infer: most of them seem to have been incurred by a hard material, most likely pottery. However, obviously it is difficult to distinguish such traces from post-depositional damage as this is also the most vulnerable area of the sherds. Handling could sometimes be related to human hands (n = 5) or soft material (n = 1), inferred from a greasy polish, but for the most part the contact material could not be specified further. Handling traces from human hands were seen on the stems of cups (see below, Vix-ALT-050 and Vix-ALT-051), on the outside body of pots and in one case on a handle of a *lekythos* (Vix-ALT-054). The covering traces were present on rim sherds and were composed of differential rounding and some polish spots (Fig. 2b.c). The cloth and soft materials caused rounding on the outside rim, whereas the wooden cover probably consisted of a wooden stopper (Vix-ALT-103). Stirring traces were inferred on nine find numbers. These involve smoothening of the production traces with very fine scratches, much finer than those from scraping, with a predominant, but not exclusive directionality (Fig. 2d). They are predominantly located in the lower part of the vessel. In none of these cases was it possible to infer the material the stirring tool was made of. Cleaning traces were much finer, thinner and shallower than stirring traces and have a different distribution, more over the entire vessel profile.

The term spalling is used to describe the removal of large flakes from the inside of the vessel, resulting in a very irregular and generally scarred surface (Fig. 2e). Based on ethnographic observations among e. g. the Gomo in South-Western Ethiopia (Arthur 2002; 2003) this has traditionally been associated with a fermentation process (Groat, this volume; Hayashida 2008; Vuković 2009) and is believed to be related to alcohol production. Twelve vessels displayed this feature. Another characteristic possibly associated with alcohol is pitting (Fig. 2f): small, usually circular pin-prick holes that we also obtained experimentally from storing wine (van Gijn et al., this volume) and that we attributed to the acidity of this liquid. However, other acidic substances like soured milk could have had the same effect, hence the umbrella term "acidic substance" as contact material. Last, a few small imported sherds showed differential rounding of their edges with especially a protruding point being rounded and displaying polish and some faint scratches. These bore a close resemblance to some of the ceramic tools found across the world that were interpreted as being related to the manufacture of ceramic vessels (van Gijn/Hofman 2008; Vieugué 2015).

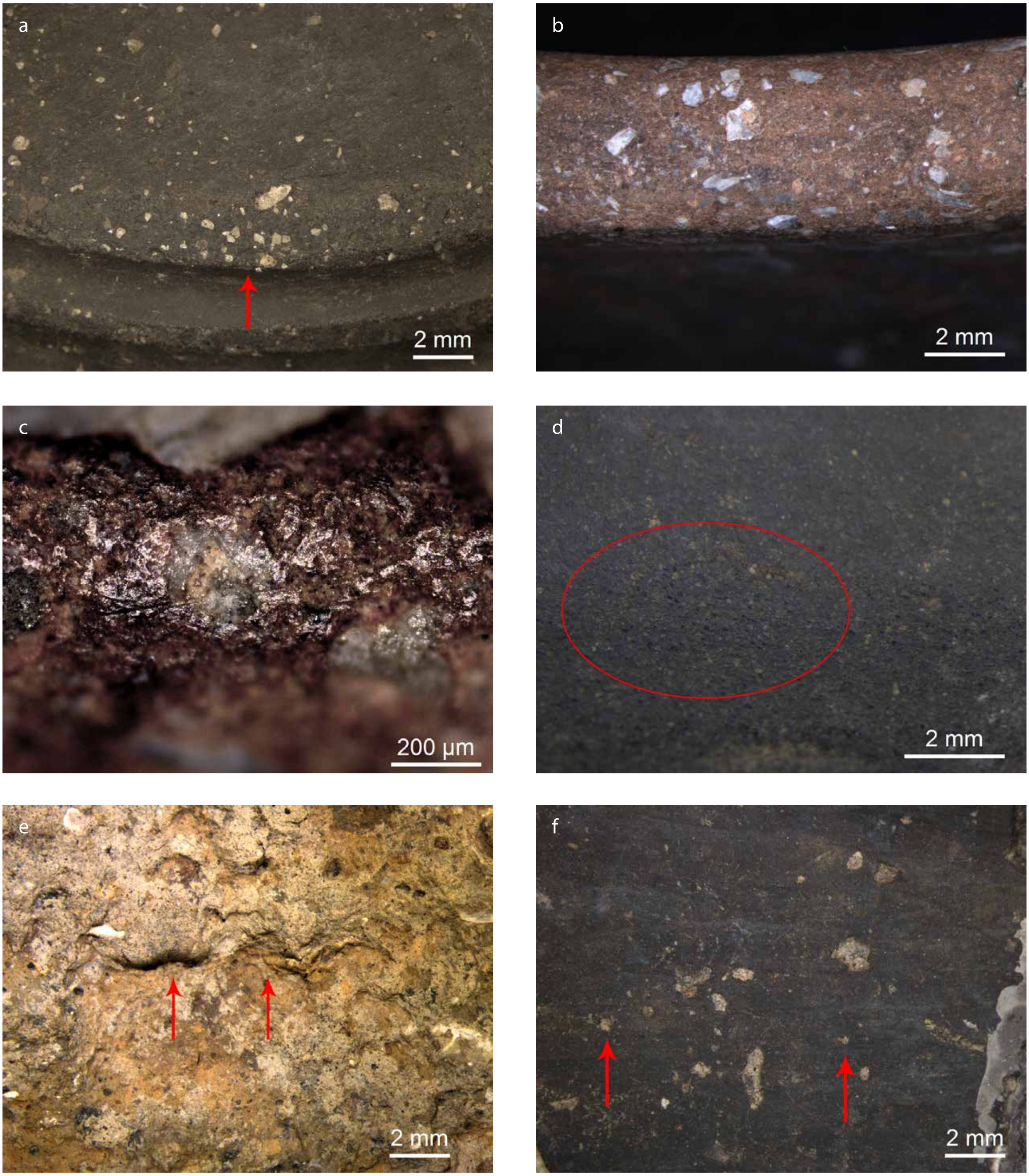

Figure 2: Overview of some of the traces observed. (a) An abraded bottom of a sherd with exposed and flattened temper seen on Vix-ALT-125. (b) Flattening of the rim seen on Vix-ALT-103. (c) Polish probably from contact with a wooden cover seen on the same sample (taken with metallographic microscope, 100x original magnification). (d) Possible stirring traces, dense pitting and abrasion as a result of this seen on Vix-ALT-129. (e) Spalling traces seen on Vix-ALT-111. (f) Rounded small circular pits, sometimes grouped in areas seen on Vix-ALT-103 (© Laboratory for Material Culture Studies Leiden University).

Locally made pottery

A total of 48 sherds of locally made vessels were studied, all deriving from the old excavations (Bardel 2009) and for the most part dating to Ha D2/D3. Of these, three displayed no traces of use, nine were not interpretable. The 36 finds which showed use-wear traces produced 69 locations (Tab. 1). The most frequently occurring inferred motions are handling (n = 14), covering (n = 13), pitting (n = 10) and stirring (n = 9), but traces from cleaning and shoving were also observed. The sherds with spalling could indicate fermentation of alcoholic beverages. The range of motions in any case suggests that this local pottery played an important role in preparing, storing and consuming foods and beverages. As has been said before, microwear analysis can only rarely give evidence for the contents of the vessels: in our case the fermentation traces point to the presence of alcoholic beverages, whereas pitting seems to be associated with acidic substances like wine. The other contact materials refer to the material the pot has come into contact with: handling by the human hand, bumping into other pottery vessels or being covered by different materials (Tab. 1).

In the following we will discuss some of the most interesting finds of local pottery as there are too many to discuss all of them individually, and their provenance and find context are unknown anyway. This will give an idea of the broad range of applications these vessels had in the daily foodways of the Celts.

Find number Vix-ALT-101 is a sherd of a cylindrical bowl with a flat bottom, decorated in a Barbotine technique. This sherd has four used zones. The rim displays flattening towards the inside, with some short, wide scratches visible (Fig. 3a). These features have been interpreted as having been caused by the use of a pottery lid. The lower part of the interior wall of the vessel shows spalling, suggesting possible fermentation (Fig. 3b). The lower part also has evidence for stirring, but the kind of stirring implement could not be ascertained. Last, the vessel must have been shoved around considerably as the edge of the bottom is heavily rounded. This bowl was therefore used to prepare or mix food or drinks, which probably also contained a fermenting substance, to store and possibly to serve them, although no evidence for the use of a ladle could be found. ORA showed traces of pine resin, fat and possibly wax (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 1).

Heavily developed spalling traces are visible on find number Vix-ALT-111, a rim and neck of a large, flask-shaped vessel (*Großgef*äß). The sherd also displayed extreme spalling (Fig. 2e), very much like what has been observed in ethnographic contexts (Arthur 2002; 2003). ORA demonstrated the signatures of plant wax, beeswax and bacterial fermentation markers (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 11). The rim displayed some slightly developed wear traces which could point to a former cover of this vessel. This vessel would have been suitable for fermenting, e. g. beer.

Another interesting find is sample Vix-ALT-125, the bottom sherd of an open vessel that was not further defined typologically (Balzer 2009, fig. 10.4). Its outside bottom displayed abrasion from being shoved around, exposing the calcite temper (Fig. 2a). Its inside showed evidence for stirring and pitting, interpreted as having been the result of contact with an acidic substance (Fig. 3c). No ORA was done, so this assumption could not be substantiated from the residue.

Bottom sherd Vix-ALT-142, an open form (Balzer 2009, fig. 11) showed abrasion at the foot, indicating that this vessel had been shoved around quite considerably (Fig. 3d). Its outer surface also had a greasy looking polish without directionality on the ridges, which was interpreted as having been due to handling. The interior of the vessel displays some general wear that could not be specified further.

Sample Vix-ALT-152, a complete profile of a bowl (Bardel 2012, fig. 64), has a rounded and quite heavily abraded rim, especially on its outer side, probably the result of covering with some unknown material (Fig. 3e). It also displays fine

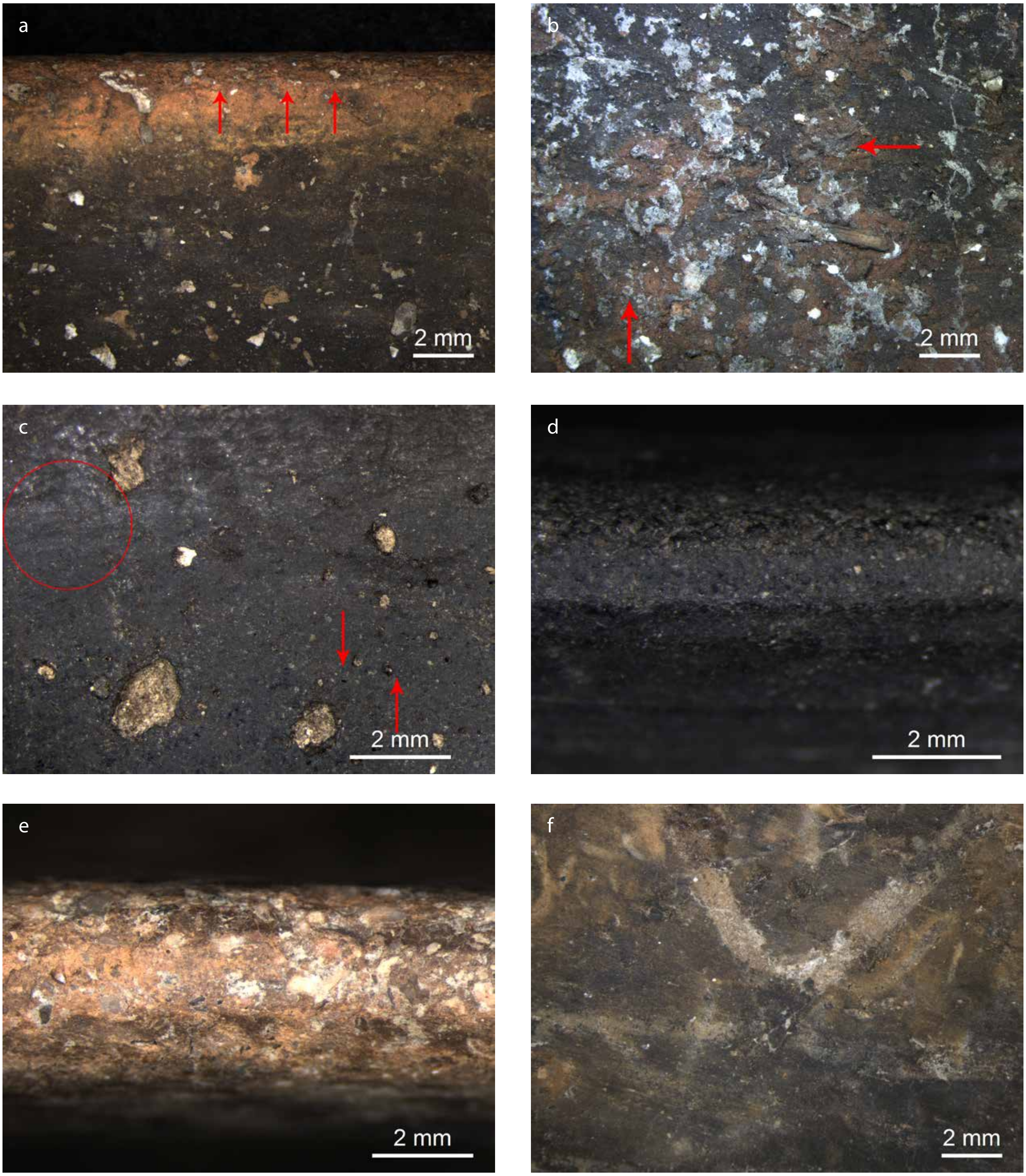

Figure 3: Traces seen on locally made pottery. (a) Flattening of the rim and short wide scratches suggesting the use of a pottery lid, seen on Vix-ALT-101. (b) Spalling seen on Vix-ALT-101 suggesting fermentation. (c) Pitting, most likely from contact with an acidic substance, and stirring traces seen on Vix-ALT-125. (d) Abrasion seen on the foot of Vix-ALT-142, interpreted as the result of shoving. (e) The rim of Vix-ALT-152, showing abrasion interpreted as the result of covering. (f) Polished and flattened shoulder of Vix-ALT-152, possibly the result of handling, but could also be post-depositional (© Laboratory for Material Culture Studies Leiden University).

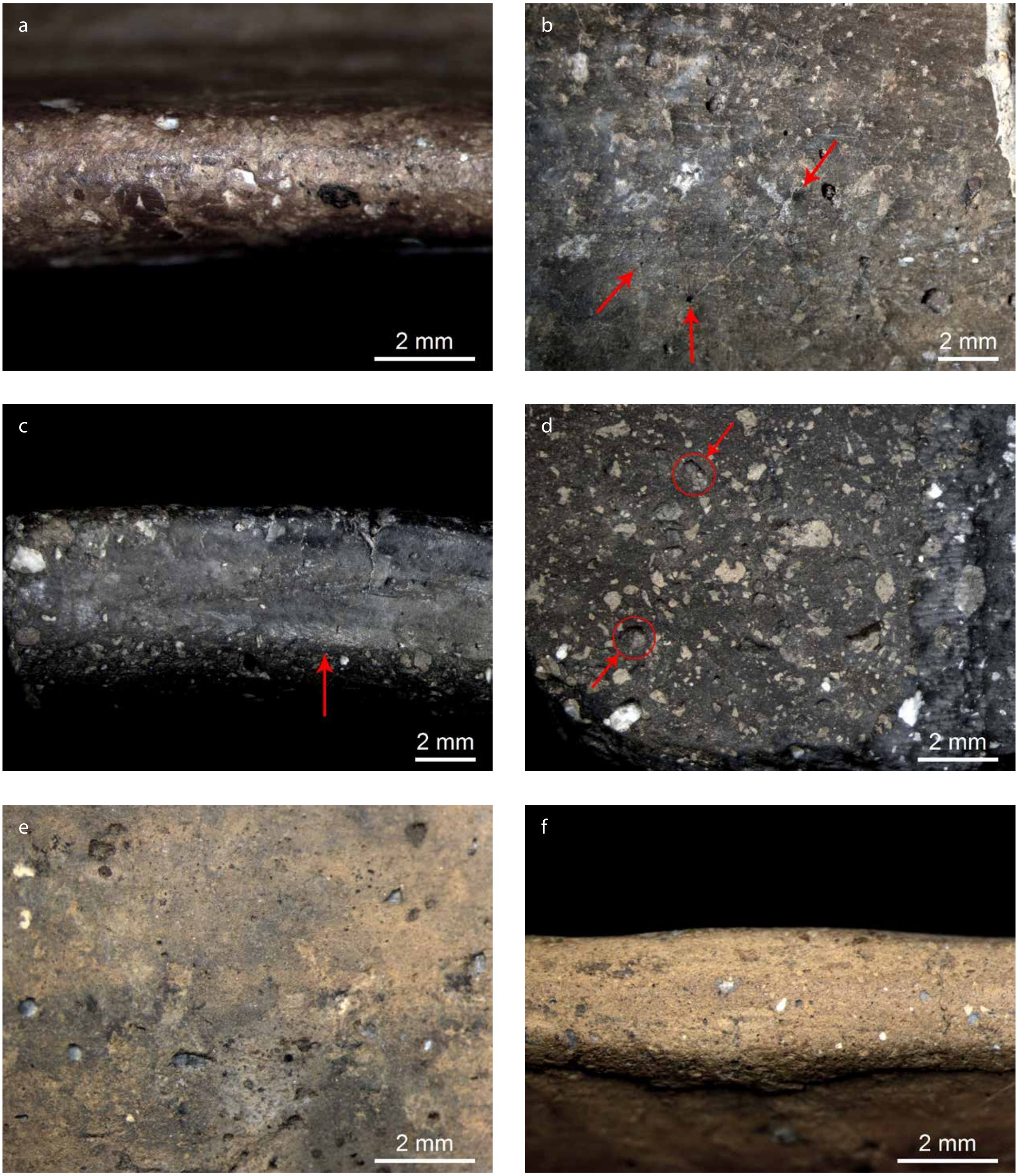

Figure 4: Traces seen on locally made pottery. (a) Wear traces seen on the rim of Vix-ALT-148 due to handling or possibly drinking. (b) Traces from pitting seen on the same vessel. (c) Polish and abrasion of the rim of sample Vix-ALT-154, suggesting the bowl was covered with an unknown material. (d) Pitting, possibly from an acidic substance seen on Vix-ALT-154. (e) Pitting seen on Vix-ALT-161, resulting from an acidic substance. (f) Abraded rim with transversely oriented striations from covering the bowl (© Laboratory for Material Culture Studies Leiden University).

scratches from stirring. The outside surface, especially along the shoulder, is polished and flattened, probably from handling (Fig. 3f), although a post-depositional cause cannot be entirely excluded.

A rim sherd of a bowl, sample Vix-ALT-148, displayed three zones of use. The rim has some slight abrasion, causing some rounding, and at the same time some lightly developed polish from contact with a soft material. We interpreted this as the result of handling (Fig. 4a). There are also some long, parallel scratches from stirring. Last, the interior has pitting, indicative of an acidic content (Fig. 4b). Pitting was also seen on the inside of sample Vix-ALT-154, a bowl of which the rim and the shoulder were preserved. Polish and abrasion of the rim suggest that the bowl was covered by some unknown material (Fig. 4c). The pitting, especially towards the lower end of the interior vessel wall, indicates that it once contained an acidic substance (Fig. 4d). Yet another example of pitting was seen on the rim/body sherd of a bowl with Barbotine decoration (Vix-ALT-161) which featured traces of pitting all over the inner surface (Fig. 4e). ORA showed potential evidence for plant oil (Rageot et al. 2019a; Mötsch et al. in BEFIM 2, Kat. 20). The rim is abraded somewhat and worn flat, with transversely oriented striations (Fig. 4f) which were interpreted as the result of covering the bowl. Last, on the inside of the vessel all production traces have disappeared, but very fine striations are visible. As these traces are present all over the surface up to the rim, they were probably the result of cleaning.

Imported pottery

A total of 32 sherds of imported pottery were studied. More than half of them (n = 19) were not interpretable, and five displayed no traces. Only eight sherds were found to have traces of wear, some in more than one location. In total, 13 locations of use were identified. The fact that so many sherds were considered "not interpretable" was not only due to the presence of post-depositional surface modifications, but also to the small size of the sherds. For meaningful inferences to be made on the basis of observations we need diagnostic sherds, like rims or bottoms, or considerable parts of a vessel wall in order to determine the location, distribution and directionality of the observed traces. As stated elsewhere, we cannot interpret the scratches on a very small body sherd of which we do not know its former position in the vessel wall (van Gijn et al., this volume). Additionally, the fact that these sherds were probably handled even more than the local pottery has produced a considerable amount of damage.

Because only eight imported vessels showed traces of use-wear, each will be described individually. Find number Vix-ALT-002 is classified as a Greek mixing vessel, a *krater*. It represents Attic black-figure pottery with a black on red design. There are eight sherds within this find number, only two of which were interpretable. The two sherds with wear traces displayed extensive spalling, interpreted as having been due to a fermentation process inside this vessel (Fig. 5a). ORA has shown signatures of plant oil (type olive), grape wine and bacterial fermentation markers (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 40), in congruence with the inferences from the use-wear traces.

Two sherds from imported amphoras were secondarily used as tools to carve or engrave pottery (Vix-ALT-006 and Vix-ALT-009) (Fig. 5b). Vix-ALT- 006 has two pointed ends with rounding and polish, Vix-ALT-009 only one, but this sherd also displays well developed handling traces. ORA of both these sherds showed evidence for plant oil and bacterial fermentation markers. In addition to these, Vix-ALT-006 also had signatures for pine resin and possibly a fruit product (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 44; 46).

The protruding ridges on the outside of Vix-ALT-011, a rim sherd of a black-slip bowl, are heavily weathered, while the edges of the sherd are not worn or rounded.

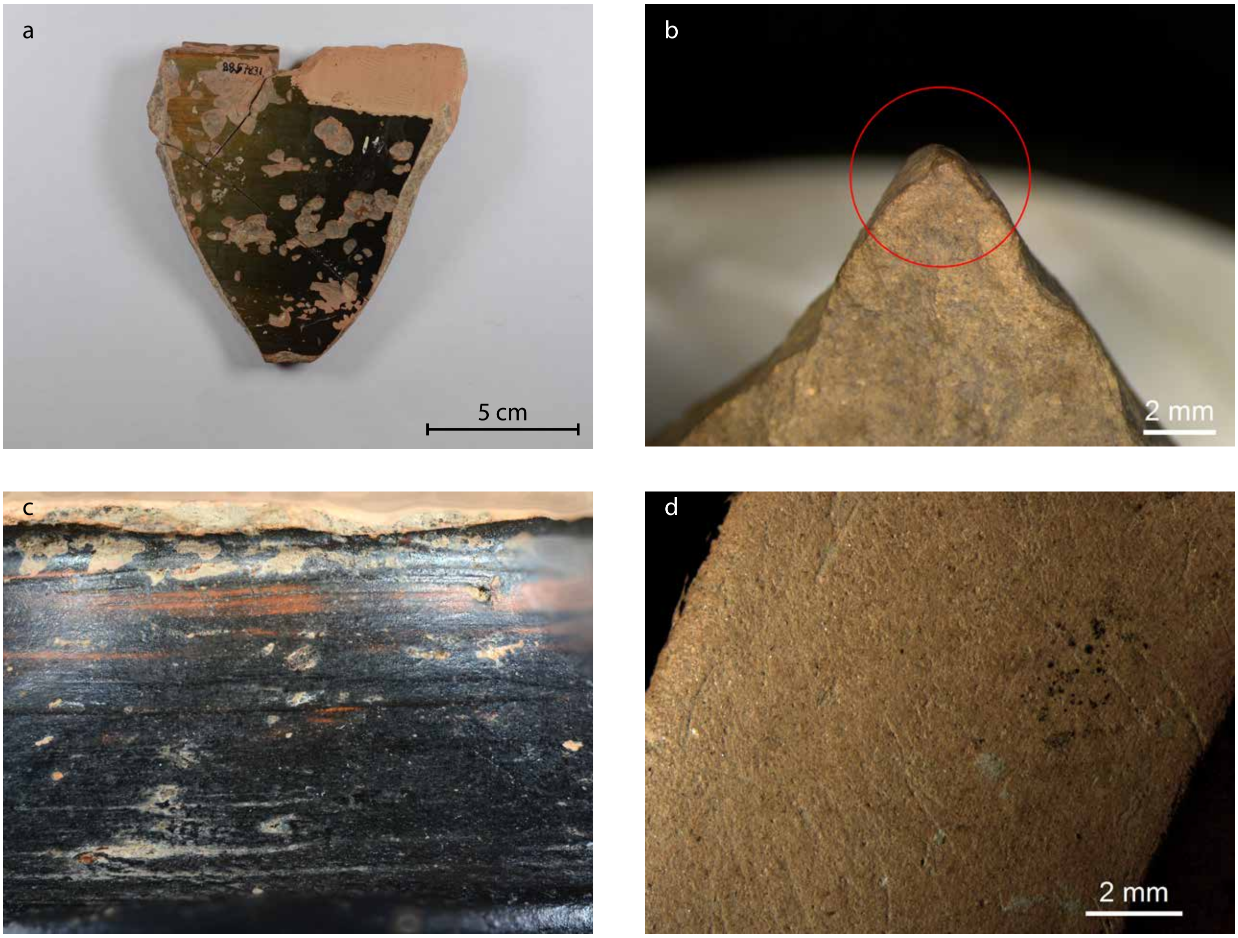

Figure 5: Traces observed on the import ware. (a) Spalling seen on a fragment of a krater (Vix-ALT-002). (b) Rounding of a sherd from an amphora, possibly used as a tool from ceramic manufacture (Vix-ALT-006). (c) Polish on the outside of the stem of kylix Vix-ALT-050, indicative of holding the stem like in antique images. (d) Abrasion seen on the foot of Vix-ALT-050/051 (© a = A. Mötsch, others = Laboratory for Material Culture Studies Leiden University).

This clearly indicates that these traces are the result of use. It probably bumped into other pots on a regular basis. No ORA was done on this sherd.

Vix-ALT-050 and Vix-ALT-051 are fragments of a *kylix* (bowl-shaped vessel with a foot and two horizontal handles usually called a "cup" in archaeological literature) that display similar handling traces around the foot, indicating the way that they were held during use. Just underneath the vessel wall and just above the protruding foot, heavily developed gloss is visible on the outside and the black slip has been polished away, probably by human hands (Fig. 5c). Greek vase paintings show that *kylikes* were balanced with two fingers on either side of the stem and the foot in the palm of the hand facing up[1], which would nicely match the observed use-wear. Alternatively, similar handling traces could be produced by the hand facing up with the fingers split on either side of the stem and the palm supporting the vessel belly like with a modern brandy balloon. Therefore, we cannot be absolutely sure that the users of the cup knew how to handle it "the Greek way", but it is very likely that they at least did not grab them with hands at both handles as might seem obvious to a present-day observer. In any case, the motion best fitting this way of handling

---

[1] For numerous pictures see e. g. http://www.antike-tischkultur.de/griechkeramikkylixgebrauch.html (accessed 10/03/2020).

is a drinking motion. Interestingly, both these vessels scored bacterial fermentation markers in the ORA (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 50; 51). The bottom of the foot of both *kylikes* is worn away as well (Fig. 5d), also indicating their long use life. Last, slightly developed spalling on the inside of Vix-ALT-050 indicates that fermentation probably took place inside this vessel. Such traces were not visible on Vix-ALT-051, but, as only the bottom of this *kylix* is preserved, they may once have been present on the walls. The last imported vessel with interpretable wear traces is Vix-ALT-054, a handle of a *lekythos*, a slim container with a vertical handle and a funnel-shaped rim. All the decoration on this fragment was worn away and its inner surface was very smooth and polished, probably indicating extensive handling by human hands.

Pottery of an unknown provenance or date

When we received the chest with sherds from the Musée du Châtillonnais - Trésor de Vix, France, there were a couple of additional sherds that were not included in the sample taken by the BEFIM team. Interestingly, three sherds (CA S14; Céramiques Peintes 1; Céramiques Peintes 2) displayed spalling to varying degrees on the inside of the wall, suggesting that a fermentation process had taken place. Similar traces were also observed by Bardel (in BEFIM 1) and Saurel (in BEFIM 1). The other type of traces seen on these finds were those from handling. As context, vessel type and date are missing, it is impossible to say more about these sherds.

The functional integrity of different vessel types

Mötsch et al. (in BEFIM 2, 57 fig. 3) proposed possible vessels types from the Mont Lassois to be associated with different aspects of drinking habits like consumption, mixing or storage. Potential drinking vessels of local origin included goblets and bowls with a flaring rim. Imported drinking vessels included *kylikes* which are

Table 2: The relationship between vessel type and observed traces related to "motion". Note that the frequencies refer to actually used zones, not sherds.

Vessel type		**Stirring**	**Covering**	**Pitting**	**Spalling**	**Cleaning**	**Bumping**	**Handling**	**Shoving**	**Carving**	**Unsure**	**Total**
Local	Bottle	-	-	-	-	-	1	-	-	-	-	1
	Bottle/jar	-	2	-	4	-	-	-	-	-	2	8
	Bowl	5	10	9	1	1	4	9	3	-	1	43
	Goblet	1	1	-	-	-	-	2	-	-	-	4
	Jug	-	-	-	-	-	-	1	-	-	-	1
	Open form	3	-	1	1	-	-	2	3	-	2	12
	Subtotal	*9*	*13*	*10*	*6*	*1*	*5*	*14*	*6*	*-*	*5*	*69*
Import	Amphora	-	-	-	-	-	-	1	-	3	-	4
	Bowl	-	-	-	-	-	1	-	-	-	-	1
	Kylix	-	-	-	1	-	-	2	2	-	-	5
	Krater	-	-	-	2	-	-	-	-	-	-	2
	Lekythos	-	-	-	-	-	-	-	1	-	-	1
	Subtotal	*-*	*-*	*-*	*3*	*-*	*1*	*3*	*3*	*3*	*-*	*13*
Unsure	Unknown	-	-	-	3	-	-	2	-	-	1	6
	Subtotal	*-*	*-*	*-*	*3*	*-*	*-*	*2*	*-*	*-*	*1*	*6*
Total		9	13	10	12	1	6	19	9	3	6	88

known from Greek pictorial sources (see above) to have been used to drink wine from during a *symposion*. Serving vessels of local origin encompass flasks and small bowls, some with a domed *omphalos* bottom, but no imported equivalents are found among the Mont Lassois material. Local mixing and storage vessels include the "large vessels" (*Großgefäße*) and simple "pots" (*Töpfe*), whereas their imported counterparts are supposed to be the *krateres* and the Attic black-figure amphora (Mötsch et al. in BEFIM 2, 57-59).

If we look at the results of the microwear analysis of the pottery we can see that the locally made bowls had the most heterogeneous functions (Tab. 2): they show signs of stirring, cleaning, covering, handling and shoving. Although microwear cannot give evidence for the contents of these bowls, several had evidence for acidic contents (inferred from pitting) and fermentation (inferred from spalling). These bowls were most likely multifunctional, used to mix ingredients (inferred from the stirring, handling and shoving traces), store the contents (considering the traces from covering and shoving) and to consume from (given the handling and shoving traces). The bumping traces may suggest the vessels were put side by side in a storage location. A similar, but more restricted range of inferred activities can be seen for the locally made, so-called open forms for which no typological classification was possible. It should be borne in mind that the frequencies of these various activities also greatly depended on the type of sherd available for study: for instance, if there are more rim sherds, we can say more about covering or the use of spoons (van Gijn et al., this volume).

The other locally made vessel types like bottles, goblets and jugs do not occur in sufficient numbers to draw any conclusions about their general function. Two bottles/jars displayed traces from covering, four also showed spalling which suggests that a fermentation process had taken place inside. One fragment of a jug bore traces from handling. Traces of handling, stirring and covering were seen on the goblets.

Unfortunately, only a limited number of imported sherds were interpretable for microwear analysis so the numbers are too low for firm conclusions about the correlation between vessel type and use. The *kylikes* (n = 2) displayed evidence for handling and being shoved across a surface, indicating that they may well have served as drinking containers. One has spalling, which is probably associated with fermentation, so possibly a fermented beverage was consumed from them. This was confirmed by ORA which showed bacterial fermentation markers for both *kylikes* (Rageot 2019a). The *krateres* are believed to function as mixing and storage vessels. Only two sherds belonging to the same sample (Vix ALT- 002) displayed spalling, presumably linked to fermentation. ORA showed traces of plant oil (type olive), grape wine and bacterial fermentation markers (Rageot 2019a; Mötsch et al. in BEFIM 2, Kat. 40), which is well in line with the microwear results. The small sherd of a *lekythos*, a former part of its handle, displayed traces of handling on its concave side. Obviously no ORA was done on this find. The amphora sherds have use-wear unrelated to their original function: the broken sherds were re-used as pottery tools (see above).

Conclusion

The microwear analysis of a sample of sherds from the Iron Age hillfort of Vix-Mont Lassois showed that traces of use were still present, despite a long history of post-excavation treatment and study. This aligns with the conclusions of ORA which also produced remarkably good results despite the extensive handling these finds must have undergone during the 90 years since their excavation. This is good news for further scientific study of assemblages that were not excavated and treated according to most recent insights. That the imported pottery especially yielded a high frequency

Table 3: Frequencies of spalling and pitting, observed through microwear analysis compared to the occurrence of bacterial fermentation markers or grape wine, as seen by organic residue analysis (ORA).

	Spalling	**Pitting**
Microscopy, no ORA	3	5
ORA, fermentation (wine)	8 (2)	1
ORA, no fermentation	1	4
Total	12	10

of finds that we could not interpret, is due to the generally small size of these sherds and the fact that they were often wall sherds.

Microwear analysis has its limitations, and in the case of the analysis of vessel use, its strength lies in revealing information about gestures and motions people performed in relation to their pottery, not so much about their contents. The latter is the field of ORA (Rageot et al. 2019a; 2019b; Spiteri et al. in BEFIM 2). Only in the case of fermentation traces in the form of spalling and of pitting, which seem to be associated with acidic substances, is it possible for microwear analysis to contribute to our knowledge of what was actually contained within these pots. It is therefore the combination of ORA and microwear that is most profitable if we want to understand pottery function (cf. Fanti et al. 2018). It is encouraging to note that especially the observation of spalling (recognized by microwear analysis) seems to correlate strongly with the presence of bacterial fermentation markers as seen by ORA (Tab. 3).

All in all, there seems to be a nice correlation between the microwear and ORA results, both showing the role of the imported vessels in the consumption of fermented beverages, probably grape wine. There is a very strong correlation between the observation of spalling, that we connected with fermentation, and the results of ORA: only one sherd on which we found spalling, Vix-ALT-101, did not reveal signatures of bacterial fermentation markers, only of fat, pine resin and possibly wax (Rageot et al. 2019a; Mötsch et al. in BEFIM 2, Kat. 1). Two of the sherds which displayed traces of spalling and bacterial fermentation markers are Attic imports: a *Kelchkrater* (Vix-ALT-002, Rageot et al. 2019a; Mötsch et al. in BEFIM 2, Kat. 40) and an Ionic bowl (Vix-ALT-050, Rageot et al. 2019a; Mötsch et al. in BEFIM 2, Kat. 50).

The few interpretable sherds of import ware all seemed to have been associated with drinking habits: all the gestures observed - the handling of the cups closely resembling ancient Greek images and the abrasion on the bases of the cups showing frequent contact with a surface - point to their frequent use in drinking events. None of the examined imported vessels shows evidence for the preparation of drinks or food, because we did not find any traces from stirring on the vessel walls. Rim sherds were unfortunately lacking among the import finds examined, so it was impossible to obtain information on the way these drinks were served, consumed or stored. Traces from covering are only visible on rim sherds.

Interestingly, some of the imported sherds, decorated amphora fragments, were secondarily used as tools in the manufacturing process of ceramics. This shows that these imported vessels had a special significance: after they had broken, the sherds were not thrown away, but were collected and kept for secondary use. This secondary use of broken sherds has not been observed for any local pottery. Although the idea that the sherds of import wares were too pretty and cherished to be rejected is an attractive one, it may also be that the fabric of these sherds lent themselves better for use as a tool: it concerned, in all cases, a fine fabric without coarse tempering material and baked at relatively high temperatures resulting in considerable hardness.

The local pottery from the Plateau showed a much wider range of wear traces than the import material. Obviously, to some extent, this is attributable to a greater sample size, but the difference with the imported pottery is, we would argue, also real. The local pottery has been used intensively, from the preparation of food and beverages (inferred from the traces of stirring) to their storage (traces from covering). Some samples showed signs of pitting, a feature we associate with acidic contents, and even though no signatures of grape wine were associated (Rageot et al. 2019a), it should be stressed that sour milk products or other acidic substances like vinegar, fruit wine or mead could have caused the same pitting traces (cf. Groat, this volume). The fact that spalling was seen on the local pottery studied for microwear is in accordance with the results of ORA. The latter showed bacterial fermentation markers in both imported and local wares in the area of the Plateau (Rageot et al. 2019a), leading the researchers to propose that these signatures may have been connected to beer production (Rageot 2019a; Mötsch et al. in BEFIM 2, 83). Grape wine signatures were absent from the local pottery from the Plateau, yet they were demonstrated on local pottery from other areas of Vix-Mont Lassois, suggesting that the inhabitants of the Plateau were drinking grape wine only from imported pottery (Winkler/Rageot in BEFIM 1). Those living in the area of Les Renards, where craft activities such as metal working were demonstrated, drank grape wine from local pottery (Winkler/Rageot in BEFIM 1).

All in all it is encouraging that sherds excavated almost 90 years ago were still in sufficiently good state to allow the analyses carried out within the BEFIM project. This applies both to ORA (Rageot 2019a; Mötsch et al. in BEFIM 2) and to the microwear study reported in this article. The two approaches complemented and strengthened each other's results and showed that there is a lot to gain from going beyond a simple typomorphological description.

Bibliography

Adams 2013: J. L. Adams, Ground stone analysis: A technological approach ^{2}(Salt Lake City 2013).

Arnold 1999: B. Arnold, "Drinking the feast": Alcohol and the legitimation of power in Celtic Europe. Cambridge Arch. Journal 9/1, 1999, 71-93.

Arthur 2002: J. W. Arthur, Pottery use-alteration as an indicator of socioeconomic status: The ethnoarchaeological study of the Gamo of Ethiopia. Journal Arch. Method and Theory 9, 2002, 331-335.

Arthur 2003: J. W. Arthur, Brewing beer: Status, wealth and ceramic use alteration among the Gamo of south-western Ethiopia. World Arch. 34/3, 2003, 516-528.

Balzer 2009: I. Balzer, Die Drehscheibenkeramik aus den Altgrabungen des Mont Lassois - ein Zwischenbericht. In: Chaume 2009, 51-68.

Bardel 2009: D. Bardel, Les vaisseliers céramiques des fouilles anciennes de Vix/le mont Lassois (Côte-d'Or): Bronze final IIIb, Hallstatt D et La Tène C/D. In: Chaume 2009, 69-152.

Bardel 2012 : D. Bardel, Société, économie et territoires à l'âge du Fer dans le Centre-Est de la France. Analyse des corpus céramiques des habitats du Hallstatt D-La Tène A (VII^e-V^e siècle av. J.-C.). Doctoral Diss. Univ. Dijon (Dijon 2012).

Bardel in BEFIM 1: D. Bardel, Analyse fonctionnelle et faciès de consommation de la vaiselle céramique dans le Centre-Est de la France à la fin du premier et début du second âge du Fer (VI^e-V^e siècle av. J.-C.). In: Stockhammer/Fries-Knoblach 2019a, 249-271.

Chaume 2009: B. Chaume (ed.), La céramique hallstattienne de France orientale: Approches typologique et chrono-culturelle. Actes du colloque international de Dijon, 21-22 novembre 2006 (Dijon 2009).

Chaume/Mordant 2011: B. Chaume/C. Mordant (eds), Le complexe aristocratique de Vix: Nouvelles recherches sur l'habitat, le système de fortification et l'énvironnement du mont Lassois (Dijon 2011).

Cuenca Solana et al. 2011: D. Cuenca Solana/I. Gutierrez Zugasti/I. Clemente Conte, The use of mollusc shells as tools by coastal human groups: The contribution of ethnographical studies to research on Mesolithic and early Neolithic technologies in northern Spain. Journal Anthr. Research 67, 2011, 77-101.

Dietler 1990: M. Dietler, Driven by drink: The role of drinking in the political economy and the case of Early Iron Age France. Journal Anthr. Arch. 9/4, 1990, 352-406.

Fanti et al. 2018: L. Fanti/L. Drieu/A. Mazuy/T. Blasco/C. Lugliè/M. Régert, The role of pottery in Middle Neolithic societies of western Mediterranean (Sardinia, Italy, 4500-4000 cal BC) revealed through an integrated morphometric, use-wear, biomolecular and isotopic approach. Journal Arch. Scien. 93, 2018, 110-128.

Forte et al. 2018: V. Forte/S. Nunziante Cesaro/L. Medeghini, Cooking traces on Copper Age pottery from central Italy: An integrated approach comprising use wear analysis, spectroscopic analysis and experimental archaeology. Journal Arch. Scien. Report 18, 2018, 121-138.

Gosden/Marshall 1999: C. Gosden/Y. Marshall, The cultural biography of objects. World Arch. 31, 1999, 169-178.

Hahn/Weiss 2013: H. P. Hahn/H. Weiss, Introduction: Biographies, travels and itineraries of things. In: H. P. Hahn/H. Weiss (eds), Mobility, meaning & transformations of things. Shifting contexts of material culture through time and space (Oxford 2013) 1-14.

Hayashida 2008: F. M. Hayashida, Ancient beer and modern brewers: Ethnoarchaeological observations of chicha production in two regions of the north coast of Peru. Journal Anthr. Arch. 27, 2008, 161-174.

Keeley 1980: L. H. Keeley, Experimental determination of stone tool uses. A microwear analysis (Chicago 1980).

Kelly/van Gijn 2008: H. Kelly/A. L. van Gijn, Understanding the function of coral tools from Anse à la Gourde: An experimental approach. In: C. L. Hofman/M. Hoogland/A. L. van Gijn (eds), Crossing disicplinary boundaries and national borders. New methods and techniques in the study of archaeological materials from the Caribbean (Tuscaloosa 2008).

Krausse et al. 2017: D. Krausse/L. Hansen/M. Fernández-Götz/I. Kretschmer, Die Heuneburg. Älteste Stadt nördlich der Alpen (Esslingen am Neckar 2017).

Maigrot 2005: Y. Maigrot, Ivory, bone and antler tools production systems at Chalain 4 (Jura, France), late Neolithic site, 3rd millennium. In: H. Luik/M. A. Choyke/C. E. Batey/L. Lõugas (eds), From Hooves to Horns, from Mollusc to Mammoth. Manufacture and Use of Bone Artefacts from Prehistoric Times to the Present. Proceedings of the 4th Meeting of the ICAZ Worked Bone Research Group at Tallinn, 26th-31st of August 2003. Muinasaja teadus 15 (Tallinn 2005).

Marreiros et al. 2015a: J. M. Marreiros/J. F. Gibaja Bao/N. Ferreira Bicho (eds), Use-wear and Residue Analysis in Archaeology (New York 2015).

Marreiros et al. 2015b: J. M. Marreiros/N. Mazzucco/J. F. Gibaja Bao/N. Ferreira Bicho, Macro and micro evidences from the past: The state of the art of archaeological use-wear studies. In: Marreiros et al. 2015a, 5-26.

Mötsch et al. in BEFIM 2: A. Mötsch/M. Rageot/B. Schorer/A. Ballmer/I. Balzer/D. Bardel/S. Cafisso/B. Chaume/Ph. Della Casa/F. Fougère/J. Fries-Knoblach/N. Nieszery/W. Reinhard/F. Sacchetti/K. Schäppi/St. Schreiber/A. Winkler/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, Essen und Trinken am Mont Lassois in Burgund. Neue Erkenntnisse zu Bedeutungen und Funktionen lokaler und importierter Keramik in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019b, 51-112.

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/P. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, The Dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Saurel in BEFIM 1: M. Saurel, Grandes jarres et fosses allongées. La production de bière à l'âge du Fer en Champagne (France), entre le VII^{e} et le V^{e} siècle av. notre ère. In: Stockhammer/Fries-Knoblach 2019a, 135-151.

Skibo 2013: J. M. Skibo, Understanding Pottery Function. Manuals in archaeology method, theory and technique (New York 2013).

Skibo 2015: J. M. Skibo, Pottery use-alteration analysis in use-wear and residue analysis. In: Marreiros et al. 2015a, 189-198.

Spiteri et al. in BEFIM 2: C. Spiteri/M. Rageot/St. Buckley, Das Potential von Biomarkern und Isotopenanalysen für die Untersuchung alter organischer Rückstände. In: Stockhammer/Fries-Knoblach 2019b, 21-50.

Stockhammer in BEFIM 1: Ph. W. Stockhammer, BEFIM 1. Neue Perspektiven auf die Kraft interkultureller Kontakte in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019a, 21-28.

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Van Gijn 1990: A. L. van Gijn, The wear and tear of flint. Principles of functional analysis applied to Dutch Neolithic assemblages. Analecta Praehist. Leidensia 22 (Leiden 1990).

Van Gijn 2010: A. L. van Gijn, Flint in focus: Lithic biographies in the Neolithic and Bronze Age (Leiden 2010).

Van Gijn 2012: A. L. van Gijn, New perspectives for microwear analysis. In: C. C. Bakels/H. Kamermans (eds), The end of our fifth decade. Analecta Praehist. Leidensia 43/44 (Leiden 2012) 275-282.

Van Gijn 2014: A. L. van Gijn, Science and interpretation in microwear studies. Journal Arch. Scien. 48, 2014, 166-169.

Van Gijn/Hofman 2008: A. L. van Gijn/C. L. Hofman, Were they used as tools? An exploratory functional study of abraded potsherds from two pre-colonial sites on the island of Guadeloupe, Northern Lesser Antilles. Caribbean Journal Scien. 44/1, 2008, 21-35.

Van Gijn et al. in BEFIM 1: A. van Gijn/L. Jacobs/N. Groat/N. de Koning/D. Braekmans/A. Verbaas, Studying vessel biographies from the Heuneburg. An experimental approach. In: Stockhammer/Fries-Knoblach 2019a, 77-99.

Verbaas/van Gijn 2007: A. Verbaas/A. L. van Gijn, Querns and other hard stone tools from Geleen-Janskamperveld. In: P. van de Velde (ed.), Excavations at Geleen-Janskamperveld 1990-1991. Analecta Praehist. Leidensia 39 (Leiden 2007) 191-204.

Vieugué 2014: J. Vieugué, Use-wear analysis of prehistoric pottery: Methodological contributions from the study of the earliest ceramic vessels in Bulgaria (6100-5500 BC). Journal Arch. Scien. 41, 2014, 622-630.

Vieugué 2015: J. Vieugué, What were the recycled potsherds used for? Use-wear analysis of Early Neolithic ceramic tools from Bulgaria (6100-5600 cal. BC). Journal Arch. Scien. 58, 2015, 89-102.

Vuković 2009: J. B. Vuković, Non-abrasive pottery surface attrition: Blagotin evidence. Journal Serbian Arch. Soc. 25, 2009, 25-35.

Winkler/Rageot in BEFIM 1: A. Winkler/M. Rageot, Neue Forschungen am Mont-Lassois (Vix, Burgund): Ein späthallstattzeitliches Handwerksareal. Zur Kontextualisierung von Importwaren. In: Stockhammer/Fries-Knoblach 2019a, 273-286.

Author information

Annemieke Verbaas and Annelou van Gijn
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
a.verbaas@arch.leidenuniv.nl
a.l.van.gijn@arch.leidenuniv.nl

Abrasion and inebriation

Investigating the application of use-wear analysis in studies of alcohol production

Nicholas Groat

Summary

Ceramic use-wear analysis has been cited in ethnoarchaeological studies as a way to identify the results and material damages of fermentation. In turn, the presence of a fermentation use-wear signature has been taken to denote the presence or absence of fermented foodstuffs and, in some cases, the possibility of alcoholic products. However, such a deterioration signature has never been fully explored, let alone had its application in archaeological interpretations critically discussed. While use-wear analysis has proven to be a valuable methodological tool in interpreting the biography and function of objects, its use in studies on alcohol production has not been meaningfully integrated into a nuanced interpretation of the craft. Integral to this, sequences of technical gestures that form specific techniques and craft practices, and mediate the creation of material culture, cannot be easily observed. Conversely, use-wear analysis has the potential to reveal technical gestures and mitigate this issue due to its intrinsic ability to explore the relationship between technical choice, action, and resulting surface damage. Combining these ideas, this study uses alcohol-related material from the Early Iron Age Heuneburg, Germany, as a basis for an exploratory experimental programme to further this methodological discussion. Through using this process, the merits of ceramic use-wear analysis as a source of information for enhancing our interpretations of the socially facilitated process of alcohol production can be discussed, while also offering a more meaningful application of the analytical procedure for this craft practice.

Keywords: *Microwear analysis, alcohol production, fermentation, technical gesture, experimental archaeology*

Zusammenfassung

Gebrauchsspurenanalysen an Keramik wurden in ethnoarchäologischen Studien als eine Möglichkeit zitiert, um Ergebnisse von und Materialschäden durch Fermentation zu identifizieren. Im Gegenzug wurde das Vorliegen einer Gebrauchsspur infolge Fermentation als Nachweis der An- oder Abwesenheit fermentierter Nahrung und in manchen Fällen des möglichen Vorkommens alkoholischer Erzeugnisse betrachtet. Allerdings wurden solche Abnutzungszeichen nie vollständig untersucht, geschweige

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 171-192.

denn wurde ihre Anwendung bei archäologischen Interpretationen kritisch diskutiert. Während Gebrauchsspurenanalysen sich als wertvolles methodisches Werkzeug zur Interpretation der Biographie und Funktion von Objekten erwiesen haben, wurde ihre Verwendung bei Studien zur Alkoholherstellung bisher nicht aussagekräftig in eine ausführliche Deutung des Handwerks integriert. Dadurch bedingt lassen sich Abfolgen technischer Handgriffe („Gesten"), die spezielle Techniken und Handwerkspraktiken bilden und die Erschaffung materieller Kultur übermitteln, nicht leicht beobachten. Umgekehrt hat die Gebrauchsspurenanalyse das Potential, technische Gesten zu entdecken und dieses Problem zu entschärfen dank ihrer naturgegebenen Möglichkeit, das Verhältnis zwischen technischer Wahlmöglichkeit, Handlung und resultierendem Oberflächenschaden zu erforschen. Diese Untersuchung verbindet diese Ideen und benutzt alkoholrelevante Funde von der früheisenzeitlichen Heuneburg, Deutschland, als Grundlage für ein experimentelles Forschungsprogramm, um diese methodische Diskussion voranzubringen. Durch diese Vorgehensweise können gleichermaßen die Stärken der Gebrauchsspurenanalyse von Keramik als Informationsquelle für eine verbesserte Interpretation des sozial geförderten Vorgangs der Alkoholproduktion diskutiert und eine bedeutungsvollere Anwendung der Analyse dieser Handwerkspraxis gegeben werden.

Schlüsselwörter: *Gebrauchsspurenanalyse, Alkoholherstellung, Fermentation, technischer Handgriff („Geste"), experimentelle Archäologie*

Introduction

Contemporary research into the "archaeology of alcohol" has enhanced our interpretations of a frequently romanticised composite product. Allied to numerous emerging lines of enquiry, archaeologists have supported the use of organic residue analysis (ORA) to increase the visibility of alcohol in the archaeological record (e. g. McGovern 2009). However, the exploration of alcohol as a craft requires further systematic investigation, considering that such a visceral product becomes imbued with meaning and sociocultural details throughout its production and consumption (cf. Dietler 2006). As widely understood from studies of technology, materials and *chaîne opératoire,* craft production is fundamentally made up of agent-centric practices that transform raw materials through specific techniques and methods (e. g. Dobres 1999; 2000; Ingold 1995; Lemonnier 1986; Sellet 1993). Such sequences of technical gestures - the corporeal bases of combining bodily engagement with materials and surrounding social conditions of crafting - underpin craft production and have direct connections with material objects (De La Fuente 2011, 89; Dobres 1999, 128-129). This is particularly important in the context of food production, as the interactions between craft practices, technical gestures, material objects and long-term culinary traditions can be recognised as active components that formulate a socially-mediated "cuisine" (Isaakidou 2007, 6).

Observing a subjective series of technical gestures might appear disembodied from the tangible archaeological record, considering that the movements and actions of seemingly invisible agents of the past cannot be directly measured. The adoption of use-wear analysis offers a potential solution, when conducted within robust methodological frameworks, to explore the connection between a physical action of a human agent and observable damages on materials. Bolstered by a history of comprehensive datasets from ethnographic and experimental studies, and critical reviews of methodologies (e. g. van Gijn 2014), the applicability of use-wear analysis to reveal said technical gestures is evident. However, when employed as an indicator for potential alcohol use or production, ethnographic data is often taken as the primary comparable trace reference and uncritically used as a marker of the presence of alcohol (e. g. Vuković 2009).

Exploratory research is therefore needed to establish the merits that approaches like use-wear analysis have for commenting on technical gestures in alcohol production. The archaeological assemblage of the Early Iron Age Heuneburg provides ample opportunities to undertake such a study within a sufficiently large and varied context. Considering the long history of alcohol-related interpretation at Heuneburg that centralises consumption and feasting (e. g. Arnold 1999; Dietler 1990; Kimmig 1968), the extent of ceramic use-wear analysis as a means to provide insights on the *chaîne opératoire* of alcohol production can be discussed in this context. This paper therefore aims to critically evaluate a method to help reveal the technical gestures and sociocultural conditions surrounding alcohol. Through a small-scale series of exploratory experiments conducted as part of the larger experimental program described within this volume (van Gijn et al., this volume), the paper considers the applicability of use-wear analysis as an analytical tool within alcohol studies.

Ceramic use-wear analysis for alcohol research

The application of use-wear analysis for interpreting alcohol production contexts is underexplored partially due to the similarly underdeveloped field of ceramic use-wear analysis. Since its conceptualisation, most use-wear investigations have been undertaken on lithic tools (van Gijn 2012, 275). Comparatively, ceramic use-wear analysis has developed slowly and lacked well-established methodological practices, instead creating assumptions on vessel function with limited equivalent value and without comparative references (van Gijn 2014, 168; e. g. Griffiths 1978). Traditionally, categories of use-wear traces have been linked to distinct materials, technological actions and in turn specific technical stages (Beck 2010, 48; Marreiros et al. 2015). Archaeologists have frequently taken this as an indicator that object function can therefore be objectively determined rather than interpreted, despite the observational ambiguity embedded in interpreting all archaeological materials without adequate references (van Gijn 2014, 166-168). Experimentation has provided a means to alleviate such ambiguity and understand how distinctive trace morphologies are created under set conditions (Adams 2010, 137). Notably in ceramic use-wear analysis, the study of potsherds as tools has relied on microscopic high-power comparisons of archaeological materials with experimental traces, producing comprehensive interpretations on trace development (e. g. López Varela et al. 2002; van Gijn/Hofman 2008). However, the disparity between undertaking detailed high-power analysis on single sherds compared with complete vessels to understand vessel function is not fully recognised. As a result, studies of ceramic surface use-alteration are frequently at the forefront of vessel function investigations (cf. Hally 1983; Skibo 1992). However, by not fully utilising the analytical value of high-power microscopic instrumentation, discussing ceramic vessel function at a use-alteration scale cannot provide enough detail and account for all contextual differences between ceramic-related practices and associated traces (van Gijn/Hofman 2008, 25-26; van Gijn/Lammers-Keijsers 2010). Furthermore, when interpreting trace patterns on pottery, simply borrowing use-wear trace classifications (such as abrasion, attrition and striations) determined in experiments not directly associated with ceramics is problematic due to the lack of unified understanding on how ceramic traces form (Schiffer/Skibo 1989). Thus, despite the methodological rigour of some experiments, results may tell little of past technological processes if they are interpreted without considering how use-wear trace collections are developed and employed.

In addition to such methodological issues, explicit and sufficiently-evaluated alcohol production use-wear signatures are sparse. Ethnographic accounts of alcohol production, and its effects on ceramic surfaces, are often referenced as an informed connection between fermentation and use-wear traces, despite focussing on trends from complete vessels through multiple trace descriptions, which are generalised without microscopic analysis (cf. Arthur 2002; 2003). Such accounts have been considered as the predominant source of information due to the rarity of direct evidence for alcohol production in archaeological contexts (e. g. Renken 1993, 474; Vuković 2009). By acting as an analogy for interpreting technological practices with observational authority, ethnographic accounts have frequently been reduced to homogenous and superficial models that are projected onto the past (Hayashida 2008, 162). This limits the potential body of significant information gained from analysing the physical traces of technical gestures observed in such projects.

Identifying explicit fermentation traces has dominated research in this area and structured analytical perspectives, employing terminological classifications of specific use-wear traces. Vessels used for producing alcohol have been considered to have a higher rate of interior surface attrition (Skibo 1992, 106) caused by acetic and lactic acids produced during fermentation (Arthur 2003, 524). This has been noted to leave a "deterioration" trace (Skibo 2015, 194), or what is described ambiguously as surface erosion (Arthur 2003, 524; Vuković 2009, 27). Assumptions on the process would suggest fermentation traces could be more visible and prominent at the surface of the liquid and below, due to heightened activity of top-fermenting yeasts needed to produce alcohol, though this remains to be observed microscopically and tested experimentally (Skibo/Blinman 1999, 182). In other examples, fermentation traces are classified as pitting, described as rounded holes on the lower interior surface created by fermenting liquids dissolving ceramic surfaces or surface inclusions to create rounded pits or voids (Hally 1983, 18). The presumed processes leading to pitting are varied, depending on the description or account (e. g. Noneman et al. 2017). Pitting traces may also be caused by fermenting liquids penetrating vessel fabrics to induce lime spalling on the interior surface (Hally 1983, 17-18; Skibo 2015, 195). Equally, wear traces of external spalling occur when liquids seep through the ceramic fabric, possibly during fermentation (Hally 1983, 19). Temporality here is seen to influence fermentation traces, as ethnographic cases have described erosion generated on interior surfaces of vessels used for serving and storing of fermented food (Arthur 2002). Yet, as traces related to fermentation are not caused by abrasive mechanical actions like stirring or cleaning, and because some ceramics are soft, visually-similar traces may be caused by other processes. For instance, both pitting and surface erosion can occur during ceramic manufacture and contact with non-alcoholic high-pH substances (Vuković 2009, 27). Fermentation traces could therefore be labelled as "surface roughness", recognising that multiple abrasive mechanisms involved in fermentation could cause attrition traces (e. g. Schiffer/Skibo 1989, 101-102) and that traces caused by this process may not be limited to one morphological grouping. However, as such terminological disparities are counterintuitive for adequate classification, more detailed description on a microscopic level is required.

Use-wear studies outside alcohol production have identified a range of recognisable traces, implying that indications of other technical gestures involved in the *chaîne opératoire* of alcohol production could be observed beyond just those associated with fermentation. Stirring and processing raw materials have been noted to create abrasion or attrition on the interior base and lower sections of ceramic vessels (Skibo 1992, 137), as implicated by the properties of utensils that affect the resulting use-wear signature definition (Biddulph 2008, 95). Such a technical gesture is required to create the sugar-rich source for alcohol fermentation, thus recognisable striations might appear in archaeological examples caused when stirring tools have been in contact with the interior ceramic fabric (e. g. Skibo 1992). Further studies have shown that consistent abrasion patches, bands, or surfaces with fewer scratches might indicate contact with a medium/soft rounded stirring tool, depending on striations being broad or isolated and thin (Vieugué 2014, 626). Comparatively, tools made of hard materials (such as metal) are expected to leave deeper scratches (Vieugué 2014, 626). Repeated stirring in the same place with a suitably hard contact material may cause the development of "polish" (Vieugué 2015, 100; cf. Dolfini 2011). Transferring liquids from one container to another may also cause abrasion and striations on the rim or upper section of the interior due to the contact between decanting tools and vessel. Moreover, contact with softer materials, such as other ceramics used for decanting, might cause surfaces to smooth in linear bands that mirror decanting actions instead of distinct striations (Vieugué 2014, 624). If actions are forceful enough, inclusions in the ceramic fabric may be removed, causing voids that could be subsequently levelled by further decanting.

As highlighted here, it is evident that there are many unconfirmed classifications of use-wear trace types both within and outside alcohol production. As there is no clear understanding of what can be explicitly recognised as a fermentation trace, and what may impact its definition beyond a series of generalisations, no established consensus on the range of use-wear traces generated during alcohol production exists. Considering a plausible range of traces through an experimental methodology is, therefore, a relevant analytical approach, which requires initial exploration to identify critical issues within existing analytical practices. Hence, the influence of ingredient processing (stirring), fermentation and decanting within a specific type of ceramic vessel, as based on a plausible method of alcohol production at Early Iron Age Heuneburg, provides a context to explore variables and gestures. Additionally, the present body of ceramic use-wear evidence requires an exploratory experimental programme of research to evaluate the application of ceramic use-wear analysis within alcohol production studies.

Methodology: use-wear analysis and experimental programme

A limited experimental campaign was undertaken in the light of previously recorded alcohol production use-wear signatures, as understood from the existing body of literature and prior fermentation trace experiments as part of the wider experimental programme undertaken by the Laboratory for Material Culture Studies at Leiden (cf. LMCS 2017, Experiment (Exp.) 3465; 3467) (van Gijn et al., this volume). The aim was to highlight plausible traces and variables affecting trace definition. Using the use-wear interpretations of the ceramic assemblage from Heuneburg (112 samples) (van Gijn/Verbaas, this volume), select archaeological examples were chosen to replicate a specific, contextualised process of honey-wine ("mead") production. This included the use of processing and serving equipment such as copper ladles and ceramic cups, in line with previously recorded feasting paraphernalia and bee-product residue-indications possibly resulting from honey-wine production. Six individual experiments were conducted in three replica vessels (Vessel 1 containing Exp. 3483a and 3483b; Vessel 2 containing Exp. 3502a and 3502b; Vessel 3 containing Exp. 3488a and 3488b) to generate a range of use-wear trace types from plausible technical gestures involved in producing honey-wine (see Tab. 1 for variable detail).

Specific sections of the experimental vessels were designated for individual actions so that traces could be understood in relation to one another and categorised in isolation. Variables affecting trace creation could then be plausibly identified. Use-wear traces characteristically associated with technical stages in alcohol production were used as a guide for trace recording during the experimental programme and assemblage analysis (Tab. 2).

Considering the exploratory nature of the experimentation, general observational statements through low power approaches were adequate to discuss the nature of the fermentation and alcohol production traces.

Technological aspect	**Sample**					
	Experiment 3483a	**Experiment 3483b**	**Experiment 3502a**	**Experiment 3502b**	**Experiment 3488a**	**Experiment 3488b**
Ceramic vessel	Vessel 1 (Experiment 3483)		Vessel 2 (Experiment 3502)		Vessel 3 (Experiment 3488)	
Mass when empty	748.6 g		749.6 g		764.3 g	
Mass when full	1748.6 g		1749.6 g		1764.3 g	
Internal/external processing and mixing of ingredients	**Internal**	**Internal**	**External**	**External**	**Internal**	**Internal**
Stage 1- Ingredient processing	Process honey (press from honeycomb)	Process honey (press from honeycomb)	Process honey (press from honeycomb)	Process honey (press from honeycomb)	Process honey (press from honeycomb)	Process honey (press from honeycomb)
Stage 2- Combining ingredients	**Add water and stir with wooden spoon for 20 minutes**	**Add water and stir with wooden spoon for 20 minutes**	**Add water and stir with metal spoon for 20 minutes (external container/ vessel)**	**Add water and stir with metal spoon for 20 minutes (external container/ vessel)**	**Add water and stir with wooden spoon for 20 minutes**	**Add water and stir with wooden spoon for 20 minutes**
Stage 3- Yeast	Add 2 g yeast	Add 2 g yeast	Add 2 g yeast	Add 2 g yeast	Add 2 g yeast	Add 2 g yeast
Stage 4- Sealing	Cover with hemp canvas and tie with string	Cover with hemp canvas and tie with string	Cover with hemp canvas and tie with string	Cover with hemp canvas and tie with string	Cover with hemp canvas and tie with string	Cover with hemp canvas and tie with string
Stage 5- Fermentation	**Ferment for 14 d**	**Ferment for 14 d**	**Ferment for 30 d**	**Ferment for 30 d**	**Ferment for 30 d**	**Ferment for 30 d**
Stage 6- Consumption	**Decant using ceramic cup**	**Decant using ladle**	**Decant using ceramic cup**	**Decant using ladle**	**Decant using ceramic cup**	**Decant using ladle**

Table 1: Honey-wine samples and their manufacture methods produced in the experiment. Properties of both the wines and the contact materials that have been used are listed. Text in **bold** *indicates which steps have differing tested variables.*

Whole or near-complete hand-made local vessels from the Lower Town settlement (*Vorburg*, HB-VB series) with discernible traces were chosen as the basis for the experiments, considering that their completeness would presumably ensure the greatest representative potential for displaying significant trace patterns. Several of the HB-VB vessels had also tested positive for bee-products, grape wine, or bacterial fermentation products (Rageot et al. 2019). This range has previously been proffered as potential indicators of alcohol (cf. Guerra-Doce 2015). Although the distribution of such residues is evident across all sections of the site (cf. Mötsch et al. in BEFIM 1; Schorer et al. in BEFIM 1; Mötsch et al. in BEFIM 2; Rageot et al. 2019), HB-VB samples were the largest proportion of the assemblage (62.5 %, *n* = 70). Interior surface abrasion and pitting traces (either loss of inclusions or disintegrated inclusions) were used as a starting point for selecting appropriate and relevant samples from the HB-VB group. The morphology and description of these traces was largely ambiguous as no comprehensive reference existed. Samples HB-VB-008, HB-VB-012, HB-VB-014, HB-VB-021, HB-VB-024, HB-VB-026 and HB-VB-071 presented indications of pitting traces, surface roughness, or

Table 2: Categorisation of traces possibly linked to alcohol production derived from current ethnographic and archaeological evidence, used as a guide to record use-wear traces in the analysis of the Heuneburg ceramic assemblage and the traces in the experiment (after Arthur 2002; 2003; Hally 1983; Skibo 1992; 2015; Vieugué 2014; 2015).

Action or technical gesture and location of traces	**Trace**	**Definition and morphology based on archaeological and ethnographic evidence**
Stirring with wooden tool (interior base and lower interior side in horizontal bands)	Shallow striations	Thin linear trace, not deep, direction depends on gesture (e. g. horizontal, angled)
	Faint striations	Faint linear trace, direction depends on gesture (e. g. horizontal, angled)
	Surface smoothing	Surface levelling traces, smooth surfaces, could be related to inclusion removal, usually in groups or bands
	Bands of abrasion	Groups of surface abrasion in a distinct direction
Fermentation (interior or exterior, below level of liquid / mid and lower sides)	Surface "erosion and deterioration"	Unclear, may be categorised with loss of inclusions and pitting
	Surface roughness	"Gravel-like" texture or abrasion to surface caused through prolonged contact with liquid
	Loss of inclusions	Sharp gradient voids, inclusions dislodged
	Pitting	Dissolving inclusions, rounded voids, regular rounded traces, sometimes rather deep and in small groups
	Spalling	Internal or external pitting trace, tends to be irregular marks rather than groups/ patches
Decanting with ceramic tool (interior from base to rim in vertical bands)	Wide striations	Comparatively wide linear trace, direction depends on gesture (e. g. horizontal, angled)
	Bands of surface smoothing	Directional and grouped surface levelling traces, smooth surfaces, could be related to inclusion removal
	Bands of surface abrasion	Notable rough groups of surface abrasion in a distinct direction
	Surface abrasion	Patches of abrasion, possibly thin
	Inclusion levelling	Flattened inclusion that may be normally pronounced, edges may be rounded, flat surface of inclusion may show direction of action, may flatten or level other traces
	Inclusion removal	Noticeable void that may be flattened from decanting material, differs from loss of inclusion in that the decanting tool removed it and smoothed the surface above it rather than being dislodged by liquid
Decanting with copper ladle (interior from base to rim in vertical bands)	Thin striations	Thin linear trace mark, direction depends on gesture (e. g. horizontal, angled)
	Deep striations	Deep linear trace, direction depends on gesture (e. g. horizontal, angled)
	Bands of surface smoothing	Directional and grouped surface levelling traces, smooth surfaces, could be related to inclusion removal
	Bands of surface abrasion	Rough notable groups of surface abrasion in a distinct direction
	Inclusion levelling	Flattened inclusion that may be normally pronounced, edges may be rounded, flat surface of inclusion may show direction of action, may flatten or level other traces
	Inclusion removal	Noticeable void that may be flattened from decanting material, differs from loss of inclusion in that the decanting tool removed it and smoothed the surface above it rather than being dislodged by liquid
	Polish	Surface trace that reflects light, has an oily or "greasy" finish, often as a patch or group

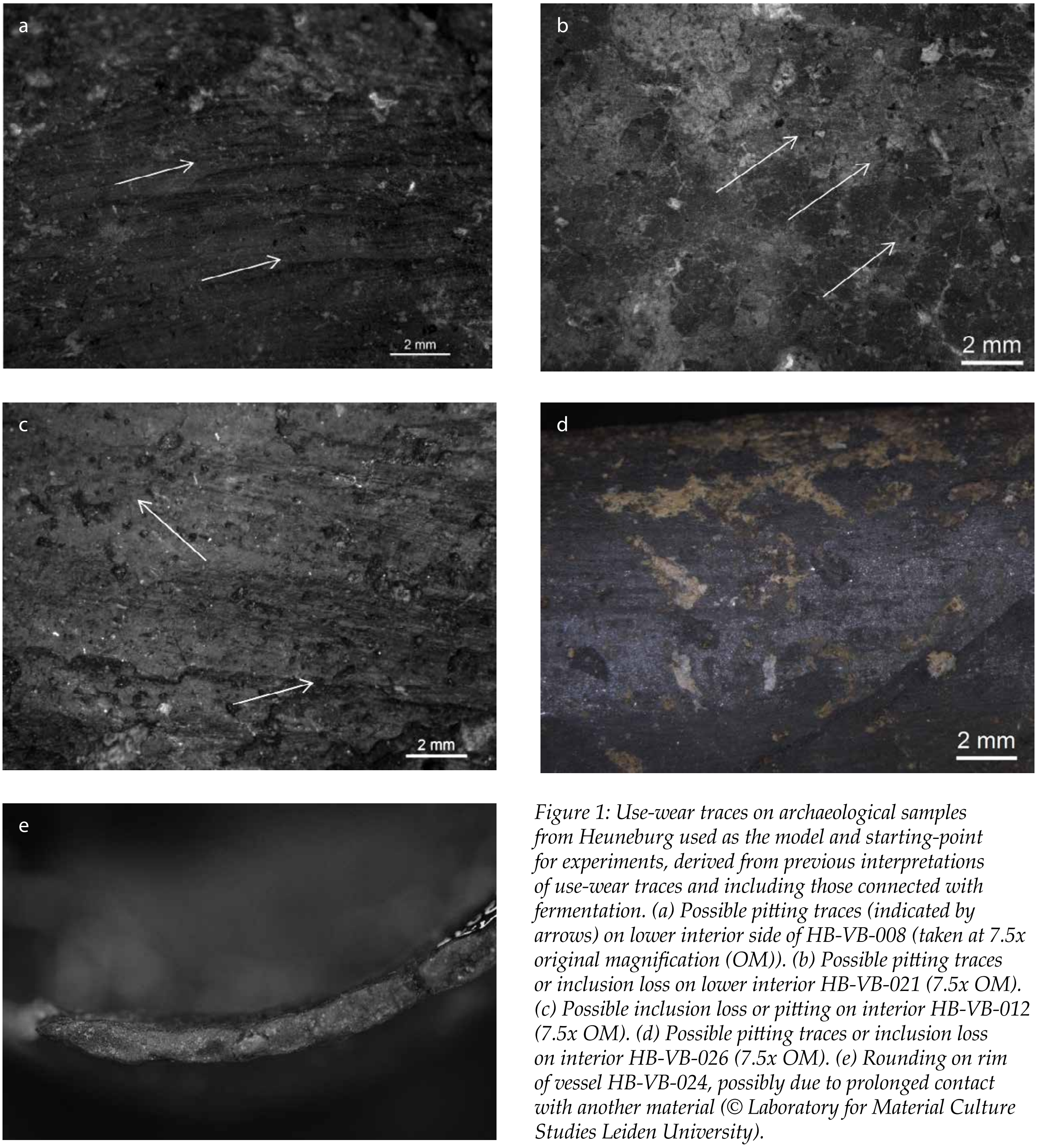

Figure 1: Use-wear traces on archaeological samples from Heuneburg used as the model and starting-point for experiments, derived from previous interpretations of use-wear traces and including those connected with fermentation. (a) Possible pitting traces (indicated by arrows) on lower interior side of HB-VB-008 (taken at 7.5x original magnification (OM)). (b) Possible pitting traces or inclusion loss on lower interior HB-VB-021 (7.5x OM). (c) Possible inclusion loss or pitting on interior HB-VB-012 (7.5x OM). (d) Possible pitting traces or inclusion loss on interior HB-VB-026 (7.5x OM). (e) Rounding on rim of vessel HB-VB-024, possibly due to prolonged contact with another material (© Laboratory for Material Culture Studies Leiden University).

heavy abrasion, although their morphology varied greatly (Fig. 1a-b). Moreover, the samples presented a range of residues some more closely related to alcohol than others. HB-VB-012 and HB-VB-014 demonstrated evidence of inclusion loss and surface abrasion or roughness, and presented extensive pitting traces across the interior surface in line with previous ideas on fermentation use-wear signatures (Fig. 1c). These latter two samples had however only produced residues indicative of animal fats (cf. Mötsch et al. in BEFIM 2; Rageot et al. 2019), though HB-VB-026 and HB-VB-071 produced indications of grape wine or bacterial fermentation products with corresponding possible pitting and inclusion loss traces on HB-VB-026 (Fig. 1d). Unfortunately, previous reconstruction practices

Figure 2: Replica of vessel HB-VB-024 (Vessel 1/Exp. 3483). Two other replicas were made with the same composition, dimensions and morphology for the experimental campaign (© Laboratory for Material Culture Studies Leiden University).

on HB-VB-071 rendered it difficult to analyse traces on the interior further, despite being a good representative sample. Conversely, HB-VB-024 was one of the most complete examples of a hand-made pot sharing typological and compositional similarities with other vessels and producing possible alcohol-product residues. On the interior, heavy abrasion at the base and some surface deterioration or inclusion-loss traces in the lower interior body were noted as consistent with those seen on HB-VB-012, HB-VB-014 and HB-VB-026. Heavy rounding on the rim of HB-VB-024 also suggested prolonged contact with another object, such as a lid or cover (e. g. a secured textile) (van Gijn/Verbaas, this volume) (Fig. 1e). These interpretations are based on assumptions of use through identified damages to the vessel, yet they stand as a good model for experimentation

Experimental vessels adhered to the properties of the archaeological materials in clay type, inclusions, manufacture process and finish, all made by Loe Jacobs of the Laboratory for Material Culture Studies. Replicas of the larger HB-VB-024 pot were made using calcite temper and clays taken from a polder near Leiden, NL, and fired at 780° C (Fig. 2). These were numbered (Vessels 1-3/Exp. 3483, 3502 and 3488) and divided into two areas (e. g. Vessel 1/Exp. 3483 containing Exp. 3483a and 3483b) with small marks on the rim to delineate areas for decanting comparison (one side for ceramic cup decanting, the other for a copper ladle). Replicas of a ceramic decanting cup (based on sample HB-AS-026) were made with 15 % calcite temper and formed with the pinching technique. The cup was reduction-fired at 780° C and left unglazed.

The experiments used sugar sources collected from honeycomb permeated with honey. This was combined with water using a wooden spoon either in the fermenting vessel (internally) or externally, depending on the variables tested in the sample. Much of the honey and beeswax could not be separated, so it was left overnight to homogenise before being used. Samples were prepared using the same mass and ratios on each occasion to maintain a level of reliability. A ratio of 1:1 (water to sugar source, 500 g to 500 g) was used to form the sample. Then 2 g of winemaker's yeast were added to the solution and left to ferment for two weeks in a room kept at around 20° C. Full vessels were weighed prior to fermentation and their contents were sampled for alcohol content readings with a hydrometer. Vessels were covered and tied with hemp canvas. Liquids were left to ferment for either 14 d (Vessel 1/Exp. 3483a and 3483b) or 30 d (Vessel 2/Exp. 3502a and 3502b, and Vessel 3/Exp. 3488a and 3488b). After the fermentation period, the vessels were weighed, and their contents tested using a hydrometer and litmus paper. All liquid contents were measured to determine volume of liquid lost. Vessels were then refilled with the same volume of water to match the final sample volume. Liquid was decanted with either a ceramic cup or copper ladle on each half of the vessel interior and refilled 15 times. This was enough repetitions to generate visible use-wear patterns.

Both interior and exterior surfaces of all experimental vessels were photographed and recorded prior to use using a Nikon D5100 with 60 mm and 18-105 mm lenses, so that a reference and comparative standard was provided for identifying created traces. Targeted inspection and photography of trace-areas were undertaken using a Leica MC 80 HD stereomicroscope, coupled with Leica DFC microscopic camera rendered in the Leica Application Suite programme. Traces were recorded on use-wear recording forms developed specifically for the experiment. Stereomicroscopic analysis was undertaken with oblique light sources with a magnification range of 7.5x to 60x. Ceramic surfaces were cleaned before fermentation, using water to remove contaminants that could impede or affect the rate of fermentation and generation of wear traces. After fermentation, the vessels were sectioned along the predetermined marks to create six individual samples and soaked in warm water for 5 h to remove most covering residues. Samples were then inspected using the same microscopic recording method prior to experiment.

Results

The exploratory experiments generated sets of traces that could be connected to specific technical gestures and variables during alcohol production, as observed microscopically (Tab. 3).

Vessel 1 (Exp. 3483a and 3483b) presented traces indicative of contact with the wooden spoon following the stirring motion when mixing honey with water inside the vessel. Before cleaning, wide horizontal bands of surface smoothing were noted along the protruding interior base, where inclusions had been removed. Subsequently created voids were levelled or smoothed. Considering the band morphology and width, such traces could be strongly associated with prolonged contact with the wooden spoon. After cleaning, these became less pronounced, though wax had become imbedded in the fabric of the ceramic and wiped in the same direction as the stirring action. Wax wipes appeared to highlight faint horizontal striations, specifically in Exp. 3483a (Fig. 3a). As noted in Exp. 3483b, surface smoothing bands were still evident after cleaning, which overlapped some inclusion loss voids and could be considered as visually more abrasive (Fig. 3b), although this is not a strong inference. Comparatively, stirring traces observed in Vessel 3 (Exp. 3488a and Exp. 3488b) were not as obvious. Some very faint horizontal striations were noted in Exp. 3488a following the stirring action around the area where the lower interior side met the base of the vessel, highlighted by wax from the honey (Fig. 3c). However, it seemed that the wax may instead have highlighted the manufacture traces of the vessel, through stirring that pressed the wax into wipes on the surface. In Exp. 3488b, no explicit traces directly associated with stirring were observed. Some minor horizontal bands of abrasion or smoothing near the base were visible over inclusion removals or losses, although no clear trends could be detected.

Traces directly interpreted as the product of fermentation were hard to confirm. Some loss of inclusion was noted on the interior base of Vessel 1 before cleaning (Exp. 3483a and 3483b, 14 d fermentation period), though it is unclear whether this was a result of fermentation processes alone. These traces may have been caused through stirring, dislodging inclusions. Small pitting was only noted on the interior base of Exp. 3483a in a rough surface grouping, which may be the most plausible connection with fermentation or contact with alcohol in the sample (Fig. 4a). Some small groupings of pitting-like traces were noted in Exp. 3483b, although these could not be differentiated from inclusion removals. Some voids were levelled and smoothed, thus suggesting that inclusion removal may have been caused by stirring. After cleaning, very small patches of pits and minor roughness could be seen at the base of Exp. 3483b (Fig. 4b), but no traces could be noted that differed from those observed prior to fermentation. Moreover, the degree of roundness of the pits could not be connected with specific fermentation traces. During fermentation, honey solution was seen to permeate through the ceramic wall of Vessel 1 (Exp. 3483a and 3483b) and collect in pores on the vessel's external surface where inclusions were

Table 3: Summary of use-wear traces produced and recorded in experiments before cleaning (no significant changes or traces revealed after cleaning).

Vessel	**Vessel 1 (Experiment 3483)**		**Vessel 2 (Experiment 3502)**		**Vessel 3 (Experiment 3488)**	
Sample	**Experiment 3483a**	**Experiment 3483b**	**Experiment 3502a**	**Experiment 3502a**	**Experiment 3488a**	**Experiment 3488b**
Stirring with wooden spoon	Faint horizontal striations and wide horizontal bands of surface smoothing at lower interior base	Surface smoothing and void levelling in wide horizontal bands, possible bands of abrasion	N/A	N/A	Very faint horizontal striations and patches of abrasive bands at lower interior side-base	Surface smoothing and abrasion in horizontal bands at interior base
Fermentation	One small group of surface roughness marked by small pitting traces at interior base, indiscriminate external spalls	Very small group of pits marking a possible surface roughness patch on interior base, some indiscriminate external spalls	Surface roughness group consisting of rounded pits and inclusion losses at interior base, some external spalling	Surface roughness group consisting of rounded pits and inclusion losses, some insignificant and indiscriminate external spalling	Some isolated groups of rounded pits and inclusion losses at interior base, possible indiscriminate exterior spalls	Isolated small group of pitting and inclusion loss in a surface roughness group at interior base, clear isolated external spalls
Decanting with ceramic cup	Wide surface smoothing bands and inclusion removal on lower-upper interior, small patch of abrasion on interior rim	N/A	Bands of surface smoothing with levelled inclusion voids and removal at mid and upper interior, small insignificant patch of inclusion levelling at interior neck	N/A	Faint vertical smoothing bands with levelled voids at mid interior, very small abrasive patch with possible inclusion removal in bands at mid interior and rim	N/A
Decanting with ladle	N/A	Thin vertical striations at interior neck and upper sides, clear polish area with inclusion levelling and removal – one can see vertical direction of action	N/A	Small horizontal group on upper interior neck, thin horizontal bands of inclusion removal and levelling, faint copper residue and polish at mid interior	N/A	Very faint patch of polish at interior neck with boundaries, faint and thin vertical bands of inclusion removal on upper interior side
Final approx. ABV % of liquid (at room temperature)	5.8 %	5.8 %	5.3 %	5.3 %	4.2 %	4.2 %
Final approx. pH of liquid (at room temperature)	4	4	4	4	4-5	4-5
Final mass (vessel and liquid)	1429.2 g (18.3 % loss)	1429.2 g (18.3 % loss)	1404.3 g (19.8 % loss)	1404.3 g (19.8 % loss)	1395.3 g (20.9 % loss)	1395.3 g (20.9 % loss)

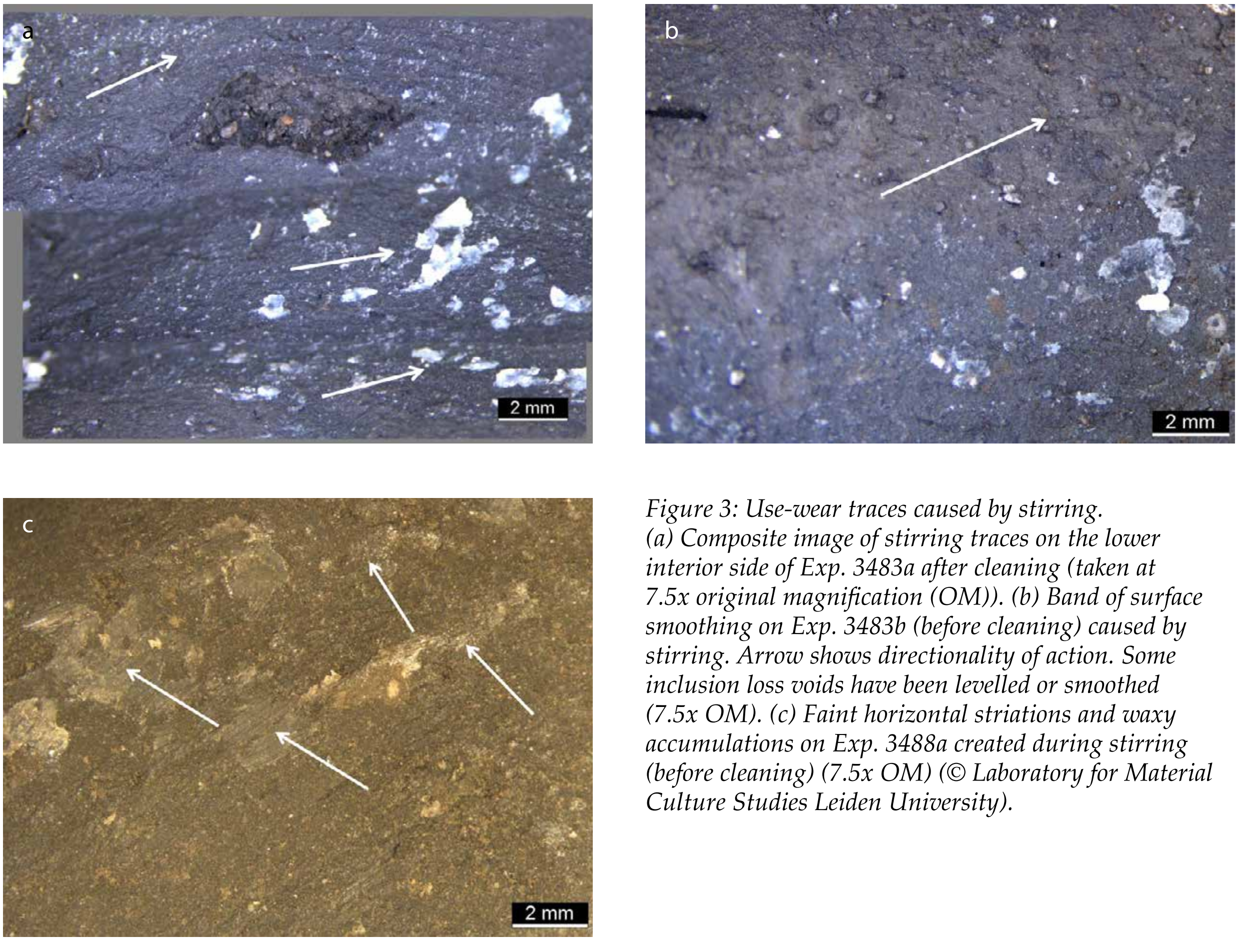

Figure 3: Use-wear traces caused by stirring. (a) Composite image of stirring traces on the lower interior side of Exp. 3483a after cleaning (taken at 7.5x original magnification (OM)). (b) Band of surface smoothing on Exp. 3483b (before cleaning) caused by stirring. Arrow shows directionality of action. Some inclusion loss voids have been levelled or smoothed (7.5x OM). (c) Faint horizontal striations and waxy accumulations on Exp. 3488a created during stirring (before cleaning) (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

present, causing spalling. These traces were seen microscopically, though could not be matched to traces on the interior of the vessel, thus not providing a convincing connection.

Fermentation traces were expected to be seen in Vessel 2 (Exp. 3502a and 3502b, 30 days fermentation period), considering that it had undergone a longer fermentation period than Vessel 1 and that any related traces should not be affected by stirring. Surface roughness with rounded pits and rounded inclusion losses were noted in small collections on the interior base. One small grouping of pitting traces forming a patch of surface roughness was observed in Exp. 3502a in the area where no decanting had occurred (Fig. 4c), possibly the result of the extended fermentation period. Patches of surface roughness were few, but clearly visible and interspersed with exposed vessel fabric temper. External use-wear traces were also noted where honey residues had permeated through the vessel fabric, causing possible spalling traces. Exp. 3502b also produced surface roughness groupings made up of inclusion losses and pitting, exposing the fabric temper (Fig. 4d). Pits here were rounded in small groups, creating a weak spread of surface roughness interspersed with sharper-gradient dislodged inclusion voids. These were more thinly distributed across the surface than those observed on Exp. 3502a, but had evidently generated on top of a set of manufacture traces, as recognised from the visible trace directionality.

Possible fermentation-associated traces were observed in Vessel 3 (Exp. 3488a and 3488b, 30 days fermentation period). At the interior base of Exp. 3488a, surface roughness traces made up of inclusion losses and rounded pitting traces were seen in a few small groupings or patches. These were isolated, clearly grouped together with

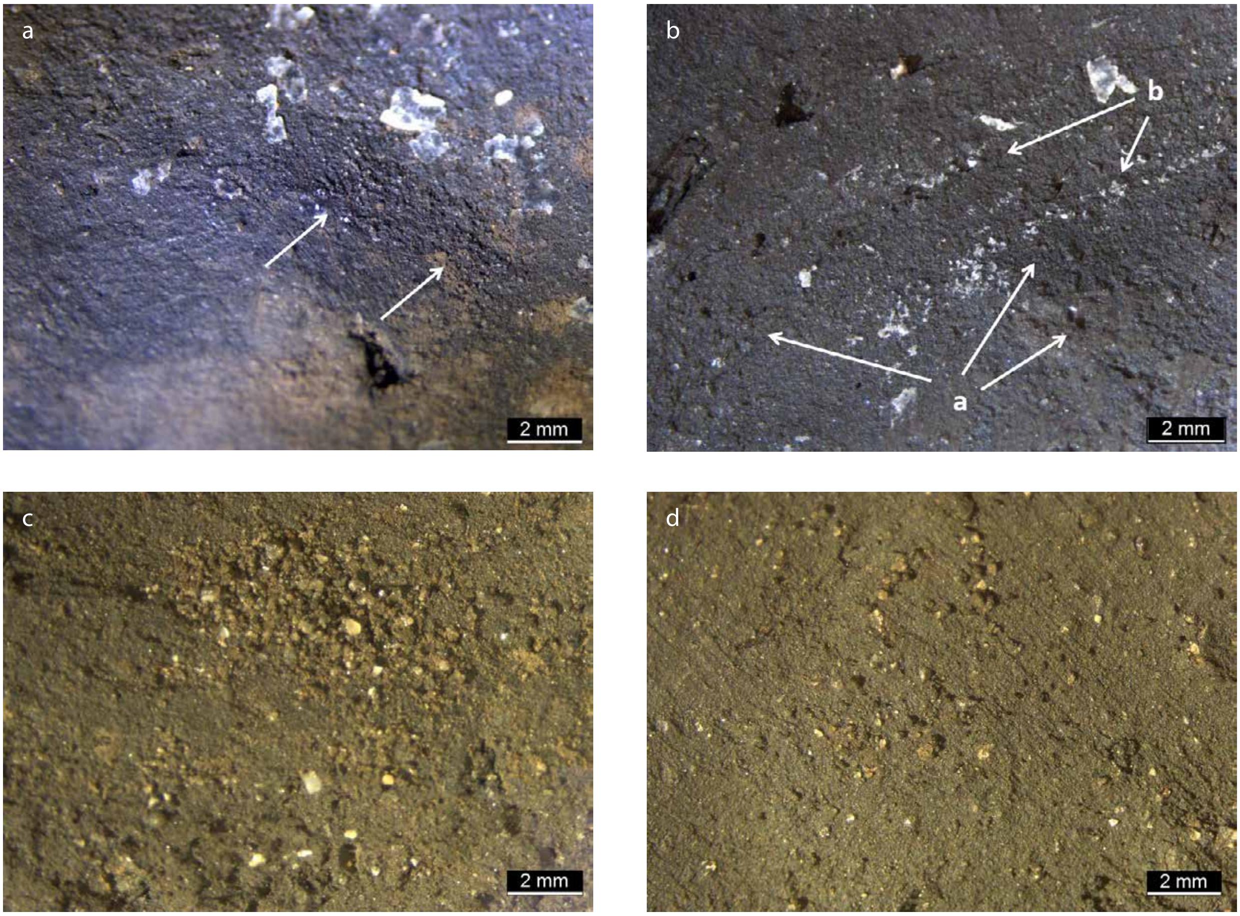

Figure 4: Use-wear traces generated during experimentation related to fermentation. (a) Possible surface roughness or pitting-patches near the base of Exp. 3483a (before cleaning) (taken at 7.5x original magnification (OM)). (b) Small, but weak indications of pitting or surface roughness ("a") and wax wipes following direction of stirring with wooden spoon ("b") on Exp. 3483b interior base (after cleaning) (7.5x OM). (c) Surface roughness patch incorporating rounded inclusion loss and pits at the interior base of Exp. 3502a (before cleaning) (7.5x OM). (d) Thinly distributed surface roughness incorporating pits and inclusion losses at the interior base of Exp. 3502b (7.5x OM). Traces have formed on top of clear manufacture marks with evident directionality, thus presenting a microstratigraphic relationship between traces (© Laboratory for Material Culture Studies Leiden University).

exposed temper, which differentiated them from inclusion removal traces created by decanting (Fig. 5a). The external surface of the vessel also displayed possible spalling traces, although these were indiscriminate and could not be differentiated from voids created on the surface through vessel manufacture. Fermentation traces were noted in 3488b, particularly surface roughness groups, consisting of rounded pits with interspersed inclusion-loss voids at the base (Fig. 5b). Externally, clear examples of permeating liquid causing spalling were noted, though these were individual occurrences and not explicit patterns (Fig. 5c).

Decanting using the small ceramic cup produced reoccurring recognisable traces identified on the vessel interior of Exp. 3483a, 3502a and 3488a, most inferable before cleaning. Long, wide, vertical bands of surface smoothing were noted running perpendicular to the vessel wall of Exp. 3483a from the lower to upper interior side, following the decanting motion (Fig. 6a). This also caused ceramic inclusions to be removed or dislodged in the same region, caused by contact between two ceramic surfaces which levelled the created voids. After cleaning, only the most pronounced trace types were observed, such as a collection of striations in the upper

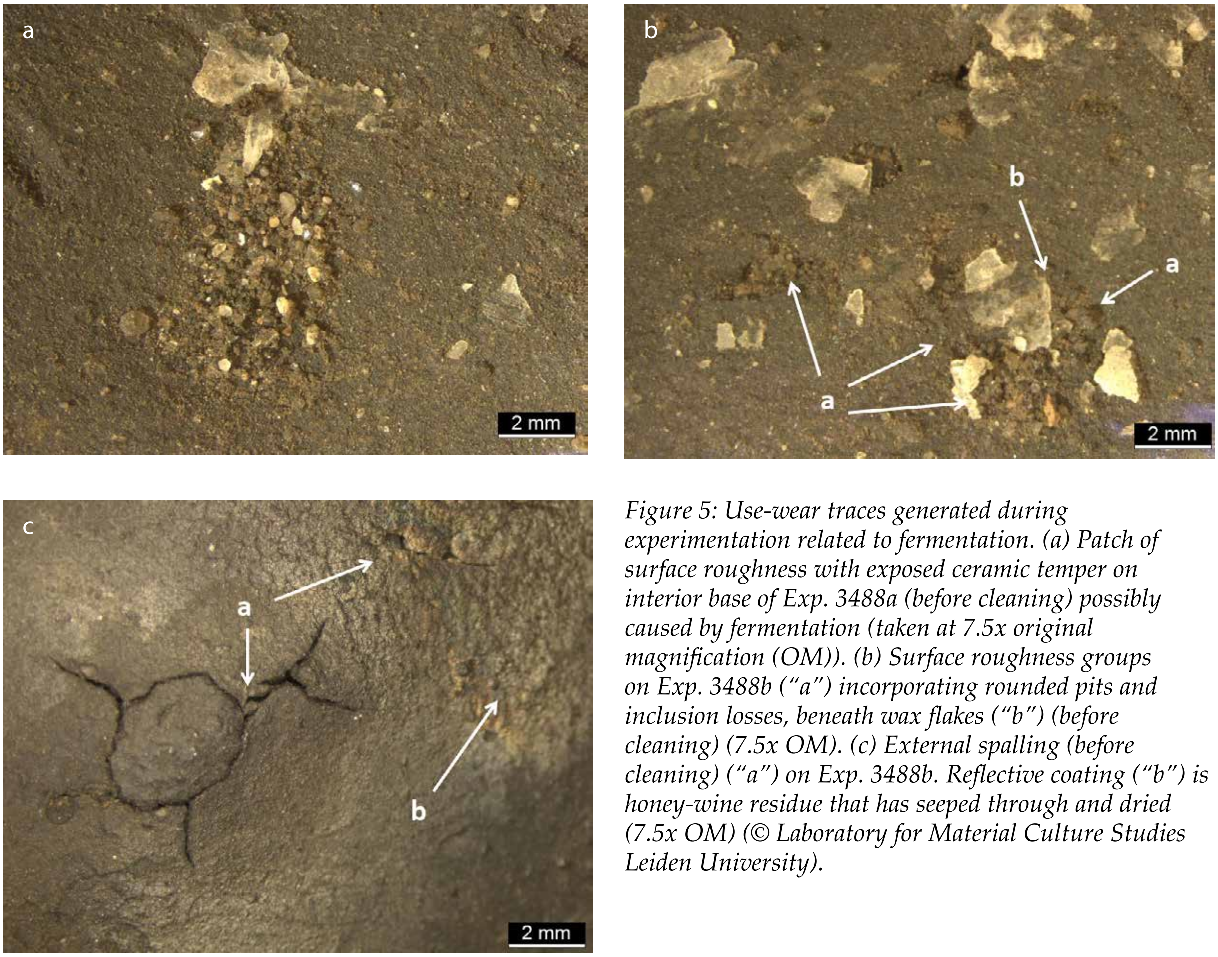

Figure 5: Use-wear traces generated during experimentation related to fermentation. (a) Patch of surface roughness with exposed ceramic temper on interior base of Exp. 3488a (before cleaning) possibly caused by fermentation (taken at 7.5x original magnification (OM)). (b) Surface roughness groups on Exp. 3488b ("a") incorporating rounded pits and inclusion losses, beneath wax flakes ("b") (before cleaning) (7.5x OM). (c) External spalling (before cleaning) ("a") on Exp. 3488b. Reflective coating ("b") is honey-wine residue that has seeped through and dried (7.5x OM) (© Laboratory for Material Culture Studies Leiden University).

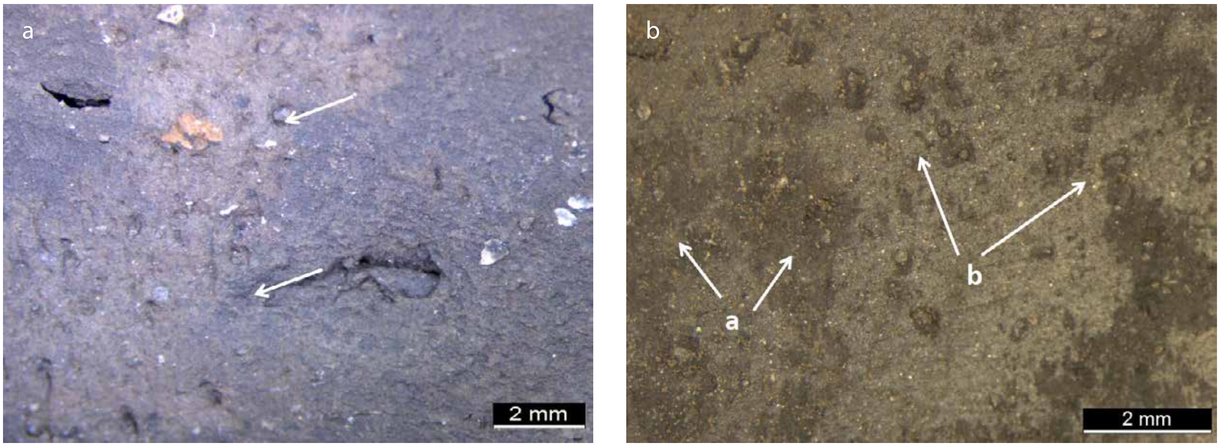

Figure 6: Use-wear traces created from decanting with a ceramic cup. (a) Exp. 3483a vertical bands of surface smoothing and inclusion removal (after cleaning) (taken at 7.5x original magnification (OM)). (b) Bands of surface smoothing ("a") and levelled inclusion-loss voids ("b") on Exp. 3502a (before cleaning) created during decanting, just above the line of where the wine residue was (10x OM) (© Laboratory for Material Culture Studies Leiden University).

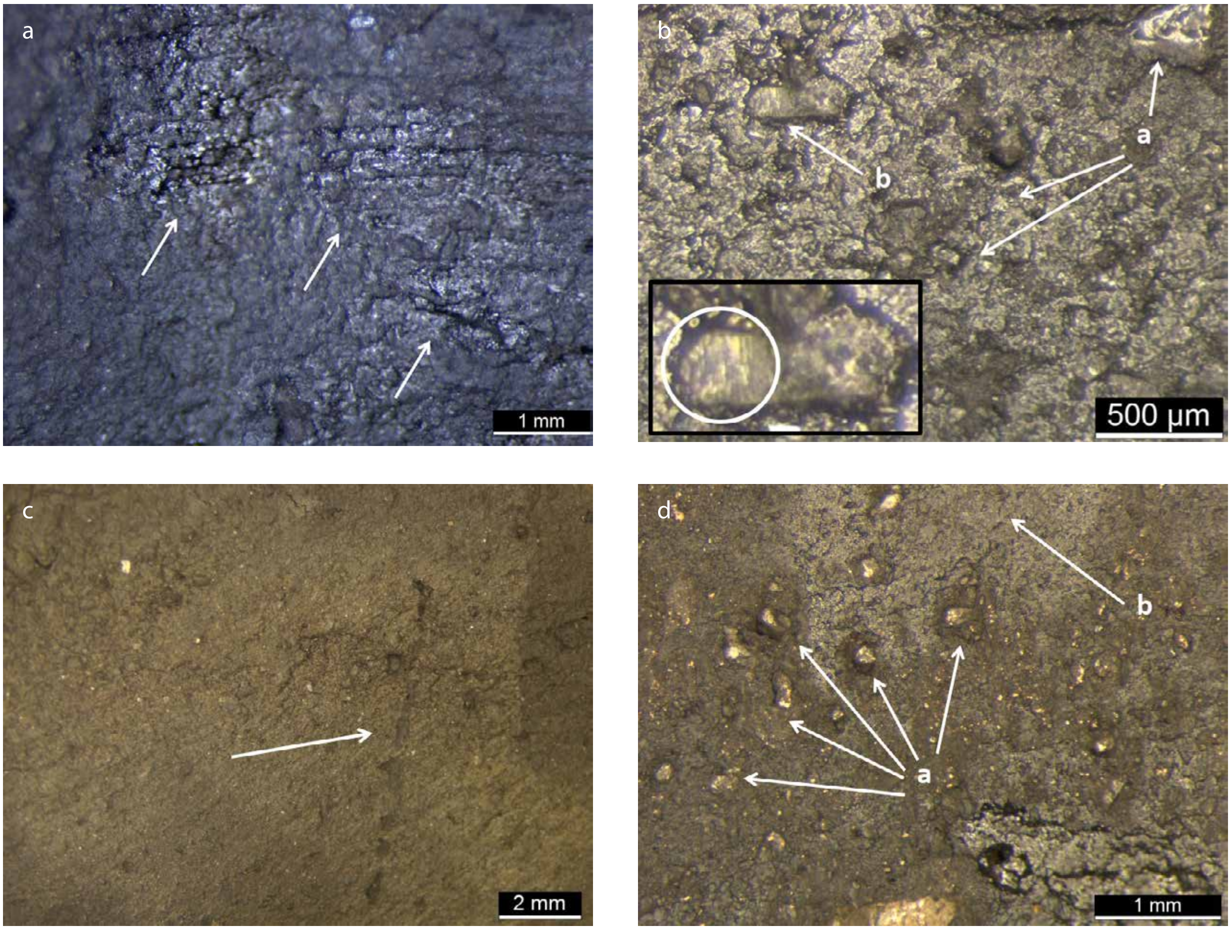

Figure 7: Use-wear traces generated during experimentation related to decanting with a metal ladle. (a) "Greasy", polish-like trace on upper interior area of Exp. 3483b caused by decanting with the ladle (before cleaning) (taken at 20x original magnification (OM)). (b) Polish area on Exp. 3483b (after cleaning) displaying inclusion levelling and rounding ("a") as well as vertical directionality of the action on an inclusion ("b") created during decanting with a metal ladle (40x OM). Detail of vertical directionality ("b") is highlighted on insert. (c) Area of polish on Exp. 3502b interior neck with thin vertical striation created during decanting (before cleaning) (7.5x OM). (d) Metal residue accumulating through decanting on levelled and rounded inclusions ("a") near boundary of polish ("b") at upper interior side of Exp. 3502b (before cleaning) (25x OM) (© Laboratory for Material Culture Studies Leiden University).

interior of Exp. 3483a with inclusion removals. Exp. 3502a (Vessel 2) displayed similar ceramic decanting traces as Exp. 3483a. More detail could be seen regarding the microstratigraphic relationships between removed inclusions and wide bands of surface smoothing on the mid and upper interior sides. Here, vertical perpendicular bands running along the concave shape of the vessel appeared to have flattened or levelled inclusion removal voids (Fig. 6b), though surface smoothing traces were less pronounced than those observed on Exp. 3483a. Moreover, no abrasive damage was noted at the rim, either before or after cleaning, like traces present on Exp. 3483a. Decanting in Exp. 3488a (Vessel 3) also created traces that matched those observed on Exp. 3483a and 3502a. Notably, some inclusion removals had been levelled and smoothed within abrasive bands. Small indications of rounding at the rim were seen, although not overtly discernible.

Traces related to copper decanting were more prominent than ceramic decanting and occurred in all relevant experiments (Exp. 3483b, 3502b and 3488b) on the upper interior side upwards to the rim. Distinctly, "greasy" polish was noted before and after cleaning in a patch near the rim of 3483b. Raised areas of the surface had been levelled or smoothed by the ladle, which created thin vertical striations within the polish patch (Fig. 7a). Moreover, inclusions within the patch were levelled and some vertical directionality was noted. Vertical bands of inclusion removal were also associated with the polish from the mid interior side upwards (Fig. 7b). As with Exp. 3483b, a patch of polish was noted in the same area as Exp. 3502b with clear boundaries. Polish was considerably fainter than Exp. 3483b. However, when examined closely, isolated thin horizontal striations and inclusion levelling were also noted within the polish patch (Fig. 7c). Outside this region, thinner horizontal bands of inclusion removal on the mid interior were noted when compared to Exp. 3483b. Exp. 3502b also produced areas of copper residue on raised inclusions on the ceramic surface that had not been noted on Exp. 3483b (Fig. 7d). A faint polish trace on the upper interior neck of Exp. 3488b could also be connected to this process, though it was not as visible as polish noted on Exp. 3483b and did not have clear directionality or inclusion levelling. Thin vertical bands of inclusion removal were also recorded on the upper interior side towards the rim, although no distinct traces of inclusion levelling or striations were observed. Such bands of removal did not have the same distinct surface smoothing morphology as those in Exp. 3483b.

Discussion

Alongside the growing body of dedicated literature connecting craft practices and use-wear traces, ceramic use-wear analysis should be evaluated through discussing how the method can reveal insights on technical gestures. To an extent, the exploratory experimental programme addressed this, but also accounted for use-wear traces generated from one specific method of alcohol production. This is often a misunderstood disparity when formulating use-wear interpretations, evident when use-wear analysis has been previously incorporated into understanding alcohol craft practices. Thus, traces generated in the experiments described here must not be used to account for all interpretational possibilities. Using experimental traces as a model for trace comparison with archaeological materials must therefore be approached with an element of caution, considering the ease at which ceramics abrade and that taphonomic processes have not been thoroughly researched within ceramic use-wear analysis (Skibo/Schiffer 1987). However, the small sample size and exploratory nature of the experiments meant the project broadly defined the bounds of what could constitute a range of use-wear traces and which variables may affect them, as each stage was produced at least three times (although under different conditions). Equally, results from the campaign can be contextualised within the larger experimental programme (as reported in this volume), thus providing a more complete perspective on the factors that can lead to trace generation.

It can be seen from the experimentation that applications of ceramic use-wear analysis for exploring alcohol production contexts are not exclusively rooted in interpreting fermentation traces. On the contrary, fermentation-specific traces were overall inconclusive, meaning they cannot be explicitly labelled as severe erosion or severe deterioration. Hence, the assumption that fermentation creates diagnostic use-wear traces must be treated with caution. Traces connected to fermentation from Exp. 3483a and 3483b (Vessel 1) were faint and not as distinct as those observed in Vessels 2 and 3, yet alcohol was still successfully produced in Vessel 1 after 14 d. This demonstrates that alcohol production can be achieved without leaving distinct fermentation traces, thus complicating the seemingly definitive relationship between alcohol production and explicit use-wear traces as alluded to in previous bodies of research. Only looking for specific types of deterioration on archaeological materials cannot therefore be used to denote alcohol production, which may potentially cause us to approach interpretation with a biased selection of archaeological materials. Conversely, traces observed in Vessels 2 and 3 (Exp. 3502a and 3502b, and Exp. 3488a and 3488b) indicated that a prolonged fermentation period may cause more fermentation-related traces in this context, but simultaneously reduce the likelihood of observing other traces, such as those related to stirring and decanting. This is important to note as supposed alcohol erosion traces that cover surfaces of complete and near-complete archaeological materials could be related to another process. As the vessels used in experimentation were not repeatedly used for fermenting honey and produced different types of use-wear traces, simply translating the observations from ethnographic cases to expect that all contexts of alcohol production will produce severe deterioration is a weak interpretation. Heavy attrition may be noted on archaeological ceramics, although this cannot be seen as an inextricable link with fermentation or alcohol production.

Despite such observational and interpretive issues, some plausible traces connected with fermentation generated under a specific set of conditions are notable. By fermenting honey for 30 d in a hand-made vessel using wine yeast, we can interpret an experimentally produced trace from a non-mechanical action that can be linked to fermentation in alcohol production. This comprises of a patch of tightly grouped rounded pits and rounded inclusion-loss voids at the base and occasionally the lower interior side, producing an area of "surface roughness". This was seen from Exp. 3502a, 3502b, 3488a and 3488b with the clearest indications in Exp. 3502a and 3502b as ingredients were mixed externally to the fermenting vessel, thus reducing overlapping traces. Pitting traces and the definition of voids produced from inclusion loss were expected to be observationally unclear. However, chemical loss of inclusion (related to fermentation) and mechanical inclusion removal (through decanting) were able to be differentiated between in Exp. 3502a. Prolonged fermentation then could be seen to cause the ceramic fabric surface to deteriorate below the level of the vessel liquid and dissolve or disintegrate inclusions leaving voids. In some instances, this also produced spalling traces externally, although a distinction could be made between the upper and lower sections of internal vessels, as fermentation traces seemed to accumulate below the level of liquid. In archaeological cases, interior surface deterioration may be induced purposefully as a technical gesture, considering that untreated ceramic surfaces provide a means for preserving and transferring yeast cultures between fermenting batches (Hayashida 2008, 167; Fries-Knoblach in BEFIM 2, 14). For instance, this has been incorporated into some industrial beer brewing practices (cf. Nakanishi et al. 1989). However, as seen across the experiments, surface roughness traces noted as a result of fermentation are small and inconsistent. Thus, observed surface deterioration on archaeological materials cannot be considered as indicative of strategies such as yeast cultivation in ceramic vessels. Hence, it is overly-ambitious to directly identify use-wear traces linked to fermentation that were created during the experiments on archaeological materials, considering the delicate nature of the traces. Other traces associated with alcohol production must therefore also be considered in reconstructing the dynamics of alcohol production.

Distinct actions, methods and techniques related to decanting and (on occasions) stirring were interpretable from the experimental collection. Vertical striations and inclusion removal in bands perpendicular to the vessel surface can be linked to specific decanting methods. Significantly, polish accumulations on the interior near the rim could be clearly connected to decanting using a copper ladle. This was observed in Exp. 3483b, 3502b and 3488b, although it was notably duller on 3502b and 3488b, possibly due to longer contact with a viscous liquid and subsequent changes to the ceramic properties during the 30 d fermentation period that made the vessel fabric more saturated. Based on the measured liquids after fermentation, all vessels fabrics reached a similar point of saturation through absorption, though Vessels 2 and 3 generated less notable post-fermentation wear traces, demonstrating the impact that the fermentation period had upon use-wear traces. Notably, the impact of internal or external ingredient processing and mixing prior to fermentation on the range of use-wear traces is important for understanding microstratigraphic relationships of the order in which technical gestures were conducted. Abrasive trace bands and striations noted in Vessel 1 were more prominent than in 2 or 3, which could suggest that producing alcohol in this context was a process involving multiple technical choices and gestures in the same vessel. Hence, processes such as ingredient combination have some impact upon the visibility of other traces. What can be suggested is that increased surface wear from fermentation is probably linked proportionally to the time that the ceramic surface is in contact with liquids, though not necessarily as the result of fermentation alone and not only in association with acetic liquids. Therefore, on archaeological materials, we might be able to compare vessels that have been used for fermentation or alcohol production over a prolonged period with others for more limited use, though the conditions that said traces develop under, need to be better established first. Traces formed during the creation of other acidic fermented products such as vinegar or soured milk may be affected under similar conditions, though the possibility exists that they could be considerably different from those related to alcohol production. Investigating this relationship does go beyond the scope of the current study, but could correspond with the range of plausible dairy residues found at Heuneburg (Mötsch et al. in BEFIM 2, 163-169; Rageot et al. 2019).

Although the faintness of some traces brings into question the likelihood that these survive at all on archaeological materials (such as abrasion from stirring or decanting with a ceramic cup), some diagnostic traces provide a sequence of technical gestures, and therefore indications of techniques and craft practices. When seen together with other use-wear traces from alcohol production, the interpretive value of ceramic use-wear analysis can support a discussion on what actions and gestures are involved in the craft. They should not be purely relied upon to identify alcohol production; instead, exploring the range and variability of technical gestures through ceramic use-wear analysis presents a dynamic interpretation of alcohol production as a sociocultural practice, regardless of how formation processes implicates trace visibility. In doing this, gestures, methods, traditions and techniques can be elaborated on, so a position of alcohol production is understood within a contextual cuisine. Such an approach can bring current interpretations of alcohol at sites like Heuneburg into a critical sphere of analysis beyond a representative assemblage of alcohol consumption activities. Although no comprehensive interpretation is presented here, experimentation provides a platform for new possibilities to interpret the technical decisions and gestures associated with the archaeological vessels. Plausibly, the hand-made ceramics of Heuneburg had a role in multiple production contexts including honey-wine production, thus contributing to the accumulating biography of the vessels. Fermentation period appears to impact use-wear trace visibility, hence fainter or duller traces related to other gestures on archaeological materials may be indirectly indicative of fermentation-related practices. Alcohol was successfully produced after 14 d of fermentation but left no discernible fermentation traces, yet still produced trace types connected with other processes such as stirring and decanting. Such an involved analysis can therefore present the *chaîne opératoire* of alcohol production as a broad technological network that incorporated several technical gestures, crafts and experiences from a variety of sources.

Conclusion

As the aim of this paper was to establish the applicability of ceramic use-wear analysis in studies of alcohol craft practices through initial experiments rather than develop a comprehensive use-wear trace reference collection for the ceramic evidence of Heuneburg, a viable case has been made to justify further exploration into how use-wear analysis can be most beneficial in such a production context. The wider experimental programme supports this argument by demonstrating how ceramic use-wear analysis clearly has a place in interpreting craft practices, including those related to alcohol production (cf. van Gijn et al. in BEFIM 1). However, the broad and varied experimental trace collection generated within this specific study including those associated with fermentation shows that this application is more salient than only identifying the physical damages of alcohol fermentation. Beyond the morphological diversity and variables that affects definition, fermentation traces are varied to an extent that cannot be adequately covered by a single classification. Evidently, the quantity of material variables, taphonomic processes and cultural choices at work during this process means other technical gesture signatures are more visible and telling than an explicit fermentation use-wear trace. Experimentation has shown a range of traces related to alcohol production, which does not explicitly match those often noted in ethnography. Whilst this body of evidence is a good analogy for possibilities, it cannot be taken to denote all use-wear traces generated from processes involved.

The search for specific and comprehensive traces directly connected to fermentation seemingly has little interpretive value in comparison to a more nuanced discussion on the decisions, techniques and ultimately actions that formulate the craft of alcohol production, alongside the wider craft tradition of which it is a facet. This includes understanding the value of observing traces that can be created in many other production contexts beyond a single attribution, such as those related to stirring. Hence, by integrating a unified theory of production and consumption as well as approaching this within technological practices conditioned by specific social concepts, ceramic use-wear analysis can reveal the transformative processes of alcohol production enacted through technical gestures. Although this analytical tool has yet to be fully integrated into discussions on the development of cuisine, use-wear analysis offers insights into the gestures underpinning its construction. Alcoholic beverages are just one product within such a socioculturally-mediated network, hence this craft cannot be interpreted only by searching for its presence. Use-wear analysis, when meaningfully adopted, enables diverse material assemblages to be subjected to contextualisation. If done well, it can be used to shed light on tradition, method, practice and its human connections in food and drink production.

Acknowledgements

I would like to thank Christina Tsoraki for helping me to put this project together and Annelou van Gijn for first involving me in the BEFIM project. I would also like to thank Annemieke Verbaas, Loe Jacobs and Eric Mulder for their assistance in developing the experimental side of my work. Finally, my thanks go to Jane Rempel for commenting on an earlier version of this paper.

Note

This paper is an adapted version of the author's MSc thesis, undertaken in 2017 within the Laboratory for Material Culture Studies, Leiden University, The Netherlands. A full archive of photographs, data recording forms and experimental materials is accessible from the Leiden University Laboratory for Material Culture Studies use-wear reference collection. Experiment numbers ("Exp.") in this paper correspond to reference numbers in the Laboratory reference collection.

Bibliography

Adams 2010: J. L. Adams, Understanding grinding technology through experimentation. In: Ferguson 2010, 129-151.

Arnold 1999: B. Arnold, "Drinking the feast": Alcohol and the legitimation of power in Celtic Europe. Cambridge Arch. Journal 9/1, 1999, 71-93.

Arthur 2002: J. W. Arthur, Pottery use-alteration as an indicator of socioeconomic status: The ethnoarchaeological study of the Gamo of Ethiopia. Journal Arch. Method and Theory 9, 2002, 331-335.

Arthur 2003: J. W. Arthur, Brewing beer: Status, wealth and ceramic use alteration among the Gamo of south-western Ethiopia. World Arch. 34/3, 2003, 516-528.

Beck 2010: M. E. Beck. Ceramic vessel use and use alteration: Insights from experimental archaeology. In: Ferguson 2010, 47-69.

Biddulph 2008: E. Biddulph, Form and function: The experimental use of Roman samian ware cups. Oxford Journal Arch. 27/1, 2008, 91-100.

De La Fuente 2011: G. A. De La Fuente, Chaine operatoire, technical gestures and pottery production at Southern Andes during the late period (c. AD 900-AD 1450) (Catamarca, Northwestern Argentina, Argentina). In: S. Scarcella (ed.), Archaeological Ceramics: A Review of Current Research. BAR Internat. Series 2193 (Oxford 2011) 89-102.

Dietler 1990: M. Dietler, Driven by drink: The role of drinking in the political economy and the case of Early Iron Age France. Journal Anthr. Arch. 9/4, 1990, 352-406.

Dietler 2006: M. Dietler, Alcohol: Anthropological/archaeological perspectives. Annual Review Anthr. 35, 2006, 229-249.

Dobres 1999: M.-A. Dobres, Technology's links and *chaînes*: The processual unfolding of technique and technician. In: M.-A. Dobres/C. R. Hoffman (eds), The social dynamics of technology: Practice, politics, and world views (Washington 1999) 124-146.

Dobres 2000: M-A. Dobres, Technology and social agency: Outlining a practice framework for archaeology (Oxford, Malden MA 2000).

Dolfini 2011: A. Dolfini, The function of Chalcolithic metalwork in Italy: An assessment based on use-wear analysis. Journal Arch. Scien. 38, 2011, 1037-1049.

Ferguson 2010: J. R. Ferguson (ed.), Designing Experimental Research in Archaeology: Examining Technology through Production and Use (Boulder 2010).

Fries-Knoblach in BEFIM 2: J. Fries-Knoblach, Ein Glas in Ehren kann niemand verwehren? Beispiele für Alkohol in der Lebenswelt von Frauen in alten Kulturen Europas und des Nahen Ostens. In: Stockhammer/Fries-Knoblach 2019b, 235-363.

Griffiths 1978: D. M. Griffiths, Use-marks on historic ceramics: A preliminary study. Hist. Arch. 12, 1978, 68-81.

Guerra-Doce 2015: E. Guerra-Doce, The origins of inebriation: Archaeological evidence of the consumption of fermented beverages and drugs in Prehistoric Eurasia. Journal Arch. Method Theory 22, 2015, 751-782.

Hally 1983: D. J. Hally, Use alteration of pottery vessel surfaces: An important source of evidence for the identification of vessel function. North American Archaeologist 4/1, 1983, 3-26.

Hayashida 2008: F. M. Hayashida, Ancient beer and modern brewers: Ethnoarchaeological observations of chicha production in two regions of the north coast of Peru. Journal Anthr. Arch. 27, 2008, 161-174.

Ingold 1995: T. Ingold, People like us: The concept of the anatomically modern human. Cultural Dynamics 7/2, 1995, 187-214.

Isaakidou 2007: V. Isaakidou, Cooking in the labyrinth: Exploring "cuisine" at Bronze Age Knossos. In: C. Mee/J. Renard (eds), Cooking up the Past: Food and Culinary Practices in the Neolithic and Bronze Age Aegean (Oxford 2007) 5-24.

Kimmig 1968: W. Kimmig, Die Heuneburg an der oberen Donau. Führer Vor- u. Frühgesch. Denkmäler Württemberg u. Hohenzollern 1 (Stuttgart 1968).

Lemonnier 1986: P. Lemonnier, The study of material culture today: Toward an anthropology of technical systems. Journal Anthr. Arch. 5, 1986, 147-186.

LMCS 2017: Laboratory for Material Culture Studies Leiden University. Use-wear experiment archive. Internal Report Laboratory for Material Culture Studies (Leiden 2017).

López Varela et al. 2002: S. L. López Varela/A. L. van Gijn/L. F. H. C. Jacobs, De-mystifying pottery production in the Maya Lowlands: Detection of traces of use-wear on pottery sherds through microscopic analysis and experimental replication. Journal Arch. Scien. 29, 2002, 1133-1147.

Marreiros et al. 2015: J. Marreiros/N. Mazzucco/J. F. Gibaja/N. Bicho, Macro and micro evidences from the past: The state of the art of archaeological use-wear studies. In: J. M. Marreiors/J. F. Gibaja Bao/N. F. Bicho (eds), Use-wear and Residue Analysis in Archaeology (New York 2015) 5-26.

McGovern 2009: P. E. McGovern, Uncorking the Past. The quest for wine, beer and other alcoholic beverages *(*Berkeley 2009).

Mötsch et al. in BEFIM 1: A. Mötsch/M. Rageot/B. Schorer, Organic residues in pottery vessels from selected archaeological features of the Heuneburg. First results of a case study. In: Stockhammer/Fries-Knoblach 2019a, 61-76.

Mötsch et al. in BEFIM 2: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen". Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Nakanishi et al. 1989: K. Nakanishi/H. Murayama/H. Sato/A. Nagara/T. Yasui/S. Mitsui, Continuous beer brewing with yeast immobilized on granular ceramic. Journal Fermentation and Bioengineering 68/6, 1989, 443.

Noneman et al. 2017: H. Noneman/C. VanPool/A. Fernandez, Examination of organic residues and tribochemical wear in low fired Casas Grandes pottery vessels. Unpublished paper prepared for the Society for American Archaeology, 82nd Annual Meeting, 2017 (Vancouver 2017).

Rageot et al. 2019: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/Th. Hoppe/ Ph. W. Stockhammer/C. Spiteri, The dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PLoS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Renken 1993: L. A. Renken, A functional analysis of whole and reconstructable vessels from northern Black Mesa, northeastern Arizona (Carbondale 1993).

Schiffer/Skibo 1989: M. B Schiffer/J. M. Skibo, A provisional theory of ceramic abrasion. American Anthr. 91, 1989, 102-116.

Schorer et al. in BEFIM 1: B. Schorer/M. Rageot/A. Mötsch, Vessels from old excavations at the Heuneburg. New evidence for their functional interpretation. In: Stockhammer/Fries-Knoblach 2019a, 47-60.

Sellet 1993: F. Sellet, Chaine operatoire: The concept and its applications. Lithic Technology 18/1/2, 1993, 106-112.

Skibo 1992: J.M Skibo, Pottery function: A use-alteration perspective (New York 1992).

Skibo 2015: J. M. Skibo, Pottery use-alteration analysis in use-wear and residue analysis. In: J. M. Marreiros/J. F. Gibaja Bao/N. Ferreira Bicho (eds), Use-Wear and Residue Analysis in Archaeology (New York 2015) 189-198.

Skibo/Blinman 1999: J. M. Skibo/E. Blinman, Exploring the origins of pottery on the Colorado Plateau. In: J. M. Skibo/G. M. Feinman (eds), Pottery and People: A Dynamic Interaction (Salt Lake City 1999) 171-183.

Skibo/Schiffer 1987: J.M. Skibo/M. B. Schiffer, The effects of water on processes of ceramic abrasion. Journal Arch. Scien. 14, 1987, 83-96.

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Van Gijn 2012: A. L. van Gijn, New perspective for microwear analysis. In: C. C. Bakels/H. Kamermans (eds), The end of our fifth decade. Analecta Praehist. Leidensia 43/44 (Leiden 2012) 275-282.

Van Gijn 2014: A. L. van Gijn, Science and interpretation in microwear studies. Journal Arch. Scien. 48, 2014, 166-169.

Van Gijn/Hofman 2008: A. L. van Gijn/C. L. Hofman, Were they used as tools? An exploratory functional study of abraded potsherds from two pre-colonial sites on the island of Guadeloupe, Northern Lesser Antilles. Caribbean Journal Scien. 44/1, 2008, 21-35.

Van Gijn/Lammers-Keijsers 2010: A. L. van Gijn/Y. Lammers-Keijsers, Toolkits for ceramic production: Informal tools and the importance of high power use-wear analysis. Bull. Soc. Préhist. Française 107/4, 2010, 755-762.

Van Gijn et al. in BEFIM 1: A. van Gijn/L. Jacobs/N. Groat/N. de Koning/D. Braekmans/A. Verbaas, Studying vessel biographies from the Heuneburg: An experimental approach. In: Stockhammer/Fries-Knoblach 2019a, 77-99.

Vieugué 2014: J. Vieugué, Use-wear analysis of prehistoric pottery: Methodological contributions from the study of the earliest ceramic vessels in Bulgaria (6100-5500 BC). Journal Arch. Scien. 41, 2014, 622-630.

Vieugué 2015: J. Vieugué, What were the recycled potsherds used for? Use-wear analysis of Early Neolithic ceramic tools from Bulgaria (6100-5600 cal. BC). Journal Arch. Scien. 58, 2015, 89-102.

Vuković 2009: J. B. Vuković, Non-abrasive pottery surface attrition: Blagotin evidence. Journal Serbian Arch. Soc. 25, 2009, 25-35.

Author information

Nicholas Groat
Department of Archaeology
University of Sheffield
Minalloy House
10-16 Regent St.
Sheffield S1 3NJ
United Kingdom
ngroat1@sheffield.ac.uk

Microstructural investigation on a selection of the Heuneburg Iron Age ceramic assemblage

Dennis Braekmans & Loe Jacobs

Summary

Iron Age ceramic materials from the Heuneburg (Baden-Württemberg, Southern Germany) were investigated through microscopic techniques (petrography and scanning electron microscopy) in order to characterise the composition of the clay materials as well as the mineral inclusions for further replication studies. A comparison of the characteristics of the mineral grains with chemical data from both matrix and inclusions provided three different types of composition and suggested discrete production recipes for these ceramics. One of these three identified groups is considered to be a main local product attributed to artisanal activities at the Heuneburg site itself.

Keywords: *Composition of ceramics, petrography, electron microscopy, Heuneburg, Early Iron Age*

Zusammenfassung

Eisenzeitliche Keramik von der Heuneburg (Baden-Württemberg, Süddeutschland) wurde mit mikroskopischen Methoden (Petrographie, Rasterelektronenmikroskopie) untersucht, um die Zusammensetzung des Tons und seine mineralischen Einschlüsse für die getreue Nachbildung von Keramikgefäßen zu bestimmen. Ein Abgleich zwischen den Eigenschaften der mineralischen Körner und der chemischen Beschaffenheit von Matrix und Einschlüssen ergab drei verschiedene Warenarten und legt feststehende Herstellrezepturen für diese Keramik nahe. Eine der drei identifizierten Gruppen wird als ein wesentliches lokales Produkt ansässiger Handwerker auf der Heuneburg selbst betrachtet.

Schlüsselwörter: *Keramikzusammensetzung, Petrographie, Elektronenmikroskopie, Heuneburg, Frühe Eisenzeit*

In: Annelou van Gijn/Philipp W. Stockhammer/Janine Fries-Knoblach (eds), Pots and Practices. BEFIM 3 (Leiden 2020: Sidestone Press) 193-203.

Introduction

The investigation of ancient ceramics involves a vast array of methodological approaches and disciplines, which is one of the major aims of the BEFIM research effort. This research is part of a technological study of how the ceramic assemblage of the Heuneburg (Fernández-Götz/Krausse 2013) was constructed and how this was ultimately used. Excellent overviews and research outputs have already been generated in previous publications of the BEFIM project (Rageot et al. 2019a; 2019b; Stockhammer/Fries-Knoblach 2019a; 2019b), as well as the other chapters in this volume. This paper reports specifically on the microstructural investigations of the composition of a small selection of Heuneburg ceramics in order to assess differences in production and/or raw material usage. Analyses were carried out through microscopic techniques, more specifically optical microscopy (or petrography) and variable pressure electron microscopy (VP-SEM-EDS).

Materials and method

During a sampling campaign in Tübingen, 21 samples were collected to act as a reference for compositional analysis and further technological studies. All 21 samples were analysed for their mineralogical composition through optical microscopy. Optical microscopy was used as a primary analytical method for providing a robust fabric classification, incorporating information on composition and an assessment of technology. Thin sections (n = 21) were analysed with a Leica DM-LP microscope (Leica Microsystems, Germany), using plane-polarised and cross-polarised light conditions. The identification of all features was based on several reference works regarding ceramic petrography (see e. g. Whitbread 1995; Braekmans/Degryse 2016; Reedy 2008; Quinn 2013).

Next to this dataset, six ceramic vessels were analysed in detail as to their mineral and matrix chemistry through VP-SEM-EDS. Samples were selected to represent the main possible local production as well as other petrographic groups. The samples are HB-AS-008, HB-AS-036, HB-PL-001, HB-PL-010, HB-VB-025 and HB-VB-047. The HB-PL-001 and HB-PL-010 samples were derived from a pit house on top of the Heuneburg Plateau. HB-VB-025 came from the Lower Town (*Vorburg*), while HB-AS-008 and HB-AS-036 were retrieved from the Outer Settlement (*Außensiedlung*).

Previous data for these vessels were kindly provided by the BEFIM team with special thanks to Angela Mötsch and Birgit Schorer. For further details of these vessels and associated analyses, please refer to other chapters in this book as well as previous volumes and publications related to the BEFIM project (Rageot et al. 2019b; Stockhammer/Fries-Knoblach 2019a; 2019b).

- HB-AS-008: Outer Settlement, Ha D1, cylindrical necked vessel, bacterial fermentation product
- HB-AS-036: Outer Settlement, Ha D1, bowl, possibly wax or fat
- HB-PL-001: settlement on top of the Heuneburg Plateau, Ha D1, bowl, dairy fat (milk product), plant wax, millet
- HB-PL-010: settlement on top of the Heuneburg Plateau, Ha D1, pot, dairy fat (milk product), beeswax/bees' product, plant wax, millet
- HB-VB-025: Lower Town Settlement, Ha D1, settlement layers of rampart (slidden down), bowl, no ORA testing
- HB-VB-047: Lower Town Settlement, (younger than) Ha D1, part of rampart 2, goblet, no ORA testing (cf. Mötsch et al. 2019, 186-205).

In order to gain a chemical overview of the clay matrix as well as the individual grains, an Environmental Scanning Electron Microscopy coupled with a variable pressure energy dispersive spectrometry system (VP-SEM-EDS) was used. The system consisted of a Hitachi SU3500 electron microscope, and measurements were conducted under a 20 kV accelerating voltage and a live time of 30 s. This environmental SEM is similar to a conventional SEM but complete objects can be put into the analysis chamber without the necessity of coating them. This allows greater flexibility to analyse larger objects and samples in a non-destructive way. While the chamber is stabilised at a low vacuum, differential pumping prevents charge build-up and thus removes the need for coating the samples (Reed 2005). An attached EDS system enables quantification of elements (C to U) with a detection limit generally around 0.1 wt. %. The uncoated thin sections were also used for SEM analyses. Data analysis was carried out through assessing the absolute values of the elemental analysis, as well as through the construction of bivariate diagrams and statistical methods such as Principal Component Analysis (PCA) (Davis 1986). For PCA analysis, PAST (v.3.25) software was used for analysis and output generation (Hammer et al. 2001).

Results and discussion

Petrography

Based on the petrographic observations, three petrofabrics (Fig. 1; Table 1) can be identified, of which the sample matrix is nearly always microcrystalline and non-calcareous in general (petrofabrics 1 and 2). One sample is an exception by being enriched in carbonates (petrofabric 3) and having a calcareous clay matrix, which is highly distinct from the two other groups. The identified main minerals and rock fragments in these petrofabrics are quartz, Fe-oxide and opaque phases (possibly including hematite), plagioclase, K-feldspars, calcite, microcline, micas (both

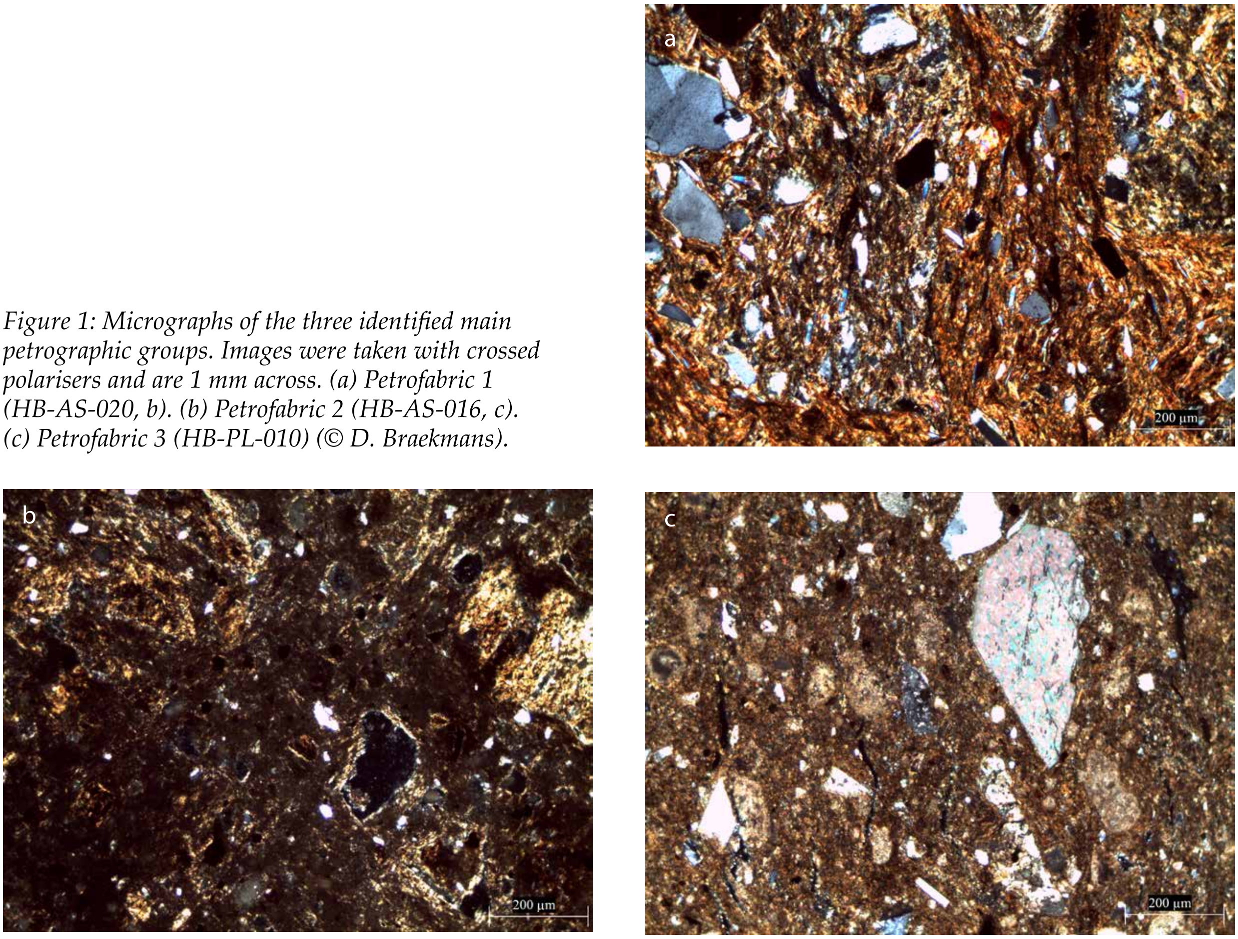

Figure 1: Micrographs of the three identified main petrographic groups. Images were taken with crossed polarisers and are 1 mm across. (a) Petrofabric 1 (HB-AS-020, b). (b) Petrofabric 2 (HB-AS-016, c). (c) Petrofabric 3 (HB-PL-010) (© D. Braekmans).

muscovite and biotite), zircon, biotite-gneiss, biotite-granite, limestone, pyroxene and amphibole. Samples from petrofabric 1 largely match the supposedly local production at the Heuneburg as already described by Maggetti and Galetti (1980) and is differentiated from petrofabric 2 by its higher optically active matrix and systematic, more frequent amount of inclusions (up to 30 %). A main distinctive feature of petrofabric 1 is the presence of frequent to abundant amounts of muscovite throughout the matrix as well as the presence of zircon, large clay nodules and grog grains.

Based on these microscopic results, this studied assemblage can be said to contain especially a carbonate and mixed materials group as opposed to two groups with a clearly metamorphic and igneous component. This indicates at least two, likely three different raw material deposits and - by extension - production sequences of the ceramics within this assemblage.

Scanning Electron Microscopy

In total, 48 measurements were taken and focussed on both (clay) matrix and (heavy) mineral compositions (Table 1). The main objective was to assess the extent of variability within the composition of the siliceous clay matrix between the different sherds. Many studies employ a bulk geochemistry strategy to identify the provenance of the ceramic materials as it incorporates both the clay and mineral fraction. These studies employ analytical equipment in which part of the samples is homogenised through powdering with the goal of providing bulk representative data for the entire sherd/sample (Degryse/Braekmans 2013). Given the limited amount of samples studied here, focus was on the clay itself in an attempt to validate whether the use of different mineral resources could be detected.

A multivariate statistical approach was chosen for assessing the chemical composition of the clay matrix measurement (Aitchinson 1986; Davis 1986). The resulting PCA plot (Fig. 2) is based on principal components 1 and 2. This graph is based on contributing variables: SiO_2, MgO, K_2O, MnO, Na_2O, MgO, Ti_2O, Fe_2O_3, CaO and Al_2O_3. P_2O_5 was not included due to the influence of post-depositional processes (Freestone et al. 1985). It can be observed from this graph that the highest variability can be attributed to SiO_2, CaO and Al_2O_3 content, which could act as proxies for the coarse/quartz fraction, carbonate content and overall clay content. These three groups signify variable mineral resources that can be preliminarily characterised: a high Ca-group and two closely related smectite-illite rich mineral resources. Illite type clays are often enriched in K and Al as they are formed from weathering of K and Al-rich rocks. Illite clays are, for example, an important constituent of ancient mudrocks and shales. Given the large mudbrick fortifications on the Heuneburg site, it might be a similar substrate for production, although this association cannot be readily verified at this point and will need further investigation. On the other hand, smectite and kaolinite clays are more commonly enriched in MgO content (Degryse/Braekmans 2013). When assessing the scatterplot (Fig. 3), samples HB-PL-010 and HB-VB-025 can be separated from the

Petrofabric	Main characteristics	Thin section
1	quartz (up to 100 µm), feldspars, biotite-gneiss, quartzite, zircon (~50 µm), grog, clay nodules, abundant muscovite, opaque grains	HB-AS-008, HB-AS-013, HB-AS-020, HB-AS-036, HB-PL-001, HB-PL-002, HB-VB-027, HB-VB-030, HB-VB-047, HB-VB-051, HB-VB-070
2	microcrystalline quartz, large quartz and feldspars (up to 200 µm), biotite/muscovite, plagioclase, K-feldspar, biotite-granite, calcite, microcline, quartzite, opaque grains	HB-AS-007, HB-AS-016, HB-PL-003, HB-VB-001, HB-VB-004, HB-VB-007, HB-VB-025, HB-VB-028, HB-VB-066
3	angular limestone, calcite, minor amount of quartzite, micritic features, fossil fragments	HB-PL-010

Table 1: Summary of the identified petrographic groups, samples and their main characteristics.

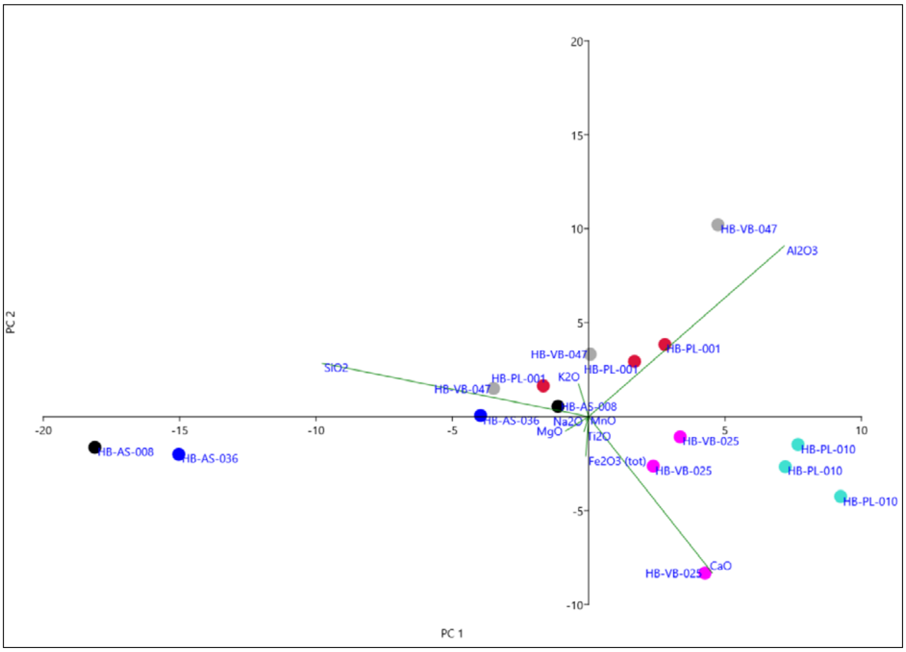

Figure 2: Principal component score plot of the first two principal components based on major element oxides, excluding P_2O_5 (© D. Braekmans).

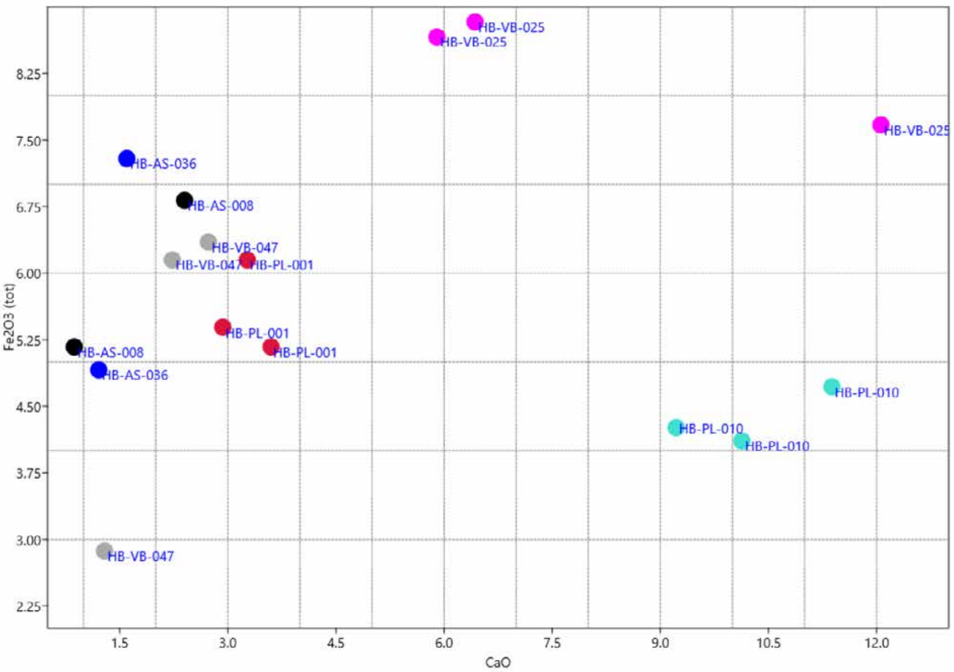

Figure 3: Scatterplot of Fe_2O_3 (wt. %) versus CaO (wt. %) separating HB-VB-025 and HB-PL-010 from the other samples (© D. Braekmans).

rest of the samples as both are more enriched in CaO. These possibly also relate to a (microcrystalline) calcareous content and likely more smectite-related resources.

A comparison with previously analysed Iron Age fine wares (Maggetti/Galetti 1980) shows a close correspondence in chemical composition, especially with samples HB-AS-008 and HB-AS-036 but not with HB-PL-010 and HB-VB-025. Maggetti and Galetti concluded that their Heuneburg samples studied can be attributed to a local production and make it likely that the two samples studied here belong to a similar production group. Nevertheless, it is still an option that the fine wares studied by Maggetti and Galetti (1980) were integrally imported from a still unknown site, but these assumptions require more systematic compositional work

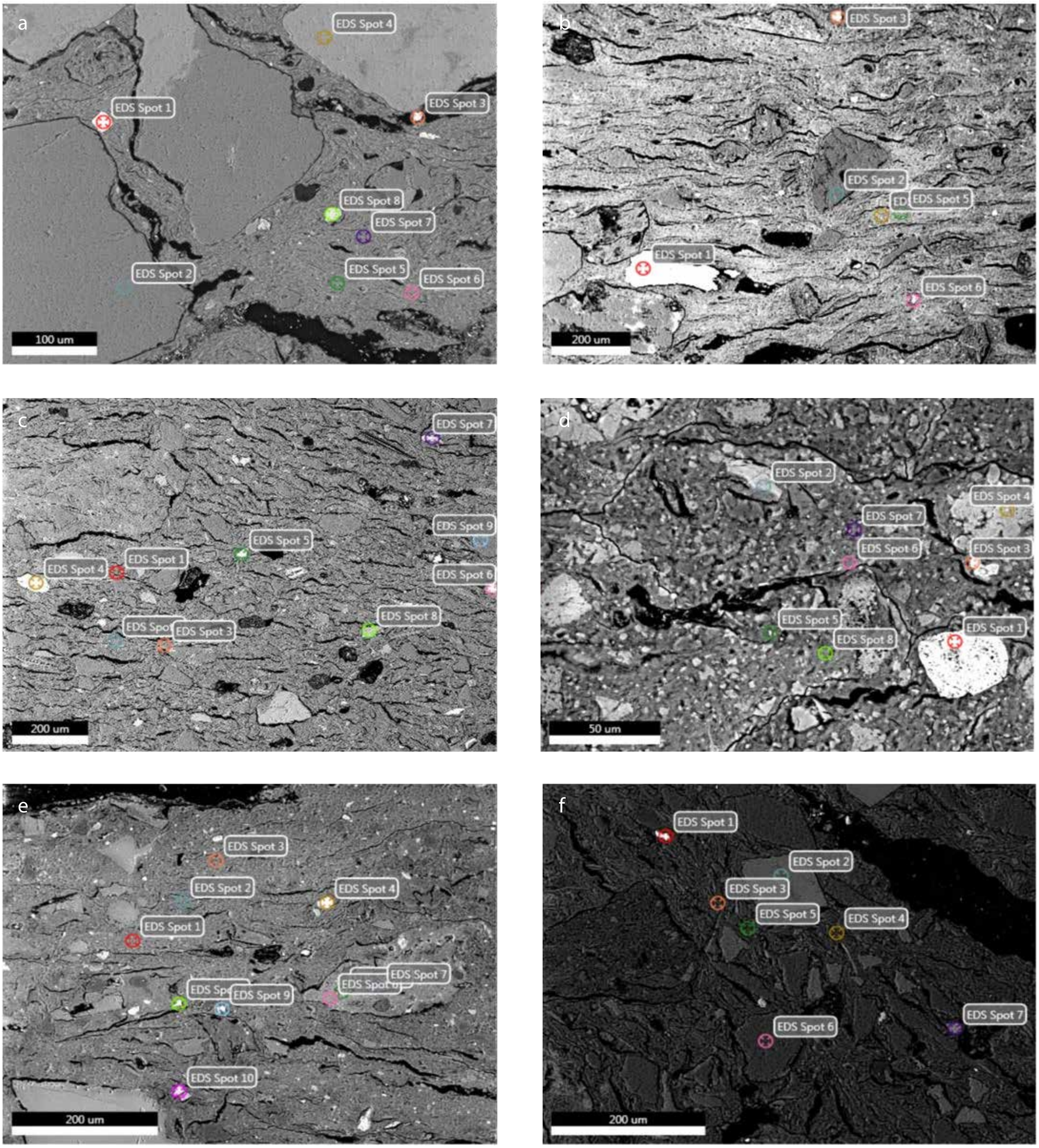

Figure 4: Backscattered electron microscopy images of Heuneburg samples. (a) HB-AS-008. (b) HB-AS-036. (c) HB-PL-001. (d) HB-PL-010. (e) HB-VB-025. (f) HB-VB-047 (© D. Braekmans).

on the coarse wares as well as the inclusion of more reference data from other known production sites.

In the investigated Heuneburg material (Fig. 4; Table 2), several minerals were identified, commonly including quartz and various Na- and K-containing feldspars in all samples. Mineral phases for chemical analysis were selected, which were impossible to characterise through optical mineralogy. This mostly concerns heavy minerals, especially Fe- and Ti-bearing oxides such as high aluminium-titaniumoxide phases, Ti-magnetite and hematite minerals, which are frequently attested. When these are part of the matrix, this could possibly indicate an exsolution from chlorite and other Fe-bearing silicates as rather small hematite grains suggest (< 100 µm). Additionally, clear zircon minerals were also identified in two samples with ZrO_2 values around 50 wt. % (HB-VB-047 and HB-AS-008). In HB-VB-047 a probable apatite phase was found, containing up to ~40 wt. % P_2O_5. Notable in HB-VB-025 was the clear presence of biotite. In sample HB-PL-010 both a pyroxene and amphibole phase were determined.

Conclusion

The observations of both the petrography and electron microscopy highlight the varied and heterogeneous nature of these nearly contemporaneous ceramics, which would indicate the usage of various raw materials. Based on the different compositional nature of these groups this likely provides an indication of import of these particular vessels, either with regard to the vessel itself or to its contents. A probably local production of vessels attributed to petrofabric 1 seems plausible and is consistent with previously conducted analyses. The limited scope and dataset of this study focused on vessels that seemed to have functioned mainly as containers for dairy products, plant wax and millet. The different morphological and compositional characteristics of the assemblage provides a rather puzzling view on the use and production of different vessels, as these all seem to facilitate a similar functionality. A larger scale analytical approach to these particular vessels will undoubtedly clear up remaining questions about the technological choices made before and during their production. The results of, in particular, the matrix data of this selected set of ceramics will facilitate the production of a nearly similar test fabric material for further functional, provenance and mechanical analysis. Undoubtedly, data on ceramic technology, provenance and mechanical properties will contribute to the holistic and synthesis research efforts that concentrate on the Heuneburg assemblages and other important contemporaneous sites.

Sample	Point		Na_2O	SiO_2	MgO	Al_2O_3	P_2O_5	K_2O	CaO
HB-AS-008	1	wt. %	0.23	41.38	0.28	2.14	2.43	0.47	0.04
HB-AS-008	2	wt. %	0.19	96.36	0.22	1.61	0.18	0.24	0.08
HB-AS-008	3	wt. %	1.28	65.28	0.04	2.96	0.28	8.80	0.40
HB-AS-008	4	wt. %	0.73	63.31	0.27	19.34	0.16	15.11	0.06
HB-AS-008	5	wt. %	0.56	53.51	2.91	24.62	4.50	3.71	2.40
HB-AS-008	6	wt. %	0.42	68.44	4.37	15.31	1.42	2.89	0.87
HB-AS-008	7	wt. %	0.35	64.68	1.61	18.76	3.63	2.57	2.11
HB-AS-008	8	wt. %	0.87	10.83	0.58	3.31	0.60	0.56	0.38
HB-AS-036	1	wt. %	0.92	9.69	0.72	3.69	3.24	0.31	1.03
HB-AS-036	2	wt. %	13.05	63.78	0.34	20.58	0.20	0.35	0.34
HB-AS-036	3	wt. %	1.06	14.49	1.26	10.77	7.04	0.84	2.51
HB-AS-036	4	wt. %	0.71	65.35	1.89	16.18	3.82	2.15	1.21
HB-AS-036	5	wt. %	0.66	55.52	2.49	22.69	4.34	3.56	1.60
HB-AS-036	6	wt. %	0.95	19.65	1.36	8.51	4.39	0.84	1.56
HB-PL-001	1	wt. %	0.44	53.42	1.90	28.85	1.95	2.66	3.27
HB-PL-001	2	wt. %	0.32	52.35	2.01	29.71	1.28	4.23	2.93
HB-PL-001	3	wt. %	0.44	56.14	2.20	26.30	2.23	2.33	3.60
HB-PL-001	4	wt. %	0.79	7.08	0.51	3.22	0.30	0.29	0.31
HB-PL-001	5	wt. %	0.32	40.44	0.66	27.90	0.11	0.30	22.05
HB-PL-001	6	wt. %	1.36	10.15	0.92	4.07	0.25	0.32	0.33
HB-PL-001	7	wt. %	0.43	33.19	14.80	25.59	0.18	0.35	0.55
HB-PL-001	8	wt. %	0.00	62.08	0.17	20.00	0.08	13.73	0.34
HB-PL-001	9	wt. %	0.15	94.72	0.32	2.65	0.24	0.28	0.23
HB-PL-010	1	wt. %	0.57	7.83	0.35	6.58	5.55	0.24	5.91
HB-PL-010	2	wt. %	0.49	9.84	0.63	5.31	1.16	0.43	79.44
HB-PL-010	3	wt. %	0.90	24.44	1.27	17.22	6.61	0.66	9.79
HB-PL-010	4	wt. %	0.61	9.74	0.64	6.23	1.81	0.27	69.27
HB-PL-010	5	wt. %	0.17	36.56	0.90	21.01	2.32	1.26	11.43
HB-PL-010	6	wt. %	0.48	48.61	1.60	29.27	3.46	1.54	9.22
HB-PL-010	7	wt. %	0.39	46.63	1.59	28.06	3.47	1.58	11.38
HB-PL-010	8	wt. %	0.44	48.94	1.66	28.31	3.23	1.47	10.13
HB-VB-025	1	wt. %	0.58	49.40	2.52	22.58	1.07	2.29	12.06
HB-VB-025	2	wt. %	0.38	50.90	2.51	26.90	1.03	2.80	5.90
HB-VB-025	3	wt. %	0.60	51.18	2.46	25.16	1.30	2.71	6.43
HB-VB-025	4	wt. %	1.09	35.99	1.67	22.01	0.15	0.29	13.20
HB-VB-025	5	wt. %	1.06	11.30	1.29	6.91	2.00	0.41	4.10
HB-VB-025	6	wt. %	1.35	46.90	1.73	27.68	0.24	2.66	6.84
HB-VB-025	7	wt. %	0.58	8.75	0.70	4.57	0.38	0.30	81.47
HB-VB-025	8	wt. %	0.76	25.35	1.45	15.56	1.91	0.85	5.25
HB-VB-025	9	wt. %	0.68	25.49	1.59	13.83	0.72	0.72	6.70
HB-VB-025	10	wt. %	0.71	29.15	1.33	15.31	1.69	1.18	6.62
HB-VB-047	1	wt. %	0.33	40.09	0.48	3.41	2.82	0.50	0.50
HB-VB-047	2	wt. %	0.47	9.73	0.43	2.90	0.60	0.32	82.76
HB-VB-047	3	wt. %	0.14	53.96	0.90	36.24	0.21	3.45	1.29
HB-VB-047	4	wt. %	0.74	54.27	2.51	27.89	0.45	4.38	2.23
HB-VB-047	5	wt. %	0.60	57.13	2.36	25.01	0.40	3.79	2.73
HB-VB-047	6	wt. %	0.06	95.75	0.18	2.16	0.11	0.28	0.35
HB-VB-047	7	wt. %	0.22	7.57	0.15	2.09	38.56	0.29	49.40

Sample	Ti_2O	MnO	Fe_2O_3 (tot)	ZrO_2	Cr_2O_3	CuO	La_2O3	Ce_2O_3	PbO_2
HB-AS-008	0.08	0.09	0.72	51.68	nd	0.44	nd	nd	nd
HB-AS-008	0.09	0.11	0.38	nd	nd	0.18	nd	nd	nd
HB-AS-008	1.10	0.40	0.95	nd	nd	0.26	nd	nd	17.43
HB-AS-008	0.14	0.04	0.39	nd	nd	0.16	nd	nd	nd
HB-AS-008	0.38	0.05	6.82	nd	nd	0.10	nd	nd	nd
HB-AS-008	0.25	0.18	5.17	nd	nd	0.16	nd	nd	nd
HB-AS-008	0.54	0.12	5.24	nd	nd	0.19	nd	nd	nd
HB-AS-008	80.53	0.12	1.23	nd	nd	0.17	nd	nd	nd
HB-AS-036	0.29	0.39	78.57	nd	nd	0.23	nd	nd	nd
HB-AS-036	0.12	0.16	0.69	nd	nd	0.21	nd	nd	nd
HB-AS-036	0.29	0.22	60.96	nd	0.83	0.09	nd	nd	nd
HB-AS-036	2.89	0.12	4.91	nd	nd	0.14	nd	nd	nd
HB-AS-036	0.64	0.22	7.29	nd	nd	0.18	nd	nd	nd
HB-AS-036	0.41	0.19	61.39	nd	nd	0.14	nd	nd	nd
HB-PL-001	0.68	0.14	6.15	nd	nd	0.19	nd	nd	nd
HB-PL-001	0.85	0.13	5.39	nd	nd	0.17	nd	nd	nd
HB-PL-001	0.57	0.21	5.17	nd	nd	0.19	nd	nd	nd
HB-PL-001	85.11	0.13	1.61	nd	nd	0.11	nd	nd	nd
HB-PL-001	0.25	0.20	7.24	nd	nd	0.17	nd	nd	nd
HB-PL-001	42.38	0.97	38.87	nd	nd	0.10	nd	nd	nd
HB-PL-001	0.15	0.13	24.19	nd	nd	0.21	nd	nd	nd
HB-PL-001	0.34	0.03	0.54	nd	nd	0.17	nd	nd	nd
HB-PL-001	0.12	0.16	0.56	nd	nd	0.19	nd	nd	nd
HB-PL-010	0.26	0.18	72.00	nd	nd	0.22	nd	nd	nd
HB-PL-010	0.29	0.11	1.06	nd	nd	0.34	nd	nd	nd
HB-PL-010	0.45	0.19	37.88	nd	nd	0.09	nd	nd	nd
HB-PL-010	0.33	0.23	9.87	nd	nd	0.30	nd	nd	nd
HB-PL-010	16.62	0.12	9.35	nd	nd	0.13	nd	nd	nd
HB-PL-010	0.93	0.11	4.26	nd	nd	0.20	nd	nd	nd
HB-PL-010	1.53	0.07	4.72	nd	nd	0.19	nd	nd	nd
HB-PL-010	1.13	0.14	4.11	nd	nd	0.12	nd	nd	nd
HB-VB-025	1.02	0.11	7.67	nd	nd	0.21	nd	nd	nd
HB-VB-025	0.56	0.09	8.66	nd	nd	0.10	nd	nd	nd
HB-VB-025	0.77	0.21	8.83	nd	nd	0.04	nd	nd	nd
HB-VB-025	0.13	0.57	12.28	nd	nd	0.19	3.88	8.42	nd
HB-VB-025	0.45	0.14	71.72	nd	nd	0.21	nd	nd	nd
HB-VB-025	0.56	0.22	10.15	nd	nd	0.17	nd	nd	nd
HB-VB-025	0.26	0.18	2.18	nd	nd	0.33	nd	nd	nd
HB-VB-025	0.54	0.22	47.37	nd	nd	0.21	nd	nd	nd
HB-VB-025	0.53	0.30	48.54	nd	nd	0.16	nd	nd	nd
HB-VB-025	0.62	0.11	42.81	nd	nd	0.13	nd	nd	nd
HB-VB-047	0.14	0.13	1.23	49.80	nd	0.49	nd	nd	nd
HB-VB-047	0.25	0.39	1.03	nd	nd	0.41	nd	nd	nd
HB-VB-047	0.38	0.17	2.87	nd	nd	0.22	nd	nd	nd
HB-VB-047	0.47	0.16	6.15	nd	nd	0.15	nd	nd	nd
HB-VB-047	0.57	0.32	6.35	nd	nd	0.18	nd	nd	nd
HB-VB-047	0.07	0.13	0.59	nd	nd	0.16	nd	nd	nd
HB-VB-047	0.13	0.19	0.89	nd	nd	0.28	nd	nd	nd

Table 2: Results of the 48 point measurements of ceramic matrices and inclusions through VP-SEM-EDS measurements (detailed points can be reviewed in Fig. 4).

Bibliography

Aitchinson 1986: J. Aitchinson, The Statistical Analysis of Compositional Data (London 1986).

Braekmans/Degryse 2016: D. Braekmans/P. Degryse, Optical Microscopy. In: A. Hunt, The Oxford Handbook of Archaeological Ceramic Analysis (Oxford 2016) 233-265.

Davis 1986: J. C. Davis, Statistics and Data Analysis in Geology (New York 1986).

Degryse/Braekmans 2013: P. Degryse/D. Braekmans. 2013. Elemental and Isotopic Analysis of Ancient Ceramics and Glass. In: H. D. Holland/K. K. Turekian, Treatise on Geochemistry ^{2}(Oxford 2013) 191-207.

Fernández-Götz/Krausse 2013: M. Fernández-Götz/D. Krausse, Rethinking Early Iron Age Urbanisation in Central Europe: The Heuneburg Site and Its Archaeological Environment. Antiquity 87/336, 2013, 473-487. https://doi.org/10.1017/S0003598X00049073

Freestone et al. 1985: I. C. Freestone/N. D. Meeks/A. P. Middleton, Retention of Phosphate in Buried Ceramics: An Electron Microbeam Approach. Archaeometry 27/2, 1985, 161-77.

Hammer et al. 2001: Ø. Hammer/D. A. T. Harper/P. D. Ryan, PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol. Electronica 4/1, 2001, 1-9.

Maggetti/Galetti 1980: M. Maggetti/G. Galetti, Composition of Iron Age Fine Ceramics from Châtillon-s-Glâne (Kt. Fribourg, Switzerland) and the Heuneburg (Kr. Sigmaringen, West Germany). Journal Arch. Scien. 7, 1980, 87-91.

Mötsch et al. 2019: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen". Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019b, 113-210.

Quinn 2013: P. S. Quinn, Ceramic Petrography. The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section (Oxford 2013).

Rageot et al. 2019a: M. Rageot/A. Mötsch/B. Schorer/D. Bardel/A. Winkler/F. Sacchetti/B. Chaume/Ph. Della Casa/St. Buckley/S. Cafisso/J. Fries-Knoblach/D. Krausse/Th. Hoppe/Ph. W. Stockhammer/C. Spiteri, New insights into Early Celtic consumption practices: Organic residue analyses of local and imported pottery from Vix-Mont Lassois. PLoS ONE 14(6): e0218001. https://doi.org/10.1371/journal.pone.0218001

Rageot et al. 2019b: M. Rageot/A. Mötsch/B. Schorer/A. Gutekunst/G. Patrizi/M. Zerrer/S. Cafisso/J. Fries-Knoblach/L. Hansen/R. Tarpini/D. Krausse/T. Hoppe/Ph. W. Stockhammer/C. Spiteri, The dynamics of Early Celtic consumption practices: A case study of the pottery from the Heuneburg. PloS ONE 14(10): e0222991. https://doi.org/10.1371/journal.pone.0222991

Reed 2005: S. J. Reed, Electron Microprobe Analysis and Scanning Electron Microscopy in Geology (Cambridge 2005).

Reedy 2008: Ch. L. Reedy, Thin-Section Petrography of Stone and Ceramic Cultural Materials (London 2008).

Stockhammer/Fries-Knoblach 2019a: Ph. W. Stockhammer/J. Fries-Knoblach (eds), Was tranken die frühen Kelten? Bedeutungen und Funktionen mediterraner Importe im früheisenzeitlichen Mitteleuropa. Internationale Konferenz, Kloster Weltenburg, 28.04.-01.05.2017. BEFIM 1 (Leiden 2019).

Stockhammer/Fries-Knoblach 2019b: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

Whitbread 1995: I. K. Whitbread, Greek Transport Amphorae: A Petrological and Archaeological Study. Fitch Laboratory Occasional Paper 4 (Oakville 1995).

Author information

Dennis Braekmans
Cranfield Forensic Institute
Cranfield University
Defence Academy of the United Kingdom
Shrivenham SN6 8LA
United Kingdom
Dennis.Braekmans@cranfield.ac.uk

Loe Jacobs
Laboratory for Material Culture Studies
Faculty of Archaeology, Leiden University
PB Box 9514
NL-2300 RA Leiden
lfhc.jacobs@casema.nl

Concordance of the pottery

quoted in this volume and in the BEFIM 2 catalogues (pottery tested by organic residue analysis (ORA))

Vix-Old excavations Plateau (Altgrabungen Plateau)

VIX-ALT-002 = Mötsch et al. 2019a, Kat. 40
VIX-ALT-006 = Mötsch et al. 2019a, Kat. 44
VIX-ALT-009 = no ORA
VIX-ALT-011 = no ORA
VIX-ALT-050 = Mötsch et al. 2019a, Kat. 50
VIX-ALT-051 = Mötsch et al. 2019a, Kat. 51
VIX-ALT-054 = no ORA
VIX-ALT-101 = Mötsch et al. 2019a, Kat. 1
VIX-ALT-103 = Mötsch et al. 2019a, Kat. 3
VIX-ALT-105 = Mötsch et al. 2019a, Kat. 5
VIX-ALT-111 = Mötsch et al. 2019a, Kat. 11
VIX-ALT-113 = Mötsch et al. 2019a, Kat. 13
VIX-ALT-119 = Mötsch et al. 2019a, Kat. 23
VIX-ALT-125 = no ORA
VIX-ALT-129 = no ORA
VIX-ALT-131 = Mötsch et al. 2019a, Kat. 16
VIX-ALT-135 = Mötsch et al. 2019a, Kat. 33
VIX-ALT-141 = no ORA
VIX-ALT-142 = no ORA
VIX-ALT-147 = no ORA
VIX-ALT-148 = no ORA
VIX-ALT-149 = no ORA
VIX-ALT-152 = no ORA
VIX-ALT-154 = no ORA
VIX-ALT-161 = Mötsch et al. 2019a, Kat. 20
VIX-ALT-164 = no ORA

Vix-Champ de Fossé

No samples from VIX-CF-series

Vix-Le Breuil

No samples from VIX-LEBR-series

Vix-Les Renards

No samples from VIX-LR-series

Vix-Plateau

No samples from VIX-PL-series

Heuneburg-Outer Settlement (Außensiedlung)

HB-AS-002 = Mötsch et al. 2019b, Kat. 111
HB-AS-007 = no ORA
HB-AS-008 = Mötsch et al. 2019b, Kat. 113
HB-AS-012 = Mötsch et al. 2019b, Kat. 114
HB-AS-013 = Mötsch et al. 2019b, Kat. 115
HB-AS-016 = no ORA
HB-AS-017 = no ORA
HB-AS-018 = no ORA
HB-AS-020 = no ORA
HB-AS-025 = no ORA
HB-AS-027 = Mötsch et al. 2019b, Kat. 118
HB-AS-028 = no ORA
HB-AS-029 = Mötsch et al. 2019b, Kat. 119
HB-AS-030 = Mötsch et al. 2019b, Kat. 120
HB-AS-034 = Mötsch et al. 2019b, Kat. 109
HB-AS-035 = Mötsch et al. 2019b, Kat. 110
HB-AS-036 = Mötsch et al. 2019b, Kat. 121

Heuneburg-Plateau

HB-PL-001 = Mötsch et al. 2019b, Kat. 50
HB-PL-002 = Mötsch et al. 2019b, Kat. 51
HB-PL-003 = Mötsch et al. 2019b, Kat. 52
HB-PL-006 = Mötsch et al. 2019b, Kat. 55
HB-PL-008 = Mötsch et al. 2019b, Kat. 56
HB-PL-009 = Mötsch et al. 2019b, Kat. 57
HB-PL-010 = Mötsch et al. 2019b, Kat. 48
HB-PL-014 = Mötsch et al. 2019b, Kat. 61
HB-PL-019 = Mötsch et al. 2019b, Kat. 66

Heuneburg-Lower Town (Vorburg)

HB-VB-001 = Mötsch et al. 2019b, Kat. 87
HB-VB-002 = no ORA
HB-VB-003 = no ORA
HB-VB-004 = no ORA
HB-VB-006 = Mötsch et al. 2019b, Kat. 72
HB-VB-007 = no ORA
HB-VB-008 = no ORA
HB-VB-010 = Mötsch et al. 2019b, Kat. 103
HB-VB-011 = Mötsch et al. 2019b, Kat. 105
HB-VB-012 = Mötsch et al. 2019b, Kat. 90
HB-VB-013 = no ORA
HB-VB-014 = Mötsch et al. 2019b, Kat. 102
HB-VB-016 = Mötsch et al. 2019b, Kat. 106
HB-VB-017 = Mötsch et al. 2019b, Kat. 107
HB-VB-021 = Mötsch et al. 2019b, Kat. 104
HB-VB-022 = Mötsch et al. 2019b, Kat. 94
HB-VB-023 = no ORA
HB-VB-024 = no ORA
HB-VB-025 = Mötsch et al. 2019b, Kat. 95
HB-VB-026 = Mötsch et al. 2019b, Kat. 96
HB-VB-027 = Mötsch et al. 2019b, Kat. 91
HB-VB-028 = Mötsch et al. 2019b, Kat. 92
HB-VB-029 = Mötsch et al. 2019b, Kat. 78

HB-VB-030 = no ORA
HB-VB-031 = Mötsch et al. 2019b, Kat. 79
HB-VB-032 = Mötsch et al. 2019b, Kat. 74
HB-VB-033 = no ORA
HB-VB-034 = no ORA
HB-VB-035 = Mötsch et al. 2019b, Kat. 83
HB-VB-036 = Mötsch et al. 2019b, Kat. 84
HB-VB-037 = Mötsch et al. 2019b, Kat. 85
HB-VB-038 = Mötsch et al. 2019b, Kat. 99
HB-VB-039 = Mötsch et al. 2019b, Kat. 100
HB-VB-040 = Mötsch et al. 2019b, Kat. 101
HB-VB-041 = Mötsch et al. 2019b, Kat. 97
HB-VB-047 = no ORA
HB-VB-048 = no ORA
HB-VB-051 = no ORA
HB-VB-052 = Mötsch et al. 2019b, Kat. 80
HB-VB-053 = Mötsch et al. 2019b, Kat. 81
HB-VB-054 = Mötsch et al. 2019b, Kat. 82
HB-VB-055 = Mötsch et al. 2019b, Kat. 67
HB-VB-056 = no ORA
HB-VB-057 = no ORA
HB-VB-065 = no ORA
HB-VB-066 = no ORA
HB-VB-067 = no ORA
HB-VB-068 = no ORA
HB-VB-069 = Mötsch et al. 2019b, Kat. 98
HB-VB-070 = no ORA
HB-VB-071 = Mötsch et al. 2019b, Kat. 93

Bibliography

Mötsch et al. 2019a: A. Mötsch/M. Rageot/B. Schorer/A. Ballmer/I. Balzer/D. Bardel/S. Cafisso/B. Chaume/Ph. Della Casa/F. Fougère/J. Fries-Knoblach/N. Nieszery/W. Reinhard/F. Sacchetti/K. Schäppi/St. Schreiber/A. Winkler/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, Essen und Trinken am Mont Lassois in Burgund. Neue Erkenntnisse zu Bedeutungen und Funktionen lokaler und importierter Keramik in der frühen Eisenzeit. In: Stockhammer/Fries-Knoblach 2019, 51-112.

Mötsch et al. 2019b: A. Mötsch/M. Rageot/B. Schorer/A. Gutekunst/I. Balzer/S. Cafisso/J. Fries-Knoblach/S. Hagmann/L. Hansen/L. Jacobs/G. Patrizi/St. Schreiber/R. Tarpini/A. van Gijn/M. Zerrer/Th. Hoppe/D. Krausse/C. Spiteri/Ph. W. Stockhammer, „Mediterran genießen“. Zum Gebrauch lokal hergestellter und importierter Keramik auf der Heuneburg im Spiegel von Nahrungsrückstandsanalysen. In: Stockhammer/Fries-Knoblach 2019, 113-210.

Stockhammer/Fries-Knoblach 2019: Ph. W. Stockhammer/J. Fries-Knoblach (eds), In die Töpfe geschaut. Biochemische und kulturgeschichtliche Studien zum früheisenzeitlichen Essen und Trinken. BEFIM 2 (Leiden 2019).

POTS AND PRACTICES

This third volume of the BEFIM series addresses the life history of vessels from the Early Celtic hillfort settlements of Heuneburg and Vix-Mont Lassois, from a detailed examination of the manufacturing process to the use and modifications of the final products. Pivotal was an extensive experimental program of dozens of experiments directed at a better understanding of the way this pottery was made and used.

The participation of an experienced potter allowed us to reproduce exact replicas of the different wares and explore in detail the traces of production and the effect of temper, baking temperature and so forth on the development of production traces and wear. Especially variations in the temper material, like the frequently observed addition of calcite in the archaeological pottery, strongly affected the characteristics of the use wear traces that subsequently developed from the preparation of different products (grape wine, honey wine, different kinds of porridge etc.).

The effect of alcohol production, including fermentation, on the pottery was also explored. We also tested the effect of different gestures of preparing food and drink (mixing, stirring, pounding), different ways of storage and handling, and the manner of consumption like decanting using various kinds of utensils.

The traces we observed on the experimental vessels, using an integrated low and high power approach, formed the basis for our interpretation of the archaeological wares from the Heuneburg and Vix-Mont Lassois. Our data on the life history of the pottery added to a more detailed insight into foodways, including drinking habits, of the Early Celtic communities of Central Europe. This book presents in detail the experimental program and the archaeological observations.

BEFIM

Bedeutungen
und Funktionen
mediterraner
Importe im
früheisenzeitlichen
Mitteleuropa

Sidestone Press
ISBN: 978-90-8890-774-6