Bridging Science and Heritage in the Balkans:
Studies in archaeometry, cultural heritage restoration and conservation

edited by

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Foreword

This volume is largely based on the scientific communications given at the *Fifth Balkan Symposium of Archaeometry 2016 (BSA5).* The Editors gracefully asked me to write this foreword given my contribution in organizing the event and despite my limited contribution to the making of the volume itself. I could hardly refuse the honour and in doing so I will include in this foreword information about the symposium, a few of the ideas that emerged from the discussions there and will only succinctly refer to the content of the book and the conditions it was put together in over two years of work by Dr Nona Palincaş and Dr Corneliu C. Ponta, the Editors, plus the authors and the referees participating in the peer review process.

The symposium

The symposium took place between 25 and 29 September 2016, in the Carpathian resort town of Sinaia, Romania. The first BSA was organised in 2008 in Ohrid (North Macedonia), the next ones in 2010 in Istanbul, in 2012 in Bucharest and in 2014 in Nessebar (Bulgaria). These symposia have therefore a tradition, even though not a long one. A question may arise whether these events, dedicated to specialists residing or working in such a restricted geographical area as the Balkans, however broadly conceived (we addressed specialists from or working in Albania, Bosnia-Herzegovina, Bulgaria, Croatia, Greece, Hungary, North Macedonia, Romania, Serbia, Slovenia, Turkey), is warranted or not, given the existence of several more general meetings and conferences on such topics. Or whether the topic is too broad and the area too small. At the time I did not doubt a single moment that yes, these meetings are needed and can be useful if we are to develop a strong local archaeometry in a systematic way. That certainly has also come from my personal connection with the field: about four decades ago my first consistent scientific project as a young physicist, newly employed at Horia Hulubei Institute for Physics and Nuclear Engineering (IFIN-HH) for a job of fundamental research in nuclear physics, was one of archaeometry (analyses of a few large numismatics hoards). And from my love of history. And while away from the field for 20 years, but with the advantages and responsibilities of the position I was having as IFIN's scientific director, I considered that we need to do as much as possible to bridge the gaps between science and heritage (see below the title chosen for this event). I had the same opinion during the organisation time, during the event itself and after! I still hold it now! We know that the region of Balkans is not merely rich, but *extremely rich* in history, in monuments and artefacts, and we know also that in most countries we are far behind the curve when it comes to the use of modern techniques in the study and preservation of material cultural heritage. While the richness, age and diversity of region's heritage is hardly matched by any other region of the world of the same size, the research in the area we are talking about here is not so developed, not enough attention is given to it by the responsible authorities! Not in all countries the authorities and the people at large understand the importance of cultural heritage and the need for its preservation and study. Not everywhere the importance of these for the economy, through tourism e.g., is understood and we face many times the impression that they are only burdens on budgets. Local budgets or national science budgets! We also know that in some areas, and by this I mean certain methods, we may have very good specialists and equipment but is also true that in some cases they are better known and appreciated abroad than inside their own countries (a good example is that from our institute for gamma irradiation techniques applied to conservation or consolidation of artefacts – see C. Ponta, in this volume). But these cases do not change the overall assessment that there is both insufficient use and demand of modern techniques in heritage sciences and practice.

The title chosen for this event was *'Bridging Science and Heritage'* and the organisers of the symposium were the Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN-HH) in Bucharest-Măgurele, the University of Bucharest (UB) and the Vasile Pârvan Institute of Archaeology in Bucharest (IAB) of the Romanian Academy.

The symposium focused on the application of modern physical and chemical methods in archaeometry, including nuclear methods and techniques used in the dating, analysis, investigation and characterisation of ancient artefacts, as well as their conservation and consolidation. Subjects from the related fields of archaeology and art history were also touched upon.

The programme included invited lectures (speaking time 40 min.), oral (20 min.) and poster presentations on the following topics:

- Analytical methods for cultural heritage diagnostics
- Lithic materials

- Archaeometallurgy
- Radiocarbon Dating
- GIS applications
- Preservation of cultural heritage – conservation and restoration
- Optoelectronic applications
- Experimental archaeology
- Multidisciplinary research in archaeology

A few more words about the organisers of BSA5. To start with, it is mandatory to mention here the members of the local Organizing Committee and Program Committee:

Organizing Committee:

Livius Trache	FIN-HH, Chair
Emilian Alexandrescu	University of Bucharest, co-chair
Ioana Stănculescu	University of Bucharest and IFIN-HH
Bogdan Constantinescu (†)	IFIN-HH
Mihaela Constantin	IFIN-HH
Roxana Morteanu	University of Bucharest
Nicolae Ionescu	University of Bucharest
Nona Palincaş	Vasile Pârvan Institute of Archaeology
Vasile Opriş	Vasile Pârvan Institute of Archaeology
Cătălin Nicolae	Vasile Pârvan Institute of Archaeology

Program Committee:

Attila László	Alexandru Ioan Cuza University, Iaşi
Nona Palincaş	Vasile Pârvan Institute of Archaeology

It is mandatory to note that among those mentioned in the longer list above we had Nona Palincaş, Corneliu Ponta and Ioana Stănculescu working extra time, with extra dedication and extra efficiency in these committees to address as wide an audience as possible, to make the right invitations, to have the booklet of abstracts ready and printed in time, to have the program ready, with appropriate sessions and chairs, etc.

At the time when the event was in its organizing phase, we insisted through invitations that we cover as many as possible of the countries in the Balkans and that we cover most of the topics in range. We succeeded to do these, but some limitations occurred for the event itself and during the editing of this volume. I note that one of our colleagues from Turkey had to cancel her trip to Sinaia in the last moment, for reasons we understood to be neither personal, nor scientific in nature. Some countries had fewer than expected representatives and unfortunately Greece and Croatia had none. Later, some of the participants would not contribute to this volume because they have other priorities imposed by their working environment (like where to publish). It is important to say here that we had a consistent support in the presence at the symposium of well-known specialists from outside the region: Walter Kutschera (University of Vienna), Laurent Cortella (ARC-Nucleart Grenoble), Ulrike Sommer (University College London), Pieter Vandenabeele (Ghent University), or attending the BSA for the first time: Milica Stojanović-Marić (National Museum Belgrad), Žiga Šmit (University of Ljubljana). The latter assumed the responsibility of organizing the next edition (at this time BSA6 has already taken place in September 2018 in Ljubljana, Slovenia, with the institutional support of the National Museum of Slovenia). The presence at BSA5 of about one hundred specialists (some attending only part-time) from different fields of expertise made us believe that our goal was reached to a large extent. We could reunite archaeologists, historians, museum curators, physicists, chemists, biologists, science managers... researchers and/or university professors, custodians of national and global heritage monuments and artefacts.

BSA5 had five ordinary sessions of half a day each and a session in round table format on the last day, a Thursday. The round table, in the organisation of which Emilian Alexandrescu from the University of Bucharest was particularly involved, was entitled *Multi-disciplinarity in archaeology: Situating archaeometry in education and research*. On that occasion, many more people joined the participants to the ordinary sessions. Officials of the host country involved in research policy and in the management of research and higher education, representatives of history departments from Romania's universities, members of the Romanian Academy, politicians and media representatives were invited. And some responded to the invitations: Octaviana Marincaş – representing the Ministry of Research (ANCSI - Agenţia Naţionala pentru Cercetare Ştiinţifică şi Inovare/the National Agency for Scientific Research and Innovation), Petre T. Frangopol from the Romanian Academy, Vasile Cotiugă from University of Iaşi – ARHEOINVEST Platform, Dorin Micle from Timişoara –ARHEOVEST Platform, Emilian Alexandresu, Carol Capiţă and Daniela Zaharia from the University of Bucharest, arheologists Eugen Teodor, Nona Palincaş, Vasile Opriş from various institutions in Bucharest, many researchers from IFIN-HH. The round table itself had two parts, a first for general discussions on the topic in the title and one specific for the situation in Romania. The first had a few interventions from participants commenting on the status of the field in their respective countries. The second one was longer and was related to the assessment of the status of archaeometry, or more generally said, of the status of the use of modern chemical and physical methods in the study and preservation of the material cultural heritage in Romania. To assess the need (large), the technical possibilities (good) and the human resources (poor) for this endeavour! Right up for the title of the whole event: we need to have these bridges between specialists in the positive sciences and those in humanistic ones. Bridges are needed between us physicists, chemists, biologists, engineers etc ... and those who are the specialists and the curators of the monuments and artefacts that constitute our common heritage. One important conclusion was that the educational system lacks a good, modern curriculum of archaeology in its universities. Fundamental changes are needed to create the specialists that can respond quickly and adequately to the challenges of the present time and society. Most challenging: the preventive archaeology connected with the increased and increasing number of construction sites and the need for specialised classes, at master level and above, on the methods of the 'positive sciences' with application in archaeology. Moreover, a wider cooperation between the people and institutions with responsibilities and possibilities in the field is needed and within reach. I cannot skip here the fact that I presented the offer of our institute (IFIN-HH) in the fields of study and preservation of cultural heritage, which is large and diverse (see http://patrimoniu.nipne.ro/), but not sufficiently known or used by the 'beneficiaries', national or regional. And is the contribution that IFIN-HH could bring to a national Centre for the Study and Preservation of Cultural Heritage, a localised or a virtual centre, set up as a network of research infrastructures and specialists dedicated fully or partially to heritage studies that we strived to organise at that time. Two years after, I have to say that, no, the center was not formally setup, despite the initial support of the ministry of research, but that in practice it works at the grass-root level. While in September 2016 we did not know about the E-RIHS (European Research Infrastructure for Heritage Sciences) initiative, at this moment we struggle to join it, as its ideas and principles are similar.

To conclude this section: the support of the University of Bucharest, directly through its Rector Mircea Dumitru, academician, was crucial in extending the number of participants – young ones in particular - by hosting at no cost some participants in its Guest house in Sinaia. The Romanian ministry of scientific research (ANSCI) supported the workshop with seed funding. IFIN-HH and IAB supported the Organisers. Not in the last, we need to acknowledge the excellent conditions offered by hotel *International***** (https://www.internationalsinaia.ro/) in Sinaia that hosted the meeting in its Conference centre and accommodated most of the participants.

This volume

The volume contains 16 papers, all solicited to the participants and carefully reviewed by the Editors and their evaluators. For the customs of the community I come from (nuclear physics), the time it took to have it put together is long. Apparently it is not so for archaeologists or people working in the fields represented here. The extra care the Editors put into having the papers selected and worked out is commendable.

The purpose of the volume itself and the restricted number of papers would not allow to treat exhaustively or extensively each topic, each section, or to offer reviews of the status of each particular topic globally or in the Balkans. It was more so done in the actual presentations at the symposium than it is here, as each presentation started with an overview of the topic or problem, while the printed text concentrates on news.

The papers in the volume are of various complexity and length. Some are focused on methods, presenting either the results of a new method (Atanassova *et al.*) or improvements of an established method (*Šmit*), new ways of resorting to established methods (Sommer *et al.*), discussion of established methods in relation to concerns raised by those still unfamiliar with them (Cortella) as well as the history of a method (Ponta). Other papers are case studies of various extents. Rather than following the division between focus on method vs. focus on applications, the editors opted for grouping the papers according to the analysed material, whenever this was possible, to help the readers – usually specialised in a certain field – to quicker identify in the book content the papers of interest. The volume is thus loosely divided in nine sections, some more consistent, many containing one or two papers only. It starts with two papers grouped under 'Multiple investigation methods combined' by Sommer *et al.* and Palincaş *et al.*, respectively. They treat directly what could be called the fundamental problem of archaeometry: what methods to be used, how to be combined, what can we learn from them? What are the limits of methods, what do we learn from apparently contradicting results and so on? In particular Sommer *et al.* ask to what extent the archaeological excavation would be different if we had archaeometry involved during excavation and not afterwards as it is usually the case, while Palincaş *et al.* show the benefits of considering together the results of methods that are usually applied separately – in this case diet studies and archaeometallurgy – in understanding people's biographies.

The second section is the most consistent one, with four papers on the use of radiocarbon dating. Three of them refer to Bronze Age cases of wide European interest: Dáni *et al.* dated cremated bones from Early and Middle Bronze Age on the territory of present day Hungary in tandem with associated organic material as part of a wider attempt to develop the radiocarbon dating of cremated bones, Palincaş *et al.* assessed the methodological accuracy in dating by radiocarbon the Middle Bronze Age in Central Romania and its impact on the long debated Aegean connections, while László revisits one still unsolved case of systematic difference between absolute dating by historical-astronomical and radiocarbon methods of the Late Bronze - Early Iron Ages in and around the Carpathian Basin. The last case study of this section is an application of the radiocarbon method to the history of an object – a wooden church of modern era (Simion *et al.*). These are followed by case studies in archaeometallurgy (Constantinescu *et al.* establishes the Danubian origins of Iron Age gold and silver pieces found today in the collections of famous museums in the USA), ceramics archaeometry (Opriş *et al.* and Dragoman *et al.* present analyses of pigments used in the decoration of Chalcolithic pottery and architecture pieces from the fifth millennium BC), glass (*Šmit* presents an improvement of the PIXE method applied to early Medieval glass from Slovenia) and pigments (Kostadinovska *et al.* study pigments used on Late Medieval manuscripts). These are followed by one case study on the DNA analysis of one human skeleton from the Cucuteni culture (usually known for its 6-7 millennia old beautiful ceramics) by Bolohan *et al.* and one on the use of GIS technology for the identification of previously unknown archaeological sites by Bakardzhiev and Valchev.

The last section is a more consistent one and includes three papers on 'Heritage conservation methods', from three different countries: Bulgaria, Romania and France. The first of the three by Atanassova *et al.* is a specific application of modern methods to the restoration of stone monuments damaged by contemporary graffiti, while the papers by Cortella and Ponta describe a wider range of applications of gamma irradiation for cultural heritage disinfection and preservation of archaeological organic materials. These latter two draw on the expertise of two trail blazing teams of scientists and the state-of-the-art installations they built in Bucharest and Grenoble respectively to introduce and test modern methods in the field of cultural heritage preservation, restoration and consolidation.

All in all, I believe that this volume is a good mirror of what the 5th Balkan Symposium of Archaeometry (held 25-29 September in Sinaia, Romania) was about and to a significant extent of the current situation in the Balkan region in the field of the use of modern scientific methods for the study and conservation of cultural heritage. And I would dare to say that what is missing from this volume reflects well what is missing in this field in our countries.

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Bucharest-Măgurele, December 2018
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Editors' note: With great sadness we learned that one of our colleagues, Dr Bogdan Constantinescu, a co-organiser of BSA5 and a contributor to this volume, had passed away unexpectedly a few days before the arrival of his chapter for proofreading. The community will miss his contribution.

Micro- and Macroarchaeology – How Can the Two Be Combined?

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Abstract

We present the scientific analyses conducted on the ongoing excavation of the late Criș settlement at Tășnad-'Sere', Satu Mare county. The excavation aims to understand the relationship between the occupation layer and sub-surface features.
We seek to achieve constant feedback between the scientific analysis and the excavation, adapting our excavation methods as needed. The ultimate aim is to develop methods that can also be applied to more conventional excavations. Soil analysis (XRF) revealed a good correspondence between sulphur, inorganic phosphorus, potassium and calcium and the archaeological features. Lipolythic microorganisms and thermophilic bacteria were identified both around and within a pit. Petrographic thin section analysis showed that a very similar fabric with fine organic inclusions was used in all areas analysed.

Keywords: taphonomy, ceramic petrography, pottery colour, phytoliths, soil biology, lipolythic microorganisms, soil analysis, X-ray fluorescent spectrophotometer.

Introduction

The following is an account of the use of methods drawn from Natural Science during an ongoing research excavation. We are thus not able to present any final results here. The account is written from the perspective of a field archaeologist and therefore very much concerns what the primary author (U.S.) learned from her co-authors and other collaborators during the process. The ceramics are analysed by Silvia Amicone; the soil by Elena Chernysheva.

Archaeometric studies are very often only undertaken after an excavation has been completed, while the results of scientific studies feed into ongoing excavations far too rarely. In the following, we reflect on how to bridge the gap between field archaeologists and archaeometrists and natural scientists, and how to arrive at research questions that are beneficial to both.

Archaeometry still has no clear place in mainstream archaeological theory (Martínon Torres and Killick 2016). At best it is accorded the status of a method (e.g. *Hilfswissenschaft* in German). The natural sciences are perceived as realist and empiricist, looking at the material properties of artefacts, while archaeologists, at least in Britain, see themselves as part of the humanities and often take a subjectivist, idealist stance, emphasising the active use of material culture (Hodder 1982) and the nature of artefacts as socially and culturally constructed (cf. Jones 2004). This is the case despite the so-called material shift in cultural studies and the recent interest in materiality, 'thingyness' and entanglement (Hodder 2011, 2012, 2014). In recent years, the concept of materiality has become very fashionable in archaeological theory, especially in the UK. Elisabeth DeMarrais *et al.* (2004: 2) offers the following definition: 'in current archaeological theory, materiality approaches concern not only the study of the characteristics of objects, but also the more general notion that humans engage with the things of the world as conscious agents and are themselves shaped by those experiences.' The concept was originally adopted from consumer studies. In the field of the history and philosophy of science, Bruno Latour (1991; 1999) has emphasised how the artificial contrast between mind and matter introduced during the Enlightenment has served to mask the complex interplay between researcher, instruments, social context and the investigated object. This was taken up in archaeology in terms of the demand for a 'symmetrical archaeology' (Shanks 2007; Olson and Witmore 2015). However, Tim Ingold (2007: 1, 3) criticised the discussion of materiality and material culture for seemingly having little to say about materials, and it was claimed that materiality had become a hindrance rather than a help in terms of understanding materials (Cooney 2016). In many respects, the discourse on materiality resembles a complicated way of returning to a position that had always been held by materialists, i.e. that humans interact with the environment via tools of their own making.

Archaeologists are often rather ignorant of the rapidly advancing possibilities provided by the scientific analysis of materials, while scientists can be badly informed or frankly uninterested in the research questions of archaeology. Indeed, scientists are often more concerned with developing and applying a new method rather than entering into a dialogue with archaeologists, something which is already difficult to achieve given their different epistemological backgrounds, let alone any terminological disparities. These problems can be alleviated by involving them in the archaeological process, allowing them to work on the excavation itself and therefore to influence the development of research questions, supervise sampling and, most importantly, suggest analytical methods, highlight their limitations and oversee their implementation on-site.

In the following, we outline the aims of the excavation in question and how these influenced the choice of scientific methods used. The results of these preliminary analyses have in turn influenced the design of the excavation. While there is constant feedback during the dig, we will probably need to rejig our excavation procedures fundamentally once the scientific analyses have been completed and explored in more depth.

The site

Tăşnad-'Sere' is located in the Satu Mare region of north-western Romania. It belongs to the Late Starčevo-Criș culture, which represents the earliest Neolithic in the upper Tisa valley. The settlement is located about 0.5 km west of the last hills of the Dealurile de Vest region, in which the town of Tăşnad is situated. The remains of the Criș settlement cover an area of around 4-5ha (Virág 2015: Fig. 1) in the valley of the Cehal River, a tributary of the Ier River, which feeds into the Tisa. Two ^{14}C dates for animal bone, analysed as part of the EuroFarm project (Vander Linden *et al.* 2013), lie between 5200 and 5000 cal BC (Vander Linden *in prep.*).

At Tăşnad-'Sere', sunken features like pits, postholes and so-called semi-pithouses, dug into a heavy clay alluvium, are covered by a dark occupation layer containing numerous finds, which in turn are covered by an alluvial layer that decreases in depth the further the distance from the Cehal River.

Finds from occupation layers are often perceived as unstratified and their provenance thus recorded in less detail than that of artefacts recovered from sunken features. In addition, given its location, there is a possibility that the artefacts in the occupation layer were displaced by the floodwaters that ultimately covered the site.

Aims of the Excavation

Relationship between features

As the dating of early Neolithic houses is often based on the content of adjacent pits (Astaloș and Sommer 2015: 82), the origin and chronology of pitfills should be of great general interest. However, these have rarely been studied in any detail (cf. Schäuble 1997; Hoga 2014). In Tăşnad, previous excavations by Ierkosan (1994/95), Németi (1990: 89-90), Virág (Virág *et al.* 2007; Virág 2016) and Astaloș (2005) have uncovered pits and houses under a substantial occupation layer. This made it a promising site at which to study the relationship between dug features and surface finds. In 2012, a trench for the joint UCL/Satu Mare excavations was laid out in an area where Neolithic sediments were buried by an alluvial deposit of more than 1m thick. This made any secondary disturbance highly unlikely. In addition, the area had been used as meadow or woodland for as long as records exist (Stanciu and Virág 2013: 173; Virág 2015). By three-dimensionally recording every find >1cm including its orientation and dip (Sommer and Astaloș 2015), we intend to trace potential post-depositional movements, caused, for example, by flowing water or argilliturbation, or changes during the use of the site, like trampling, and to elucidate the relationship between the occupation layer and dug features, such as postholes and pits. While there were some unexpected problems in recording artefact orientation due to the inexperience of the excavators, it is clear that fluvial action can be ruled out for the formation of the occupation layer.

Two layers can be differentiated in the alluvium. We tested the section for pH as well as trace elements (Figure 1) using portable X-ray fluorescence spectroscopy (Hunt and Speakman 2015). While the strong fluctuation of many trace elements may be due to either repeated short-term sedimentation events or a pronounced inhomogeneity of the sediment, there are some clear trends that seem to indicate a change in the sediments being eroded in the catchment area of the Cehal River and hence a change in land use. There is a visible change in sediment at *c.* 0.7m beneath the surface. This corresponds to a decrease in iron and rubidium and a rise in strontium and zirconium, while the values for titanium, zinc and yttrium do not show any clear correlation. The lower alluvium, which contains a few rolled sherds and is probably an eroded archaeological horizon, and the occupation layer proper have lower levels of iron and yttrium, while the occupation layer has lower levels of rubidium and zirconium. While the results need to be verified using a larger number of samples in order to understand the nature of the fluctuating values, they demonstrate the value of pXRF (portable X-ray fluorescence) measurements in understanding the origin of sediments and verifying the visual assessment of the stratigraphy. The pH is alkaline throughout but drops with increasing depth.

Soil micromorphology will improve our understanding of deposition processes and the formation of the interface between the occupation layer and archaeological features. Samples at the interfaces between dug features and the occupation layer were collected but have not yet been analysed.

The excavation in UCL Trench 1 has so far revealed a pit in the southeast corner and a row of four postholes that may indicate the location of a house (Figure 2).

Settlement structure

The mapping of each individual find will allow us to study the settlement structure and the activity areas associated with individual houses. The results of the previous excavations indicate a regular layout of small houses arranged in parallel rows (Virág and Stanciu 2013). Given the sheer size of the settlement at Tășnad, it seems improbable that the whole area was used simultaneously. In the middle Neolithic Alföld linear pottery culture, rows of houses were occupied one after the other, as, for example, at Tiszaszőlős-Domaháza-Puszta (Domboróczki 2010: 210). A similar pattern may have been common in the preceding period as well.

At Tășnad and other comparable sites, dug features only appear once the occupation layer has been removed, as both occupation layer and dug features are normally dark greyish brown or black and consist of heavy clay. In addition, soil formation and a changing ground water level have probably masked former disparities in terms of colour and composition. Most finds in the occupation layer occur in dense concentrations of *c.* 0.6-0.9m in diameter and separated by areas almost entirely devoid of bigger finds, both horizontally and vertically. We interpret these concentrations as being individual dumping episodes outside a dwelling, maybe on an empty plot of land. If this assumption is correct then each of these dumping episodes represents a unique moment in time relating to a specific household, even if the corresponding houses cannot be identified as yet.

Despite an extensive programme of flotation – with ten litres of soil from each excavated square and spit being processed – very few plant remains have been found so far. Systematic bucket flotation has delivered hardly any carbonised seeds, and charcoal is rare except for the top spits. Amanda Leon, who is in charge of the archaeobotany programme, has tested a variety of procedures in the hope of improving the recovery rate, albeit without significant success. After processing samples from other sites in the area with similar soils – a Pișcolt pit from Blaja (corresponding to Linearbandkeramik in Alföld, the Great Hungarian Plain: Németi and Hágo 2015) and Eneolithic pits from Moftin – with the same negative results, we suspect a deleterious influence of the heavy clay soil, either in terms of the destruction of carbonised remains or their failure to float after prolonged soaking to break up the lumps. A separate programme of wet sieving yielded scarcely better results (Pomazi 2014). The effect of soil and especially of argilliturbation on charred remains is under-researched, however, and we are planning taphonomic experiments using modern charred cereal remains.

Alternatively, the dearth of plant remains – compared, for example, with the *Linerarbandkeramik* (LBK) settlements (Bakels 1995; Bogaard 2004, 2011; Kreuz 1990) – could also indicate the existence of separate crop processing areas outside of the core settlement. The heavy fraction of the archaeobotanical flotation shows that microrefuse from chipped or ground stone work is also very rare in UCL Trench 1. This tallies with the densely built-up space inside the settlement, which does include not any of the yards associated with individual houses as in the later LBK.

Soil analysis

The thick soil cover over the Neolithic remains provided effective protection from later disturbances. This encouraged us to devote more attention to the actual composition of the soil itself. Since 2017, we have therefore been systematically taking samples to analyse the soil composition (granulometry, loss on ignition), magnetisation and pH from each excavated square and spit. Elena Chernycheva is analysing the content of major and trace elements as indicators of human activity on the site.

Soil samples were taken from spit 8 (*c.* 1.80m beneath the surface) in each excavated square. After cleaning the surface of the excavated area, a sample was taken from the centre of each quarter-square if the sediment was homogeneous. If any features were visible, separate samples were taken for every feature or layer. Sub-samples from the same contexts were then combined to eliminate any local variation.

Spit 8 was chosen because it is situated near the lower limit of the occupation surface. However, this choice was based on an educated guess. As yet, the vertical movement of prehistoric anthropogenic trace elements in soils is badly understood. In settlement contexts, it is mainly the distribution of phosphates that has been investigated (Stäuble and Lüning 1999; Lüning and Reich 2011; Weiner 2010: 59-61). The effects of different

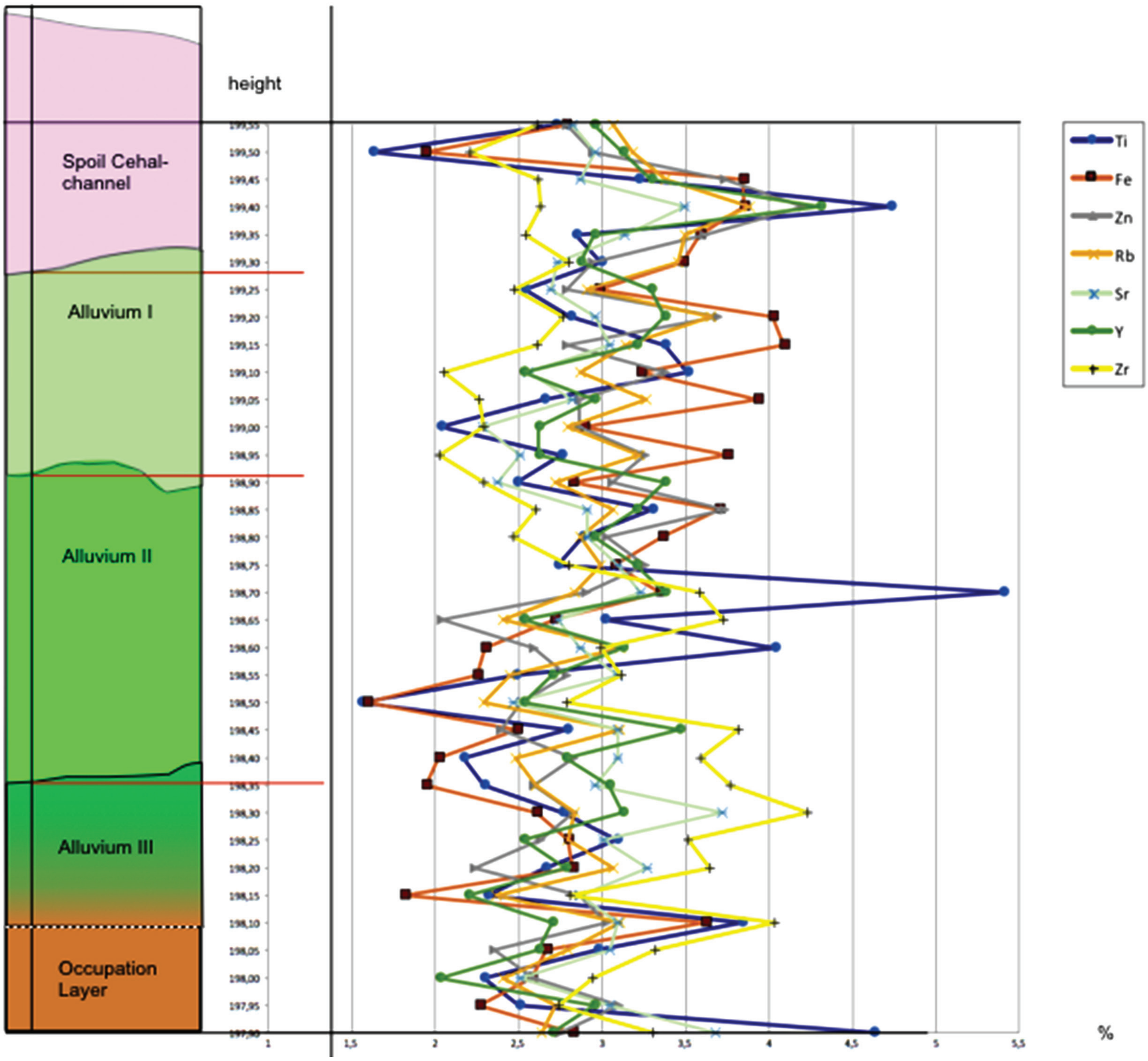

Figure 1. Tăşnad-'Sere', South-section of UCL Trench 1, horizontal distribution of selected elements (normalised values) detected by p-XRF.

soils and groundwater regimes have not been explored systematically. Therefore, in future the horizontal distribution of trace elements will be sampled in more detail. As the Neolithic surface is sloping to the East, the artificial horizontal spits may intersect different parts of the occupation surface.

The bulk content (%) of major and trace elements (Na, Mg, Al, P, S, K, Ca, Ti, Mn, Fe, Cu, Rb, Sr, Ba, Hg, Zr, and Sn) was determined using an X-ray fluorescent spectrophotometer. The determination of the concentrations of macro- and micro-elements in the soil was carried out by measuring the mass fraction of metals and metal oxides in powder samples. The soil samples were dried and ground to a particle size of about 50 microns. The ground sample (200mg) was then pressed into pellets and analysed using a spectrometer. The inorganic phosphorus content was determined after extraction using a strong acid (2N HCl) at a soil-liquid ratio of 1:20 and determined colorimetrically through reaction with ammonium molybdate. It is possible to measure about 70-80% of the total phosphorus after this treatment.

Sulphur, inorganic phosphorus, potassium and calcium have high values in the area of the pit and of feature 2, which is probably a small pit (Figure 3). The sulphur and phosphates may have originated from rotting organic refuse. Ash is a possible source for S, K, Ca and P (Braadbaart *et al.* 2012: tab. 3). The calcium could also originate from decomposed bone. Most of the bones in the occupation layer and in the upper layers of features are badly preserved and often completely lacking in collagen. Spit 8 in fact contains the maximum number

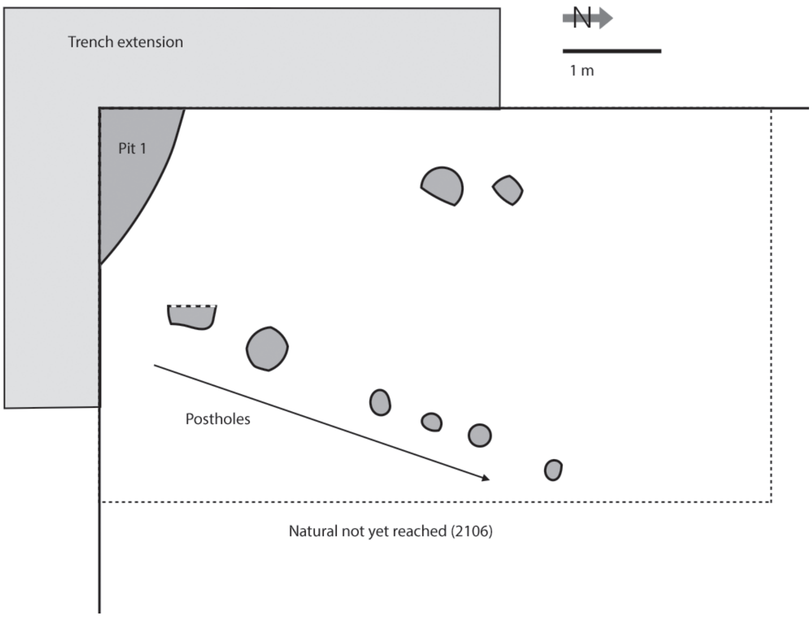

Figure 2. Features in UCL-Trench 1, south-east corner.

of preserved bones, while the number of most other materials peaks in higher layers. This, together with a lack of bones of small mammals or birds in the animal bone assemblage (El Susi 2017), hints at a considerable loss of bone. However, the pit does not show up in the strontium distribution.

Other elements, such as Al and Mg, show a regular W-E decline, which corresponds to the absolute height. The distribution is thus most likely related to groundwater action and probably postdates the archaeological deposits. The distribution of Fe_2O_3 shows a similar pattern, but the area of the pit and its environ has low values. This corresponds to the macroscopic observation that iron staining is less common in the anthropogenic sediments, which may relate to a different redox-potential. Most of the heavy elements, as well as sodium and magnesium, bear no relation either to features or to absolute height. Of course, they may reflect activities in the occupation layer or corresponding finds/concentrations, which are yet to be analysed.

Overall, the results are promising, but can only be fully interpreted once the excavation is finished. The exploratory 1m sampling grid is too coarse to catch small features like postholes, so we will try using a finer grid. However, worm casts and fossil polygonal cracks introduce a pattern of their own, which can easily mask small-scale anthropogenic signals. We will explore the use of a pXRF device in areas where we expect subsurface features that are not yet visible. This offers a reasonably fast way to analyse the sediment and could be of great help in the excavation and interpretation of comparable layers.

Soil biology

The analysis of soil microorganisms has been used successfully in the study of Medieval relic soils (Chernycheva *et al.* 2014, 2015 and 2016). We held out little hope of success in this much older sediment; however, preliminary studies have found soil microorganisms still to be present, albeit in lower concentrations.

The amount of lipolythic microorganisms was examined to identify fatty compounds introduced into the soil in the past. The determination of lipolythic microorganisms was performed using the plate count method. Briefly, soil samples (1g) were mixed with 10ml of 0.5% tetrasodium pyrophosphate, with the resulting suspension then being serially diluted: 1ml of each dilution was added to 9ml water and then poured into sterile Petri dishes containing (w/v): 0.5% polysorbate 20, 5% polysorbate 80, 1.0% peptone, 0.5% NaCl, 0.01% CaCl2 and 2.0% agar. Soil samples plated on agar were incubated at 28^{o}C for seven days.

While differentiating between vegetable and animal fats is not possible with this method, it still provides an important way of exploring the organic component of prehistoric refuse. The analysis revealed a concentration of lipolythic microorganisms around Pit 1. As the area above the dug feature was relatively poor in finds, this may indicate that it was once full, with the area being used to deposit organic refuse. This is supported by the presence of thermophilic bacteria.

Adaptation to a new type of environment

Tășnad is located in the boundary region between the hills of Transylvania (*Crișana*) and the Great Hungarian plain to the West. According to most Romanian authors (Lazarovici 1996, 1998; Virág 2008), the first Neolithic settlers in this area came from central Transylvania, with Gura Baciului (Lazarovici and Maxim 1995) representing one of the oldest known Neolithic settlements in the country (Luca 2011). In contrast, many Hungarian archaeologists favour a model of Neolithic colonisation from the South, following the course of the Tisa. Only a greatly increased number of ^{14}C-dates combined with a detailed stylistic analysis of the pottery can help decide between these two possibilities. However, whichever route was followed, the settlers in Tăşnad and a number of comparable locations in the piedmont had to adapt to a new environment. The 'Neolithic package' ultimately derived from Western Asia was made up of cultigens and domesticated animals adapted to dry steppic conditions. In contrast, the Alföld, before the large scale drainage and meliorisation begun under Joseph II, was a patchwork of riverine woodlands, steppe and swamps (Feurdean *et al.* 2015; Magyari *et al.* 2010). Several sites in the Northern Alföld have already illustrated the great importance of hunting to the human diet in this area (Bartosiewiecz 2005; Kovács *et al.* 2010) as well as other areas (El Susi 2011; Orton 2008: fig. 5.9) and, as the work of Georgeta El Susi indicates (El Susi *in prep.*), this is also true for Tăşnad, where 42% of the identified bones are from wild animals. Both steppe (wild horse, wild ass) and hill species (brown bear) are present. If we receive the necessary funding, we plan to perform isotope analyses to obtain a better picture of the habitats of both domestic (cf. Knipper 2011) and wild animals.

Given the extreme rarity of charred plant remains, we had to turn to alternative sources of evidence for the environment and agricultural activities at Tăşnad – namely, phytoliths and the frequent plant impressions in the pottery. Phytolith samples have been taken systematically since 2015, but have not yet been analysed. The utility of plant impressions on the surface of pottery depends on their origin, i.e. whether they were caused by the use of organic temper, the accidental inclusion of plant remains present in the settlement for other reasons at the time the pottery was produced or the use of chaff and similar materials as a separating agent during the production process. This problem is being investigated by Bruno Vindrola as part of his PhD dissertation.

Mobility and social structure

Currently, genetic studies indicate a solution to the heated debate surrounding the mechanism by which agriculture spread to Europe in terms of population movement, given a strong genetic input from Southwest Asia in most early Neolithic populations. However, this does not explain the nature of this mobility. Demic diffusion (Ammerman and Cavalli-Sforza 1973),

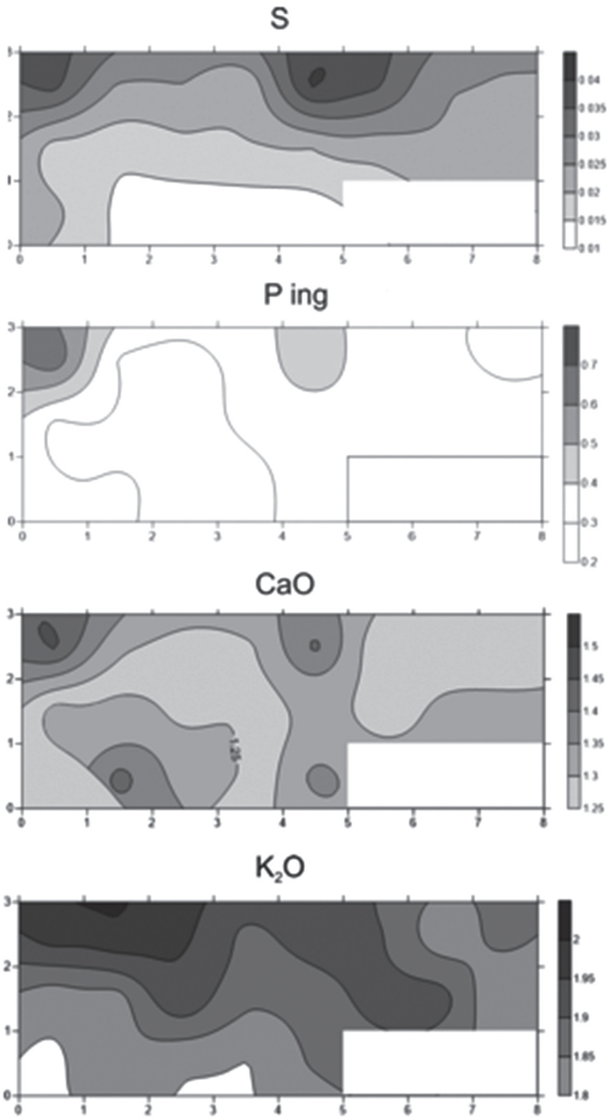

Figure 3. Distribution of sulphur, inorganic phosphorus, potassium and calcium. The values are averaged per square, the distribution map is created with Surfer, using kriging. The shape of the concentrations are thus determined partly by the values in adjacent squares and do not represent the variation inside the square.

colonisation, leap-frog colonisation (see Forenbaher and Miracle 2005: tab. 1 for a useful overview) have been discussed as possible causative mechanisms.

Given the lack of formal cemeteries in the entire Starčevo-Körös-Criş (SKC) area, and the concomitant lack of human remains, genetics is unlikely to be of much help here. There are four skeletons from Tăşnad (Astalos and Virág 2006-2007: 79-80; and analysis currently in preparation by R. Pinhasi), but it is unclear how representative these and other isolated burials are. The isotope data for the LBK, commonly derived from either the Starčevo-Körös-Criş or the Starčevo culture alone (Bánffy 2006, 2014; Bánffy and Oross 2010) indicate high individual mobility (Hofmann 2016), which may go a long way to explaining the extreme homogeneity of this culture over large areas. For the LBK, this high mobility is also reflected in the presence of different forming techniques and paste composition within the same settlement (Gomart 2014; Gomart *et al.* 2017). Corresponding studies for the SKC are being prepared by Sébastien Manem.

While individual mobility cannot yet be proven for the SKC, it should certainly be included in the list of possible mechanisms for the northward and westward spread of the culture complex. We are therefore looking for indications of variation within the settlement. Such variation can also provide indications about the organisation of the villages. Are land and other resources held in common, or controlled by individual households? Are artefacts manufactured together, or do individuals learn from family members?

Pottery, while the most frequent category of find, is unfortunately highly fragmented. In addition, the late Criş-pottery (phase IIIB/IV according to Lazarovici 1979) is only very sparsely decorated. Both factors limited the scope for stylistic analysis. Consequently, we concentrated on paste composition and surface treatment. During excavation, we noticed that a pottery concentration would very often be dominated by sherds of one colour and similar thicknesses, i.e. probably the remains of a single pot. In all cases, however, they were accompanied by other artefacts like chipped stone, ground stone and burnt clay, as well as a few sherds of differently coloured pots. It appears that the breakage of a particular pot had initiated a general clean-up. The assemblage would therefore represent the taphocoenosis (Sommer 1991) present at one specific moment in time on the floor of an individual house. The colour of the pottery ranges widely, from light grey to orange, red, brown, dark grey and black. Pottery surface colour rarely receives much attention, but we were interested in whether the colour corresponded with vessel shape/pottery use and was caused by clay selection or paste preparation, or whether it was intentionally created during the production process through the addition of pigments or a manipulation of the firing process. If colour is related to the use of a vessel, there should be a correlation between shape/size, temper and colour. If pigments are used, this could indicate personal or household preferences.

Pottery

Composition

In a pilot study, petrographic thin section analysis (Quinn 2009, 2013; Whitbread 1995, 2001) was carried out on 13 samples (Figure 4). The samples are characterised by a soft fine fabric (apart from TS 9 and 10, which have a thicker wall and are coarser), with small white and red inclusions and numerous 'channel' and 'vesicle' type pores. The colour of the samples varies from light brown to red and very dark grey. Particles previously identified as grog by the archaeologists turned out to be natural clay pellets contained in the clay.

Viewed under the microscope, the 13 specimens analysed do not display any significant compositional variability (Figure 5). Therefore, it was not possible to subdivide them into meaningful separate petrographic groups. Samples are characterised by the presence of equant and elongate sub-angular inclusions of quartz, polycrystalline quartz, feldspars, muscovite and, less frequently, chert, amphibole, clay pellets and opaque minerals. More rarely, fragments of metamorphic rocks, probably schist, occur. In all the specimens, the average grain size of the inclusions is around 0.4mm and the maximum size is 0.8mm, while TS 9-10 shows a coarser texture (average 0.6mm, maximum 1.2mm). All specimens apart from TS 3 are characterised by organic temper, which is particularly abundant in samples TS 1, 5, 6, 11, 12 and 13 (Figure 5). The bimodal distribution of the inclusions characteristic of coarser samples (TS 9 and 10: Figure 5e-g) could indicate tempering with a material derived from metamorphic rocks, probably schist.

The matrix of the majority of samples is optically active (Quinn 2013: 190-198). This indicates low firing temperatures. Some samples (TS 1, 4, 7 and 8) have a matrix that is optically inactive, but these may have been re-fired in a destruction event, as indicated by several extremely highly fired pieces of daub from UCL Trench 1 (Figure 6), probably the result of a house fire that reached temperatures of well over 1100°C, possibly 1200°C or even higher (Veronesi 2014).

The analysis of clay samples collected *c.* 15m to the east of UCL Trench 1 shows that suitable clay sources for pottery making whose compositional characterisation is compatible with that of the samples analysed were available in the immediate vicinity of the settlement. These alluvial clay samples are characterised by the presence of a coarser sandy fraction that includes quartz, chert, muscovite, amphibole and rare fragments of metamorphic rocks (Figure 4h). Sources of tertiary clay, used until recently for brick making and still used for mud-bricks, exist in several locations on the hilltops west of the town of Tăşnad (Marinescu *et al.* 1967).

While it would require a larger number of samples to monitor the compositional and technological variability in pottery paste preparation at the site, we can still make some preliminary observations. First of all, it is clear that the organic material was the most common temper used in Tăşnad. Surface impressions on other sherds indicate the use of fine chaff or grasses. This organic temper was used in combination with mineral and rock tempering when producing vessels with thicker walls (cf. TS 9 and 10). Indeed, large fragments of micaceous schist occurring in the hills located some 500m away were found in the occupation layer.

These results fit well with those of petrographic studies carried out on samples from contemporary sites in Southern Romania (Kreiter *et al.* 2013; Spataro 2014). In particular in Southern Romania, Spataro (2014) observed a low variability in the temper employed in pottery manufacturing, moderate firing temperatures and the absence of any strong correlation between shape and fabric in Miercurea and Parţa, as well as a general lack of evidence for any pottery exchange in the Starčevo-Criş culture in general.

Colour

The ceramic matrix is not homogenous, its colour changes considerably within each specimen and from sample to sample. In PPL (plane polarised light), the samples' matrix is light yellow to yellow and grey. In XPL (cross polarised light), the matrix is light red to brown; in the majority of samples, it is red (in TS 4 and 7) or very dark grey (TS 8). Most of the samples with organic temper are characterised by a black core and light red edges (TS 2, 6, 9 and 10). Even if it is tempting to interpret the high variability in the colour of the fabrics as the outcome of different deliberate firing procedures used with the aim of obtaining vessels of different colours, this phenomenon could also be the result of the non-controlled atmospheric conditions in which these vessels were fired. The presence of a 'black core' in the majority of the samples could indicate that pottery was fired in a bonfire, where the firing is too short to permit the complete oxidation of the ceramic body (Cuomo di Caprio 2007: 494).

The results suggest a differentiation of ceramic paste according to vessel thickness and form, but no correlation between colour and paste. The slight differences in the ceramic matrix could have been caused by the use of different clay sources, but in an alluvial environment the differences are too slight to allow us to make any definitive statement. More analysis, comparing pottery from different squares, is being conducted by Silvia Amicone and Johannes Seidler (University of Tübingen).

In order to explain the observed colour variability it is important to ascertain whether this pattern reflects the original repertoire of colours the producers wanted to achieve or if secondary factors are responsible for the pattern detected in the archaeological record.

Pottery colour is primarily determined by the choices taken by the artisans during the production process (e.g. Rice 2015: 276-290). First of all, the selection of clay plays a very important role in determining the vessel's colour. Different methods of processing clay (e.g. levigation or the addition of temper) can also alter the compositional characteristics of the original clay and have an impact on the final colour of the pottery. Very importantly, surface treatments like the addition of a slip or pigment can also have an impact (Cuomo di Caprio 2007: 305-376).

The most important factor is probably the firing process (Rice 2015: 289). It is during this phase of the production process that pottery acquires different colour according to the properties of the raw material and the firing technique employed. The amount of oxygen present and the temperature reached are the determining factors here. For example, firing under oxidising conditions will result in light coloured pots. When there is a lack of oxygen, the fuel does not burn completely and the atmosphere becomes full of free (elemental) carbon, which combines with oxygen to produce CO. Under these conditions, dark iron oxides are formed (Jones 1986: 762-763). Another way to obtain black colours is the introduction of carbon during the firing process (smudging: Jones 1986: 764).

However, it is important also to take into consideration other factors that may have altered the original surface colour of the pottery. Firstly, there is the possibility of erosion. The colour of the body of the pot can differ from a slip that became removed by erosion or stick to the ground when removed, as is common in Tăşnad. More severe erosion can remove parts of the surface of the pot proper and expose the core, which is often less oxidised and thus darker. We have uncovered some sherds with different surface colours that were clearly caused by the partial erosion of the surface. Experiments are currently under preparation to elucidate the change of colour and outer appearance of pottery due to abrasion using badly provenanced sherds. The colour of the sherds from UCL Trench 1 also needs to be compared with that of better preserved assemblages from the same site located at slightly higher elevations.

In addition, pots fired in an open fire can have several surface colours ('flaming'), which is caused by different exposure to oxygen and direct contact with the flames. Overall, this phenomenon seems to be quite rare in the Tăşnad assemblage, but, again, this observation is in need of careful study and quantification. A preliminary firing experiment with pots made of local clay in shallow pits produced pots with dark red and black surfaces that were far more mottled than the archaeological samples. Further firing experiments in more controlled conditions will be conducted in order to find out whether all the surface colours observed

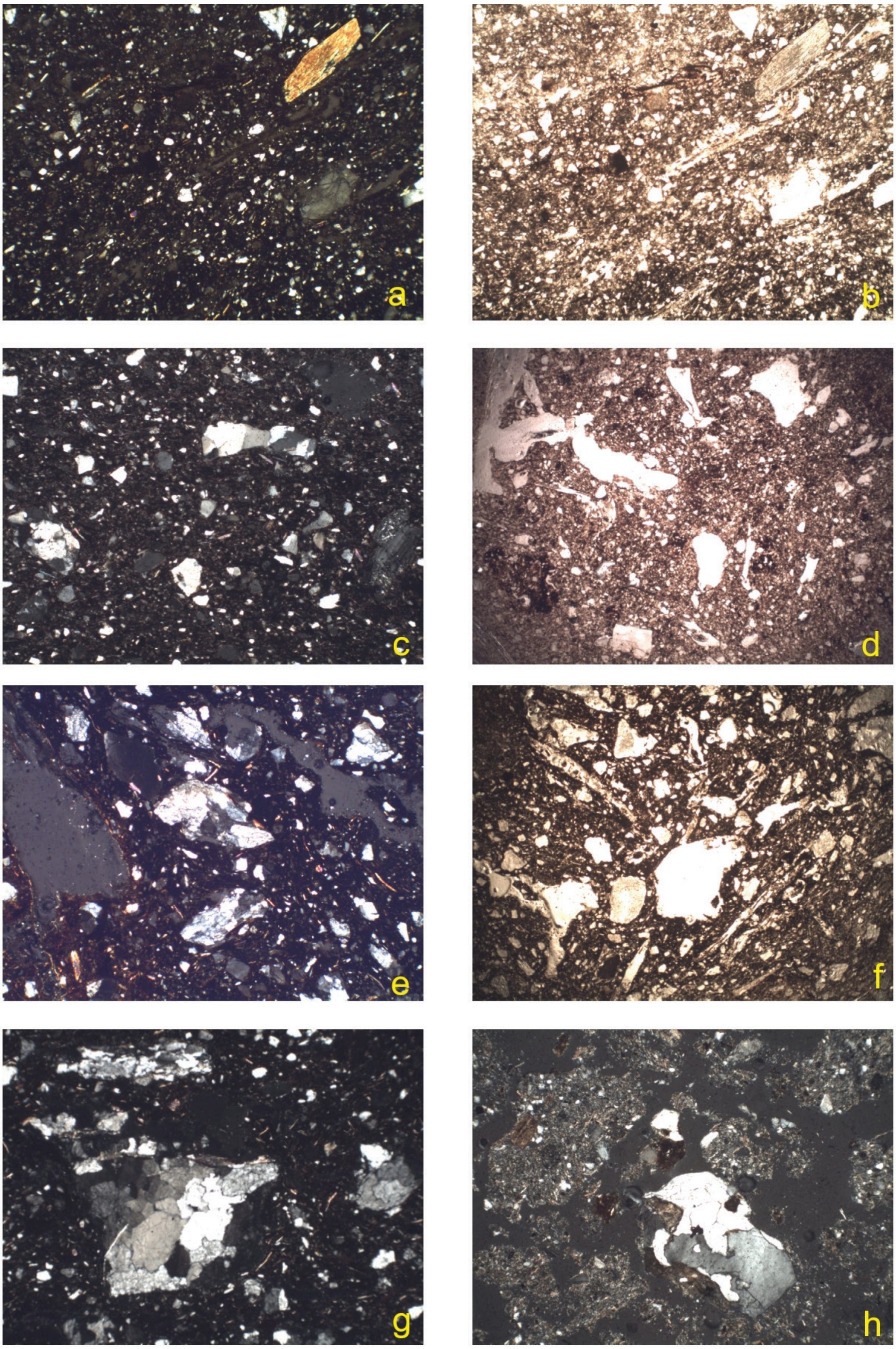

Figure 4. Thin section photomicrographs of selected ceramics from Tăşnad analyzed in this study. a) TS 8: organic tempering (XP). b) TS 8: organic tempering (PPL). c) TS 3: non tempered (XP). d) TS 5: abundant organic tempering (PPL). e) TS 10: mineral and organic tempering (XP). f) TS 10: mineral and organic tempering (PPL). g) TS 10: metamorphic rocks (XP). h) Geological sample (XP). Image width = 3mm (a, b, c, g, h); except d, e, f = 6mm.

can be produced with local clays using different firing conditions alone. This is supported by the analysis of sherds from other sites. For example, Luca and Tudorie (2012: 23) report finding only 7% of flamed sherds from Săliştea (Cioara) in Alba County. Hence, the firing of prehistoric pots was better controlled than commonly believed. However, we also need to determine how deep into the matrix the effects of flaming reach, something which determines the effects of subsequent erosion.

Cooking pots can also change colour during their use on the hearth. In this case, as with flaming, change is restricted to the outer surface (Forte *et al.* 2018). Finally, the original colour of pottery could be altered by secondary firing during random or intentional destruction episodes – for example, a house burning down. The presence of over-fired sherds and burnt clay in the archaeological record can be seen as indicative of this phenomenon.

We also plan to analyse the pottery surfaces to ascertain whether pigments were used to produce the different colours observed. Pigments used in pottery painting have been studied mainly using ED-XRF spectrometry (López-Montalvo *et al.* 2014; Olivares 2013; Roldàn 2014), SEM-EDS, X-Ray diffraction or Raman spectrometry (e.g. Buzgar *et al.* 2013 for the area under consideration). The use of pigments in slips to colour the whole surface of a pot could be demonstrated by using the same technique; however, this has not yet been studied systematically. With most possible admixtures, the way the pot is fired substantially affects the results.

Phytoliths

Ongoing work on microfossil extraction (Lionello Morandi, University of Tübingen) also revealed the

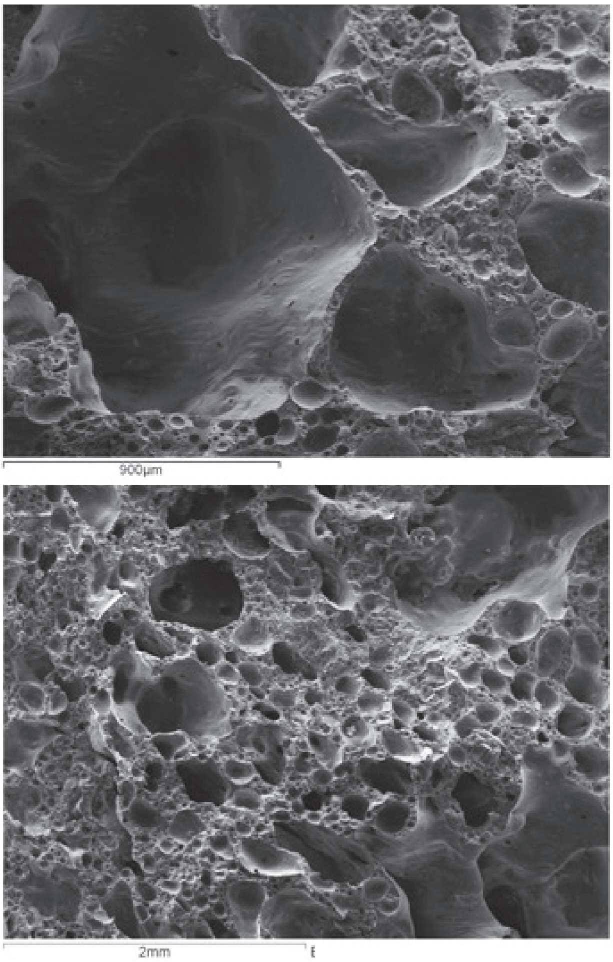

Figure 5. Secondary electron images of the fresh fracture of a piece of slagged clay from Trench 1 at different magnitudes. The extent of the bloated area, the size of the pores and the smoothness and glass-like appearance of the surfaces are clearly visible and indicate temperatures over 1100°C.

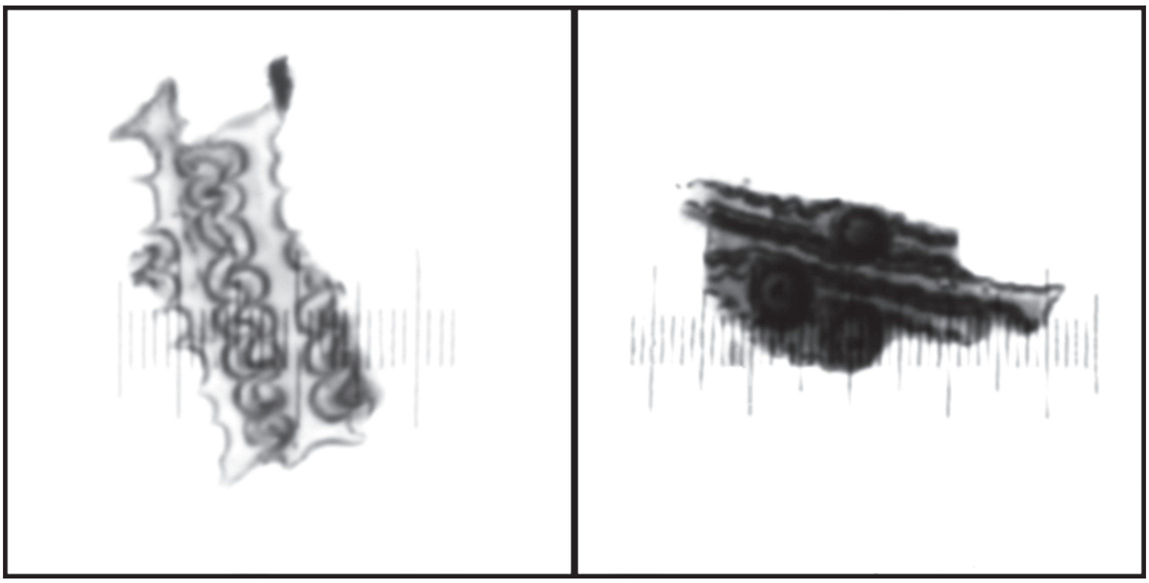

Figure 6. Micrographs showing burnt phytoliths within the ceramic body of Criş-pottery from Tăşnad.

presence of both pollen and phytoliths in the pottery. The pollen was badly preserved and could only be identified at a family level; however, these results match with the charred remains identified by Péter Pomazi (2014). Phytoliths (Figure 6) have also been identified in a Körös ritual object (cf. Kreiter *et al.* 2017), as well as in or on the surface of pottery (Kreiter *et al.* 2013, 2014; Starnini *et al.* 2007; Szakmány and Starnini 2007). Phytoliths melt between 750 and 800 °C (Starnini *et al.* 2007; cf. Pető and Vrydaghs 2016), which means that this temperature was not reached in the interior of the pottery during the firing process.

Phytoliths have been used to trace imported ceramics (Vrydaghs *et al.* 2014; Wallis *et al.* 2014). They can be also be used to identify the type of organic temper used, and, in some cases, the season of use (Vrydags *et al.* 2014: 36). However, this raises the question of how they got into the clay in the first place: as parts of plants selected as a temper, in cow dung (Delhon *et al.* 2008; Shahack-Gross 2011: 207) used as a temper or as part of the original sediment (cf. Ting and Humphris 2014: 35)? Surface deposits can also result from separating agents like chaff. Bruno Vindrola is currently studying the voids in Criş pottery using microtomography so as to obtain a better idea of the shape of the organic temper. If the organic temper is derived from cow dung, the phytoliths could potentially offer information as to the season of pottery making and the location of grazing areas and their organisation, i.e. communal or dispersed. As our trench is located on commonly owned land in Tăşnad, which is still used for grazing today, we have been systematically collecting modern dung samples in order to investigate the identifiable plants and their potential seasonal variation in comparison with the current vegetation (cf. Verges *et al.* 2016).

Conclusion – does it work?

All in all, the use of archaeometry during the excavation has opened up intriguing new vista. The main difficulty seems to be that archaeologists are often simply not aware of methods already in existence in other disciplines. Once we discover them, we tend to become overenthusiastic due to a lack of understanding of the limitations of said methods. Scientists seem very reluctant to give definite answers, but the same is probably true the other way around. In addition, archaeologists do not understand the rationale behind scientific protocols. Most frustratingly, the hermeneutic circle of any empirical methodology sits badly with the archaeological process, which depends on the application of a consistent excavation method, ideally to the whole site. An excavation method once adopted is rarely changed, as evidenced by the various national schools of excavation. Very often we must first realise that we need to dig differently and solve a whole battery of subsidiary methodological problems before we can return to our seemingly simple main question. In the case of the Tăşnad excavation, this probably means that, drawing on all that we have learned, we will need to begin a second trench, collect all the samples and data we need and continue to discover new problems and questions. Starting this process earlier rather than later has proved extremely beneficial, if occasionally exasperating.

Works cited

Ammerman, A. J. and Cavalli-Sforza, L. L. 1973. A Population Model for the Diffusion of Early Farming in Europe. In C. Renfrew (ed.), *Explaining Culture Change*: 343-357. London: Duckworth.

Astaloş, C. and Sommer, U. 2015. The village and the house in the early Neolithic. Research into activity areas and rubbish disposal at the late Criş settlement of Tăşnad (Satu Mare County, Romania). In C. Virág (ed.), *Neolithic cultural phenomena in the upper Tisa Basin*: 75-96. Satu Mare: Editura Muzeului Sătmărean.

Astaloş, C. and Virág, C. 2006-2007. Descoperiri funerare neolitice din judeţul Satu Mare. *Studii şi Comunicări Satu Mare. Seria Arheologie* 22-23: 73-94.

Bakels, C. 1995. In search of activity areas within Bandkeramik farmyards: the disposal of burnt chaff. In H. Kroll and R. Pasternak (eds), *Res archeobotanicae. International Work Group for Palaeoethnobotany. Proceedings of the Ninth Symposium, Kiel 1992*: 1-4. Kiel: Oetker-Voges.

Bánffy, E. 2006. Eastern, Central and Western Hungary – variations of Neolithisation models. *Documenta Praehistorica* 33: 125-142.

Bánffy, E. 2014. Nachalo osedlogo obraza zhizni v zapadnoj chasti karpatskogo bassejna i rolyo pervykh zemledeltsev tsadunavnya v evropejskom neolite. *Stratum Plus* 2: 115-182.

Bánffy, E. and Oross, K. 2010. The Earliest and Earlier Phase of the LBK in Transdanubia. In D. Gronenborn and J. Petrasch (eds). *Die Neolithisierung Mitteleuropas, internationale Tagung, Mainz 24. bis 26. Juni 2005*: 255-272. Mainz: Verlag des Römisch-Germanischen Zentralmuseums Mainz.

Bartosiewicz, L. 2005. Plain talk: animals, environment and culture in the Neolithic of the Carpathian Basin and adjacent areas. In A. W. R Whittle and D. Bailey (eds), *(Un)settling the Neolithic*: 51-63. Oxford: Oxbow Books.

Bartosiewicz, L. 2007. Mammalian bone. In A. W. R Whittle (ed.), *The Early Neolithic on the Great Hungarian Plain: investigations of the Körös culture site of Ecsegfalva 23, County Békés.* vol. 1: 287-325. Budapest: Archaeolingua.

Bogaard, A. 2004. *Neolithic farming in Central Europe: an archaeobotanical study of crop husbandry practices.* London: Routledge.

Bogaard A. 2011. *Plant use and crop husbandry in an early Neolithic village: Vaihingen an der Enz, Baden-Württemberg* (Frankfurter archäologische Schriften 16). Bonn: Habelt.

Bogaard, A., Charles, M., Twiss, K. C., Fairbairn, A., Yalman, N., Filipovic, D., Demirergi, G. A., Ertug, F., Russell, N. and Henecke, J. 2009. Private pantries and celebrated surplus: storing and sharing food at Neolithic Çatalhöyük, Central Anatolia. *Antiquity* 83: 649-668.

Braadbaart, F., Poole, I., Huisman, H. D. J. and van Os, B. 2012. Fuel, Fire and Heat: an experimental approach to highlight the potential of studying ash and char remains from archaeological contexts. *Journal of Archaeological Science* 39: 836-847.

Buzgar, N., Apopei, A. I. and Buzatu, A. 2013. Characterization and source of Cucuteni black pigment (Romania): vibrational spectrometry and XRD study. *Journal of Archaeological Science* 40: 2128-2135.

Chernysheva, E. V., Borisov, A. V. and Korobov, D. S. 2016. *Biological memory of soils and cultural layers of archaeological sites*. Moscow: GEOS.

Chernysheva, E. V., Kashirskayaa, N. N., Korobov, D. S. and Borisova, A. V. 2014. Biological Activity of soddy-calcareous soils and cultural layers in Alanian settlements of the Kislovodsk Basin. *Eurasian Soil Science* 47(9): 884-891.

Chernysheva, E. V., Korobov, D., Khomutova, T. and Borisov, A. 2015. Urease activity in cultural layers at archaeological sites. *Journal of Archaeological Science* 57: 24-31 (10.1016/j.jas.2015.01.022).

Cooney, G. 2016. Material Culture. In A. Gardner, M. Lake and U. Sommer (eds), *Oxford Handbook of Archaeological Theory*. Oxford: Oxford University Press (DOI 10.1093/oxfordhb/9780199567942.013.019).

Cuomo di Caprio, N. 2007. *Ceramica in Archeologia 2, antiche tecniche di lavorazione e moderni metodi di indagine.* Roma: L'Erma Di Bretschneider.

Delhon, C., Martin, L., Argant, J. and Thiébault, S. 2008. Shepherds and plants in the Alps: multi-proxy archaeobotanical analysis of Neolithic dung from 'La Grande Rivoire' (Isère, France). *Journal of Archaeological Science* 35: 2937-2952.

DeMarais, E. 2004. The materialisation of culture. In E. DeMarrais, Ch. Gosden and C. Renfrew (eds), *Rethinking Materiality: The Engagement of Mind with the Material World*: 11-22. Cambridge: McDonald Institute for Archaeological Research.

Domboróczki, L. 2010. Report on the excavation at Tiszaszőlős-Domaháza-Puszta and a new model for the spread of the Körös culture. In J. K. Kozłowski and P. Raczky (eds), *Neolithization of the Carpathian basin: northernmost distribution of the Starčevo/Körös culture. Papers presented on the symposium organized by the EU project FEPRE (The Formation of Europe: Population Dynamics and the Roots of Socio-Cultural Diversity):* 140-176. Kraków: Polska Akademia Umiejętności; Budapest: Institute of Archaeological Sciences of the Eötvös Loránd University.

El Susi, G. 2011. The management of livestock in Early Neolithic settlements (Starcevo-Criş complex) from Transylvania and Banat. In S. A. Luca and C. Suciu (eds), *The First Neolithic Sites in Central/South-East European Transect. Volume II: Early Neolithic (Starčevo-Criş) Sites on the Territory of Romania*: 47-56. Oxford: Archaeopress.

El Susi, G. in preparation. The animal bones of Tăşnad.

Feurdean, A., Marinova, E., Nielsen, A. B., Liakka, J., Vere, D., Hutchinson, S. M., Braun, M., Timar-Gabor, A., Astalos, C., Mosburgger, V. and Hickler, Th. 2015. Origin of the forest steppe and exceptional grassland diversity in Transylvania (central-eastern Europe). *Journal of Biogeography* 42: 951-963.

Fohrenbaher, S. and Miracle, P. T. 2005. The spread of farming in the Eastern Adriatic. *Antiquity* 79: 514-528.

Forte, V., Cesaro, S. N. and Medeghini, L. 2018. Cooking traces on Copper Age pottery from central Italy: An integrated approach comprising use wear analysis, spectroscopic analysis and experimental archaeology. *Journal of Archaeological Science Reports 18*: 121-138.

Gomart, L. 2014. *Traditions techniques et production céramique au néolithique ancien: traditions techniques et production. Étude de huit sites rubanés du nord est de la France et de Belgique*. Leiden: Sidestone Press.

Gomart, L., Constantin, C. and Burnez-Lanotte, L. 2017. Ceramic production and village communities during the Early Neolithic in north-eastern France and Belgium. Issues regarding tempers and pot-forming processes. In L. Burnez (ed.), *Matières à penser: sélection et traitement des matières premières dans les productions potières du Néolithique ancient. Actes de la table Ronde de Namur (Belgium), 29-30 May 2015. Séance de la Société Préhistorique Française 1*: 133-158. Paris: Société Préhistorique Française.

Hodder, I. 1982. *Symbols in Action*. Cambridge: Cambridge University Press.

Hodder, I. 2011. Human-thing entanglement: towards an integrated archaeological perspective. *Journal of the Royal Anthropological Institute* (N.S.) 17: 154-177.

Hodder, I. 2012. *Entangled: An Archaeology of the relationships between humans and things*. Chichester: Wiley Blackwell.

Hodder, I. 2014. The Entanglements of Humans and Things: A Long-Term View. *New Literary History* 45(1): 19-36.

Hofmann, D. 2016. Keep on walking: the role of migration in Linearbandkeramik life. *Documenta Praehistorica* 43: 235-251.

Hoga, C. 2014. Archaeological knowledge gained by 3D-single-find plotting: a preliminary report of the analysis of a Linear Pottery Culture settlement pit in Peres, Dist. Leipzig, Saxony (DE). In H. Duinker, E. Hopman and J. Steding (eds), *Proceedings of the 11th annual Symposium Onderzoek Jonge Archeologen. Lectures presented at the University of Groningen, April 12, 2013*: 39-45. Groningen: Stichting Onderzoek yonge Jonge Archeologen.

Hunt, A. M. W. and Speakman, R. J. 2015. Portable XRF analysis of archaeological sediments and ceramics. *Journal of Archaeological Science* 53: 1-13.

Ingold, T. 2007. Materials against materiality. *Archaeological Dialogues* 14: 1-16.

Jones, A. 2004. Archaeometry and materiality: materials-based analysis in theory and practice. *Archaeometry* 46(3): 327-338.

Jones, R. E. 1986. *Greek and Cypriot pottery: a review of scientific studies*. Athens: British School at Athens.

Knipper, C. 2011. *Die räumliche Organisation der linearbandkeramischen Rinderhaltung, naturwissenschaftliche und archäologische Untersuchungen*. Oxford: Archaeopress.

Kovács, Zs. E., Gál, E. and Bartosiewicz, L. 2010. Early Neolithic animal bones from Ibrány-Nagyerdő, Hungary. In J. K. Kozłowski and P. Raczky (eds), *Neolithization of the Carpathian Basin: Northernmost distribution of the Starčevo/Körös culture*: 238-254. Kraków: Polish Academy of Arts and Sciences.

Kreiter, A., Pető, Á. and Pánczél, P. 2013. Materializing Tradition: Ceramic Production in Early and Middle Neolithic Hungary. In E. Bánffy (ed.), *The Early Neolithic of the Danube-Tisza Interfluve*: 127-140. Oxford: Archaeopress.

Kreiter, A., Riebe, D. J., Parkinson, W. A., Pető, Á., Tóth, M., Pánczél, P. and Bánffy, E. 2014. Unique in its chaîne opératoire, unique in its symbolism: undressing a figurine from the 6th Millennium BC Körös culture, Hungary. *Journal of Archaeological Science* 44: 136-147.

Kreuz, A. 1990. *Die ersten Bauern Mitteleuropas – eine archäobotanische Untersuchung zu Umwelt und Landwirtschaft der Ältesten Bandkeramik*. (Analecta Praehistorica Leidensia 23). Leiden: Sidestone Press.

Latour, B. 1991. *Nous n'avons jamais été modernes*. Paris: La Découverte.

Latour, B. 1999. *Pandora's Hope. Essays on the Reality of Science Studies*. Cambridge (Mass.): Harvard University Press.

Lazarovici, Gh. 1979. *Neoliticul Banatului* (Bibliotheca Musei Napocensis 4). Cluj-Napoca: Comitetul pentru Cultură și Educație Socialistă al Județului Cluj.

Lazarovici, Gh. 1998. About the Neolithization process of the second migration of the early Neolithic. In Florean Draşovean (ed.), *The late Neolithic of the middle Danube region*: 7-38 (Biblioteca Historica Banatica 14). Timişoara: Eurobit.

Lazarovici, Gh. and Maxim. Z. 1995. *Gura Baciului*. (Bibliotheca Musei Napocensis 9) Cluj-Napoca: Muzeul Național de Istorie a Transilvaniei.

López-Montalvo, E., Villaverde, V., Roldán, C., Murcia, S. and Badal, E. 2014. An approximation to the study of black pigments in Cova Remigia (Castellon, Spain). Technical and cultural assessments of the use of carbon-based black pigments in Spanish Levantine Rock Art. *Journal of Archaeological Science* 52: 535-545.

Luca, S. A. and Suciu, C. 2011. *Early Neolithic (Starčevo-Criş) sites on the territory of Romania*. Oxford: Archaeopress.

Luca, S. A. and Tudorie, A. 2012. Another Early Neolithic site discovered in Alba County. The Starčevo-Criş settlement from Săliştea (Cioara, Romania). *Acta Terrae Septemcastrensis* 11, 21-32 (http://arheologie.ulbsibiu.ro).

Lüning, J. and Reisch, L. 2011. Phosphatanalysen in der bandkeramischen Siedlung von Altdorf-Aich, Ldkr. Landshut/Isar, Niederbayern. In J. Lüning (ed.), *Untersuchungen zu den bandkeramischen Siedlungen Bruchenbrücken, Stadt Friedberg (Hessen) und Altdorf-Aich, Ldkr. Landshut (Bayern)*: 245-252 (Universitätsforschungen zur prähistorischen Archäologie 203). Bonn: Habelt.

Magyari, E. K., Chapman, J. C., Passmore, D. G., Allen, J. R. M., Huntley, J. P. and Huntley, B. 2010. Holocene persistence of wooded steppe in the Great Hungarian Plain. *Journal of Biogeography* 37: 915–935.

Marinescu Fl., Stancu J. and Ghenea C. 1967. *Republica Socialistă România, Harta Geologică, Scara 1:200.000. L-34-V. 2, Satu Mare*. București: Comitetul de Stat al Geologiei, Institutul Geologic.

Martínon Torres, M. and Killick, D. J. 2016. Archaeological Theories and Archaeological Sciences. In A. Gardner, M. Lake and U. Sommer (eds), *Oxford Handbook of Archaeological Theory*. Oxford, Oxford University Press (DOI: 10.1093/oxfordhb/9780199567942.013.004).

Németi, J. and Hágo, A. N. 2015. Cultic and miscellaneous clay finds from Pișcolt-Lutărie. In Cristian Virág (ed.), *Neolithic cultural phenomena in the upper Tisza basin. International Conference, July 10-12, 2014*: 185–207. Satu Mare: Editura Muzeului Sătmărean.

Olivares, M., Castro, K., Corchón, M. S., Gárate, D., Murelaga X., Sarmiento A. and Etxebarria, N. 2013. Non-invasive portable instrumentation to study Palaeolithic rock paintings: the case of La Peña Cave in San Roman de Candamo (Asturias, Spain). *Journal of Archaeological Science* 40: 1354-1360.

Olsen, B. and Witmore, Ch. 2015. Archaeology, symmetry and the ontology of things. A response to critics. *Archaeological Dialogues* 22(2): 187-197 (https://doi.org/10.1017/S1380203815000240)

Orton, D. 2008. Beyond Hunting and Herding: Humans, animals, and the political economy of the Vinča period. Unpublished PhD dissertation, University of Cambridge, Darwin College.

Pető, Á. and Vrydaghs, L. 2016. Phytolith Analysis of ceramic Thin-Sections. First taphonomical Insights from Experiments with Vegetal Tempering. In E. Sibbesson, B. Jervis and S. Coxon (eds), *Insight from Innovation: New Light on Archaeological Ceramics.*

Papers presented in honour of Professor David Peacock's contributions to archaeological ceramic studies (Southampton Monographs in Archaeology New Series 6): 57-73. Oxford: Oxbow.

Pomazi, P. 2014. Archäobotanische Untersuchungen zur körös- und piskoltzeitlichen Fundstelle Tășnad-Sere, Rumänien, vorläufiger Bericht (manuscript).

Price, G. C., Krigbaum, J. and Shelton, K. 2017. Stable isotopes and discriminating tastes: Faunal management practices at the Late Bronze Age settlement of Mycenae, Greece. *Journal of Archaeological Science* 14: 116-126.

Quinn, P. 2009. *Interpreting silent artefacts: petrographic approaches to archaeological ceramics*. Oxford: Archaeopress.

Quinn, P. 2013. *Ceramic Petrography. The Interpretation of archaeological Pottery and related Artefacts in Thin Section*. Oxford: Archaeopress.

Rice, P. 2015. *Pottery Analysis*. Chicago and London: The University of Chicago Press.

Roldán, C., Villaverde, V., Ródenas, I., Novelli, F. and Murcia, S. 2013. Preliminary analysis of Palaeolithic black pigments in plaquettes from the Parpalló cave (Gandía, Spain) carried out by means of non-destructive techniques. *Journal of Archaeological Science* 40: 744-754.

Schäuble, H. 1997. Häuser, Gruben und Fundverteilung. In J. Lüning (ed.), *Ein Siedlungsplatz der ältesten Bandkeramik in Bruchenbrücken, Stadt Friedberg/Hessen* (Universitätsforschungen zur prähistorischen Archäologie 39): 17-150. Bonn: Habelt.

Shahack-Gross, R. 2011. Herbivorous livestock dung: formation, taphonomy, methods for identification, and archaeological significance. *Journal of Archaeological Science* 38: 205-218.

Shanks, M. 2007. Symmetrical Archaeology. *World Archaeology* 39(4): 589-596.

Sommer, U. 1991. *Zur Entstehung archäologischer Fundvergesellschaftungen. Versuch einer archäologischen Taphonomie* (Studien zur Siedlungsarchäologie I. Universitätsforschunngen zur prähistorischen Archäologie 6)3. Bonn: Habelt.

Spataro, M. 2013. Continuity and change in pottery manufacture between early and middle Neolithic of Romania. *Archaeological and Anthropological Sciences* 6(2): 175-197.

Starnini, E., Szakmány, G. and Madella, M. 2007. Archaeometry of the First Pottery Production in the Carpathian Basin: Results from two Years of Research. In C. D'Amico (ed.), *Atti Del IV Congresso Nazionale Aiar. Pisa, 1-3 febbraio 2006*: 401-411. Bologna: Pátron Editore.

Stäuble, H. and Lüning, J. 1999. Phosphatanalysen in bandkeramischen Häusern. *Archäologisches Korrespondenzblatt* 29: 169-187.

Szakmány, Gy. and Starnini, E. 2007. Archaeometric research on the first pottery production in the Carpathian Basin: Manufacturing traditions of the Early Neolithic, Körös Culture Ceramics. *Archaeometriai Műhely* 2: 5-19.

Ting, C. and Humphris, J. 2017. The technology and craft organisation of Kushite technical ceramic production at Meroe and Hamadab, Sudan. *Journal of Archaeological Science Reports* 16: 34-43.

Vander Linden, M., Orton, D., Pandžić, I., Đurđević, M., Vujinović, B., Srdić, L., Balen, J., Forenbaher, S., Mihailović, D., Gazivoda, D., Hopkinson, T., Marriner, G., Rajkovača, T., French, Ch. and Miracle, P. 2013. EUROFARM: comparison and modeling of early farming and associated technologies in Europe. *Antiquity* 87 (336) https://www.antiquity.ac.uk/projgall/linden336/ (last accessed 19 November 2018).

Verges, J. M., Burguet-Coca, A., Allue, E., Exposito, I., Guardiola, M., Martín, P., Morales, J. I., Burjachs, F., Cabanes, D., Carrancho, A. and Vallverdú, J. 2016. The Mas del Pepet experimental programme for the study of prehistoric livestock practices: preliminary data from dung burning. *Quaternary International* 414: 304-315.

Veronesi, U. 2014. Archaeometric investigation of a ceramic artifact from Tăşnad (Romania) (manuscript).

Virág, C. 2008. The Neolithic in Nord-West of Romania and neighbouring area. Unpublished dissertation (abstract), Ministry of Education, Research and Youth, Lucian Blaga University, Sibiu, Nicolae Lupu Faculty of History. http://doctorate.ulbsibiu.ro/obj/documents/REZ-ENG-VIRAG.pdf

Virág, C. 2015. Some aspects about the Neolithic settlement from Tăşnad (Satu Mare County, Romania). In C. Virág (ed.), *Neolithic cultural phenomena in the upper Tisza basin: International Conference: July 10-12, 2014*: 97-126. Satu Mare: Editura Muzeului Satmarean (https://www.academia.edu/14503588).

Virág, C. 2016. Câteva considerații privind un pandantiv de lut de la Tăşnad-Sere. *Acta Mvsei Porolissensis* 38: 65-72.

Virág, C. and Stanciu, I. 2013. Neue Frühslawische Siedlungsfunde aus dem oberen Theissbecken (Tăşnad-Sere, Nordwestrumänien). *Acta Archaeologica Carpathica* 48: 171-194.

Virág, C., Marta, L., Gindele, R. and Kadas, Z. 2007. Tăşnad. *Cronica Cercetărilor Arheologice din România. Campania 2006*. Bucharest: CIMEC – Institute for Cultural Memory (http://cronica.cimec.ro/detaliu.asp?k=3783).

Vrydaghs, L., De Paepe, P., Rutten, K. and Haerinck, E. 2014. Regional exchanges in Southeastern Arabia during the Late Pre-Islamic Period: Phytolith analysis of ceramic thin sections from ed-Dur (UAE). In M. Madella, C. Lancelotti and M. Savard (eds), *Ancient plants and people: contemporary trends* *in archaeobotany*. Tucson: University of Arizona Press (Stable URL: http://www.jstor.org/stable/j.ctt1814hr4.7).

Wallis, N. J., Cordell, A. S., Deagan, K. A. and Sullivan, M. J. 2014. Inter-ethnic social interactions in 16th century La Florida: sourcing pottery using siliceous microfossils. *Journal of Archaeological Science* 43: 127-140.

Weiner, S. 2010. *Microarcheology: Beyond the visible archaeological record*. Cambridge: Cambridge University Press.

Whitbread, I. K. 1995. *Greek Transport Amphorae: A Petrological and Archaeological Study* (Fitch Laboratory Occasional Paper 4). Athens: British School at Athens.

Whitbread, I. K. 2001. Ceramic petrology, clay geochemistry and ceramic production – from technology to the mind of the potter. In D. Brothwell and A. M. Pollard (eds), *Handbook of Archaeological Sciences*: 449-459. Chichester: John Wiley.