

A Chalcolithic Pottery Kiln from the Cucuteni-Cetățuie Settlement (Iași County, Romania)

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Abstract. *As a result of the magnetic survey on an area of more than five hectares, located south-west of Cetățuie, we are currently aware of an extension of the Cucutenian habitation, consisting of numerous burned and unburned structures, pits and two defensive ditches in the form of circular arcs. The magnetic map allowed, beginning with the 2017 campaign, the placement of smaller (test trenches) or larger excavation units for the verification of various types of anomalies (burnt houses, defence ditch, pits). In the last (2022) campaign, in addition to investigating a defensive ditch and a dwelling, it was decided to excavate also an anomaly initially considered a pit. The surprise was the identification of a pottery kiln, belonging to phase B of the Cucuteni culture, located in the immediate vicinity of the last defensive ditch (in the north-western part of the settlement). Its excavation revealed a quasi-unique type of pottery firing installation, partially buried, updraught, with two chambers (a lower, combustion chamber, and an upper firing chamber). Its unique feature is the absence of the usual stoking chamber and stoking pit for fuel supply in front of the kiln. Instead, the kiln had an elongated stoke hole, placed laterally, which communicated with just one channel, to the south. Being a rather rare discovery, at least in the Cucuteni area west of the Prut River, the presence of this kiln brings evidence of the specialized practice of the pottery craft in the eponymous settlement and nuances the known typology of pottery firing installations in the prehistory of south-eastern Europe.*

Rezumat. Ca urmare a realizării măsurătorilor magnetometrice pe o suprafață de peste cinci hectare, situată la SV de Cetățuie, ne este cunoscută în prezent o prelungire a locuirii cucuteniene, constând în numeroase structuri arse și nearse, gropi și două șanțuri sub forma unor arce de cerc. Harta magnetometrică a permis, începând cu 2017, amplasarea unor sondaje și casete de mai mari dimensiuni pe diverse tipuri de anomalii (locuințe incendiate, șanț de apărare, gropi). În campania anului 2022, pe lângă cercetarea primului șanț situat în afara celor două cunoscute anterior și a unui fragment de locuință, s-a dorit și sondarea unei anomalii considerată inițial groapă. Surpriza a fost identificarea unui cuptor de ardere a ceramicii, aparținând fazei B a culturii Cucuteni, amplasat în imediata apropiere a ultimului șanț de apărare (în partea de NV a așezării). Cercetarea lui a relevat un tip cvasi-inedit de instalație de ardere a ceramicii, foarte puțin adâncit, cu două camere (una de combustie, inferioară, și una superioară, a vaselor) și tiraj vertical. Caracterul inedit constă în absența unei gropi a fochistului pentru

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alimentarea cu combustibil din fața cuptorului. În schimb, cuptorul avea o gură de foc alungită, practică laterală, care comunica cu un singur canal, spre sud. Fiind o descoperire mai degrabă rară, cel puțin în arealul cucutenian de la vest de Prut, prezența acestui cuptor aduce dovezi despre practicarea specializată a meșteșugului olăritului în așezarea eponimă și nuanțează tipologia cunoscută a instalațiilor de ardere a ceramicii din preistoria Europei de sud-est.

Keywords: *Cucuteni-Trypillia culture, Chalcolithic pottery kiln, pyrotechnology, spread of technological innovation*

Introduction

The study of the pyrotechnology of the Cucuteni-Trypillia culture (especially regarding the pottery firing) has experienced, in recent years, a considerable boost, thanks both to the new discoveries of firing installations and their thorough documentation, as well as to advanced archaeometry techniques. The presence of pottery firing kilns within a settlement indicates, first of all, a local production; then, it provides clues to the intensity of production and the craft specialization. Until recently, pottery kilns were a rather discreet presence in the Cucuteni-Trypillia settlements, most of the time being accidental discoveries during archaeological excavations⁴. In recent years, however, the intensification of geophysical prospecting in larger or smaller settlements throughout the Cucuteni-Trypillia area has led to the identification and investigation of several such installations⁵, all of which belong to the dual-chambered, updraught type, differentiated by dimensions and various structural details. The kiln investigated in 2022 in the eponymous settlement of the Cucuteni culture, which is the subject of this article, was also identified following the magnetic survey made in 2016-2017; through its constructive characteristics, it resembles, but also, to the same extent differs from the contemporary discoveries, nuancing the known typology of ceramic firing installations from the prehistory of south-eastern Europe.

The site Cucuteni-Cetățuie (Figure 1) practically needs no introduction, since its investigation, begun almost 150 years ago, is a perfect reflection of the whole archaeological research in Romania, both chronologically and methodologically. Started at the end of the 19th century (1884-1896, researches undertaken by N. Beldiceanu, G. Buțureanu, G. Diamandy *et alii*), continued in 1909-1910 by the German scholar Hubert Schmidt and then in the second half of the 20th century (1961-1966) by M. Petrescu-Dîmbovița and others, the excavations of Cetățuie meant over the years the awareness of, the naming of, and establishing the chronology of the Cucuteni culture. On the Cetățuie all three main phases of the Cucuteni culture (A, A-B and B) were attested, to which sporadic traces of habitation from Horodiștea-Erbiceni culture, and later periods (Early bronze age, La Tène period) are added⁶. Recent magnetic surveys, pedological investigations and archaeological excavations have revealed that the Cucuteni

⁴ Ellis 1984; Tsvek 2004; Tencariu 2015.

⁵ Korvin-Piotrovskiy *et alii* 2016; Țerna *et alii* 2019; Rud *et alii* 2019; Diachenko & Sobkowiak-Tabaka 2020.

⁶ Petrescu-Dîmbovița & Văleanu 2004.

settlement has expanded considerably, opening a new chapter in the long history of research of the eponymous site⁷.

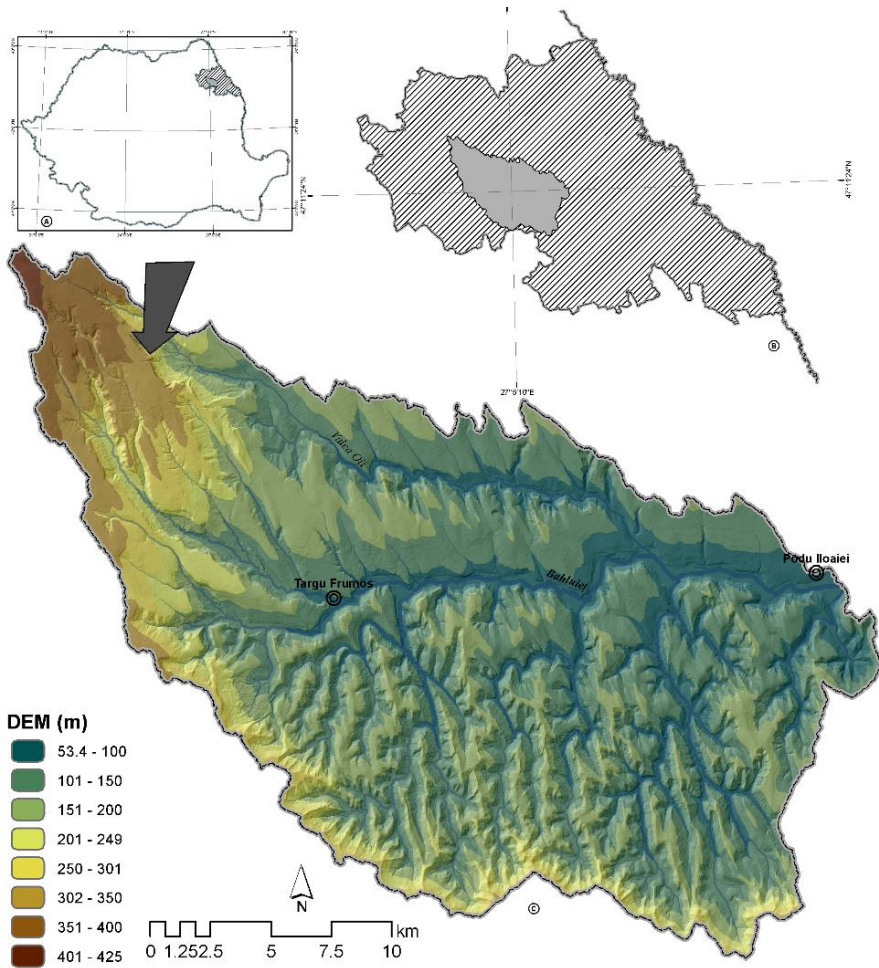


Figure 1. The location of the Cucuteni-Cetățuie in NE Romania (A), within Iași county (B), and Bahluieț river basin (C) (Map by A. Asăndulesei).

The kiln from Cucuteni-Cetățuie

The magnetic measurements from Cucuteni-Cetățuie were made to the west of the known settlement⁸, on an area of about 5 ha, using a Sensys gradiometer with five probes, connected to a Leica GNSS receiver. The resulting magnetic map revealed a significant extension of the

⁷ Tencariu *et alii* 2019; 2021a; 2022; Asăndulesei *et alii* 2022.

⁸ Petrescu-Dîmbovița & Văleanu 2004.

eponymous settlement to the west, on the vast Laiu plateau (Figure 2/a). Broadly speaking, the interpretation of magnetic anomalies allows to estimate several types of archaeological features in this newly discovered area, as follows: two rows of dwellings separated by a free space (probably an access way to the settlement); two defensive/delimitation ditches in the form of circular arcs (one, intermediate, located about 40 m from the two nearby ditches, previously known, and the other almost 80 m from the first, practically closing the vestiges of the Cucutenian habitation); a fairly large number of pits containing burnt materials (daub, ceramics). In the sector outside the outer ditch, there are two circular anomalies, with thermoremanent magnetism (intensity of 35-55 nT), which lend themselves to be interpreted as kilns⁹ (Figure 2/b).

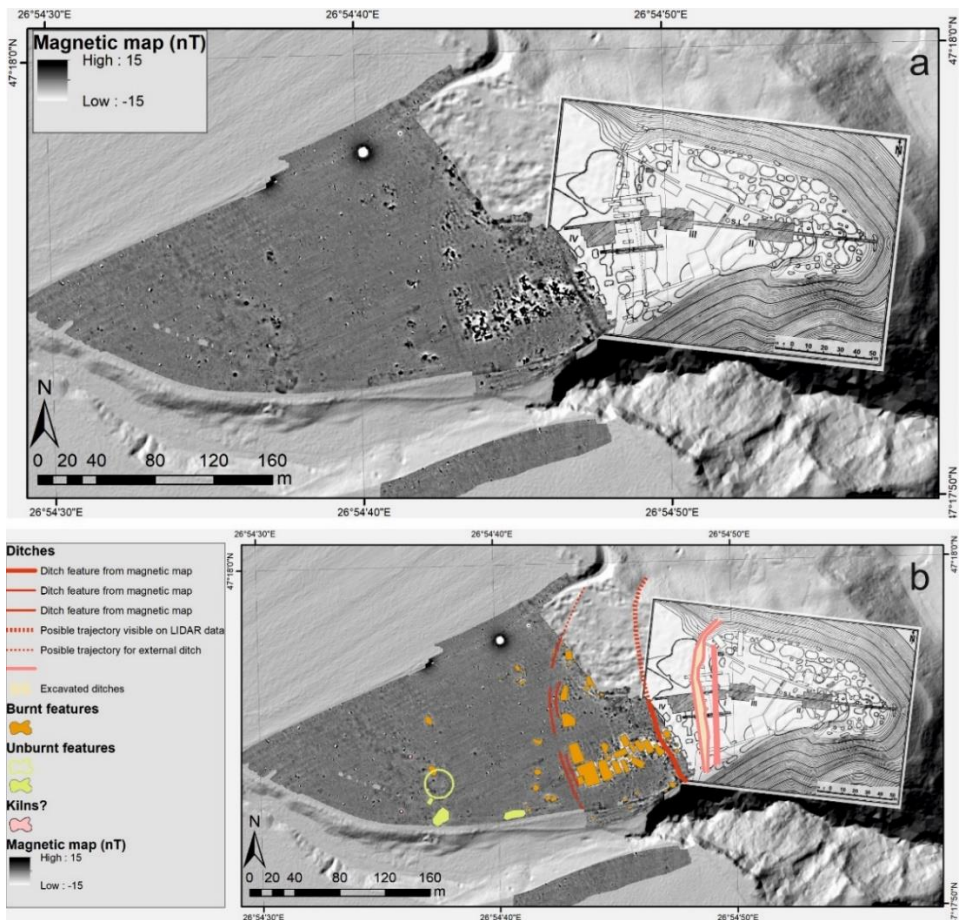


Figure 2. The magnetic map of the Cucuteni-Cetățuie settlement, together with older excavations (a); interpretation of the magnetic map (b) (Maps by A. Asăndulesei).

⁹ Asăndulesei *et alii* 2022.

Magnetic surveys in 2017 and 2020, as well as more consistent excavations in 2021¹⁰, have confirmed all initial interpretations of the magnetic anomalies. The archaeological excavations in 2022 aimed, in addition to investigating the first ditch and a dwelling in its vicinity, to test a circular anomaly located at the north-western extremity of the Cucutenian settlement, in the immediate vicinity of the outer ditch (Figure 3). The not very strong magnetic intensity (~30 nT) and the depth of the anomaly was not clear enough to indicate before excavation the nature of the feature (either a burnt structure or a pit containing burnt materials). It is worth mentioning that a similar but stronger anomaly (35-55 nT), investigated in 2020, revealed a pottery firing kiln belonging to the Sântana de Mureș culture¹¹.

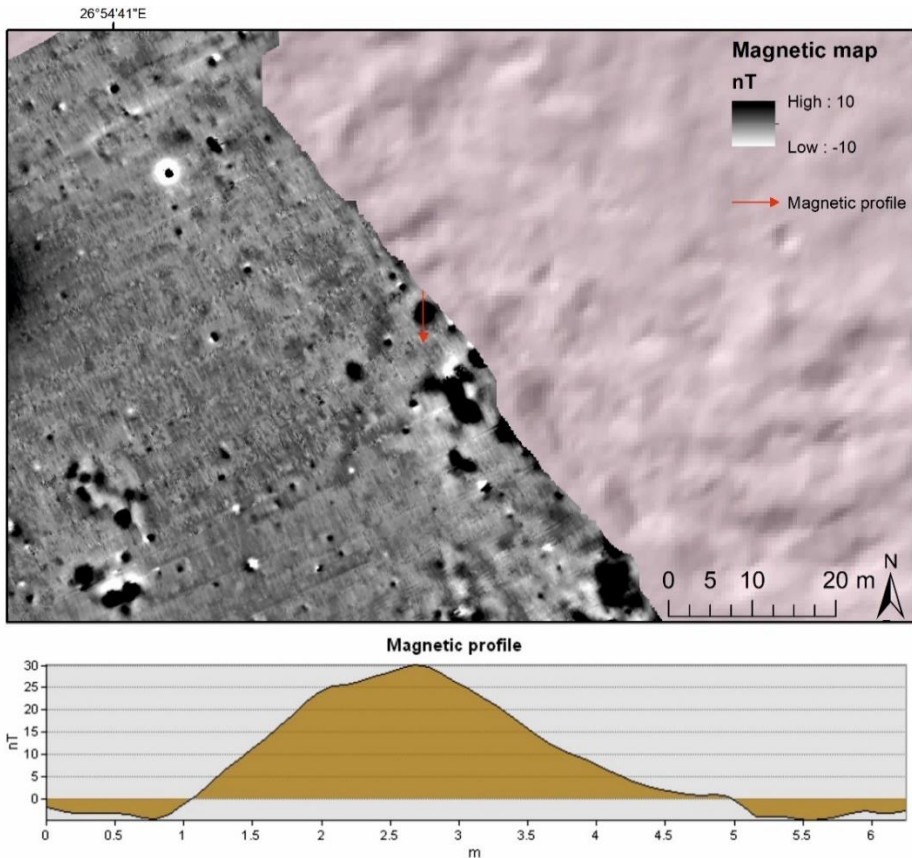


Figure 3. Detail of the magnetic map where the possible kilns can be observed; magnetic profile of the anomaly (by A. Asăndulesei).

¹⁰ Tencariu *et alii* 2019; 2021a; 2022.

¹¹ Tencariu *et alii* 2021a.

Our archaeological excavation (an area of 5 x 3 m) also brought to light a pottery kiln, this time unequivocally belonging to the Cucuteni culture, both on stratigraphic and typological basis, as well as based on the pottery discovered inside the complex. The feature has, broadly speaking, a structure similar to those known for the Cucuteni-Trypillia complex, being a bicameral kiln with vertical draught. It consists of a combustion (lower) chamber, a firing (upper) chamber and a stoke hole. Its approximate dimensions are 1.50 m on the N-S axis, and 1.40 m on the E-W axis, having a quasi-rectangular shape in plan, with slightly rounded corners (Figure 4).



Figure 4. General view of the pottery kiln (photo by R. A. Brunchi).

The upper room, built above the ancient ground, has not been preserved, being attested only by the presence of small and thin adobe fragments. Hypothetically, but logically, this chamber was built as a vault, made of clay on a skeleton of wooden twigs. Its state at the moment of the discovery suggests it collapsed or even that it was removed (completely or partially) at some point; the remaining fragments, burned incompletely, eroded over time under the action of moisture and acidity of the soil. The exception (Figure 5) is a fragment smoothed on one side (the outside of the vault), with clear prints of thick twigs (4 cm in diameter). The vault was built on a base, 10-12 cm wide, made also of clay. Four imprints of twigs, with the same diameter, were also observed on this base, only on the northern side of the kiln (Figure 6). So, given the thickness of the twigs, which are less flexible at this dimension, and their unidirectionality, we have reason to believe that the kiln's vault had, at least up to a certain height, relatively vertical walls, and not curved inwards, in order to optimize the volume of the enclosure.



Figure 5. Daub fragments with imprints of twigs, probably from the kiln's vault (photo by M.C. Ciobanu)

After removing the sediment containing small fragments of the vault, reaching the surface of the kiln (Figure 7) we noticed a thick coating of clay (mixed with chaff, strongly burned, to vitrification point in some parts) that constituted the base on which the vessels stood in the upper room. This coating, quite disturbed, seems to have been built together with the edge of the kiln (basis) on which the vault rested, partially covering the lower (combustion) chamber. The latter consisted of two parallel, quasi-oval fire channels, oriented east-west, shallow dug in the ancient soil (~15 cm). In addition to the two channels that were already relatively clear, being filled by the layer of daub, there was also an empty space between them, in the centre of the kiln.



Figure 6. The northern channel of the pottery kiln, with indication of the imprints of twigs on the northern edge (photo by V. D. Cioată).

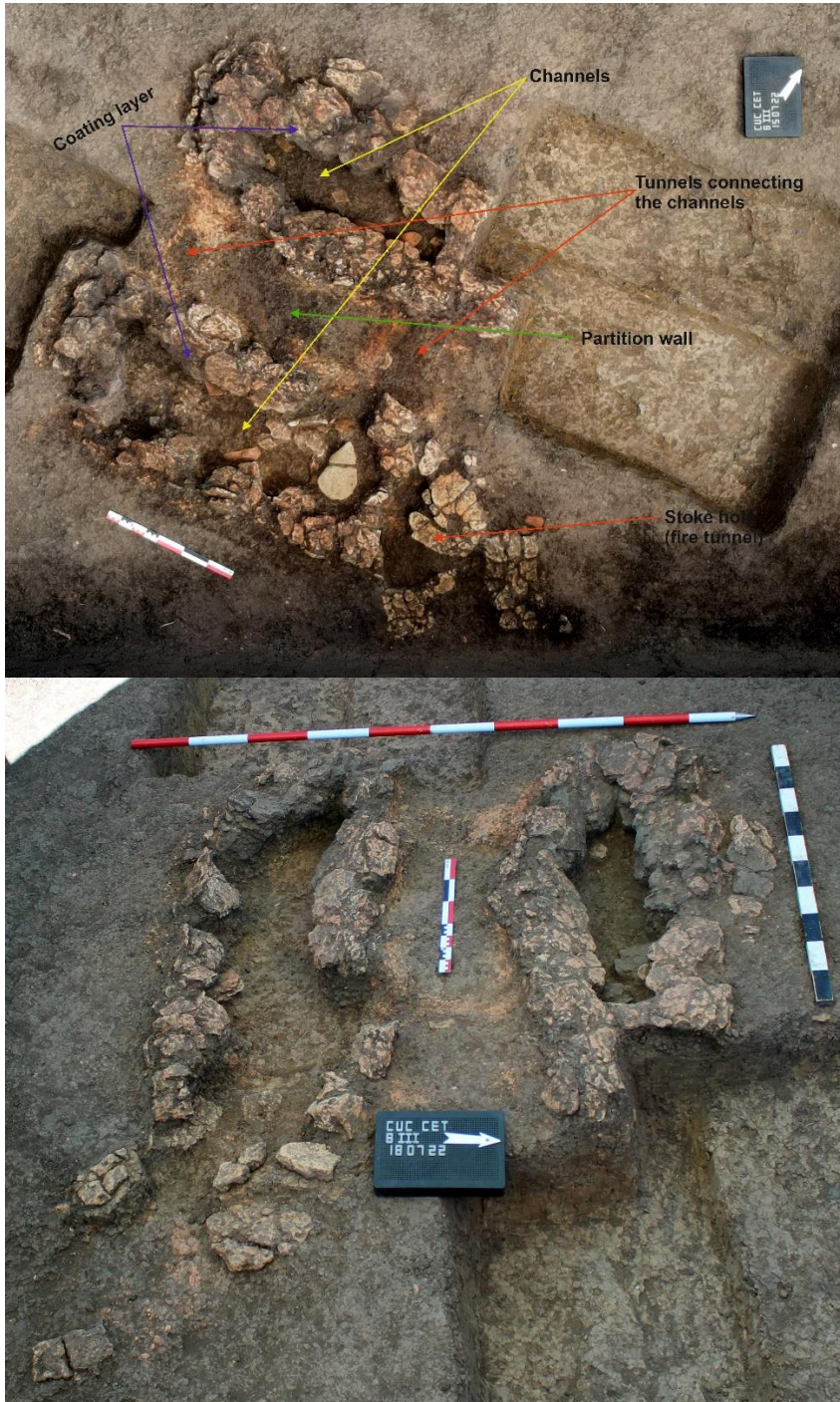


Figure 7. The pottery kiln: the base of the upper chamber, the two channels of the lower chamber and the stoke hole (photos by R.A. Brunchi - up, V.D. Cioată - down).

This has somewhat misled us, initially assuming that there are three channels, as in the case of the kilns from Ștefănești¹², Majdanetske or Taljanky¹³. The cleaning and partial shallow excavation of this area showed that, in fact, it was an earth wall spared between the channels (Figure 7), from which the layer of clay that formed the surface of the kiln was removed at the time of its decommissioning. As for the channels, these had an oval, elongated shape, with lengths of 77 cm (N channel) and 90 cm (S channel), maximum width of 50 cm and U-shaped profile, with a depth of ca. 25 cm (15 cm dug in the ground and another 5-10 cm built, by adding the clay coating). On the walls and bottom of the channels the coating of clay identified above was absent (or not preserved); instead, a thermal impression of the surrounding soil, caused by high temperatures, was observed for about 5 cm in depth (Figure 8/a-b).



Figure 8. Construction details of the pottery kiln: section through the northern channel (a); section through the southern channel (b); section through the partition wall (c) (photos by V. D. Cioată).

¹² Țerna A. *et alii* 2021.

¹³ Korvin-Piotrovskiy *et alii* 2016.

A technical element not very common to the contemporary Cucutenian kilns (the only known case being the one from Glăvăneștii Vechi - Cucuteni B2¹⁴) is constituted by the two connecting tunnels passing through at the base of the partition wall between the two channels, intended to ensure the flow of the hot air. The tunnel from the east has a width and height of about 15 cm, and a strong thermal impression of the surrounding soil is also observed (about 7 cm in all directions); the tunnel from the west is smaller in size (about 10 cm wide x 8 cm high), showing the same thermal impression around it (Figure 8/c).

The presence of these tunnels is related to another unique feature of the kiln, namely the stoke hole. Contrary to all expectations, we have not identified, as in the case of all known kilns of this period, a stoke hole located in front of the furnace, with access to both channels, nor a pit to serve it. Of course, the kiln had a fire box, but it was atypical, built in the SE corner of the kiln and feeding only one channel – the southern one. It was elongated in the shape of a tunnel with a length of about 60 cm and a width of about 50 cm, in the extension of the channel, partially preserved in the form of collapsed small plates of clay of about 3 cm thick, with large amounts of vegetal admixtures (Figure 9).



Figure 9. Construction detail of the kiln: the southern channel and the stoke hole, prolonged as a tunnel (photo by R.A. Brunchi).

¹⁴ Comșa 1976; Tencariu 2015.

On the bottom of both channels, as well as on the bottom of the connecting tunnel from the east, several ceramic fragments, few unburned bones and a piece of local Sarmatian sandstone (also unburned) were discovered. The pottery, fragmented and without any painting, has typical characteristics of the Cucuteni B phase (a fragment of a pyriform vessel and several bowl fragments – Figure 10). The presence of these archaeological materials reinforces the idea of an intervention immediately after the decommissioning of the kiln.



Figure 10. Pottery fragments from the kiln's channels and from the tunnels between them (photos and drawings by M.C. Ciobanu and F.A. Tencariu).

Based on the characteristics captured in the excavation, we can propose, with a margin of uncertainty, a graphic reconstruction of the kiln from Cucuteni – *Cetățuie* (Figure 11), as well as a possible scenario regarding its manner of use. Most likely, the fire was built and maintained inside the stoke hole (fire tunnel), the circulation of hot air throughout the kiln being ensured through the two channels, from the southern one, through the connecting tunnels, to the northern one and simultaneously upwards, to the firing chamber, through the openings spared in the clay coating that covered the surface of the upper chamber. This type of draught apparently caused higher temperatures to the north (the "back" of the oven), in this area the clay being highly burnt, partially vitrified.



Figure 11. Graphic reconstruction proposal of the pottery kiln from Cucuteni-Cetățuie and its manner of use (drawings by B.Ș. Novac).

Discussion and conclusions

This kiln is the first attested for the *Cetățuie* site and one of the few of its kind investigated in Romania. In the general context of the pottery kilns discovered in the Cucuteni-Trypillia area, the installation investigated in the eponymous site falls within the "norms" of its era, as general principle of operation, namely the vertical draught and a separation of the two chambers. However, regarding the constructive details and the technical solutions chosen for the uniform circulation and distribution of flue gases, we have not identified exact analogies.

Based on these constituent elements, we observe a fairly large variety of variants of the bicameral kilns specific to the Cucuteni-Trypillia complex. If the basic principle is the same for all (two separate, overlapping chambers with side fuel supply and circulation of flue gases from the bottom up), there are however notable differences in the number of channels of the lower chamber, the way of separating the two chambers, the solutions for ensuring the efficiency of the circulation of warm air, and the location of the stoke hole. A relatively recent typology¹⁵, based on all the firing installations attested in the Neolithic and Chalcolithic from the territory of today's Romania and neighbouring areas, concludes that the bicameral, updraft kiln (type E) represents the most evolved form, without making a distinction between subtypes. In a more recent work¹⁶, an internal typology of the bicameral kilns from the Cucuteni-Trypillia area is made, based on the arrangement of the base of the upper chamber (elements of separation between the two chambers and other constructive details) that determine, in the authors' opinion, the technique of managing the circulation of flue gases inside the kiln. Thus, three types of furnaces are distinguished: A – the separation of the chambers consists in ovoid or discoidal clay plates, mobile, under which the fuel burned (in two or more channels), and which also constituted supports for the batch of pottery; B – the same type of separation of chambers, with plates, to which air holes are added, made on the kiln surface near the channels and communicating with them, intended to improve the draught (a more uniform and strong circulation of flue gases); C – the lower (combustion) chamber is covered by a clay grate with perforations, which allows the circulation of hot air and is also a stable support for the pottery batch. If we refer to this typology, then we can fit the kiln from *Cetățuie* within the A type, with some caution. In this kiln, no fragments of movable plates were discovered, the separation between the chambers being achieved, probably, by extending above the channels the coating of clay starting from the base of the kiln. Also, unlike all other known installations, where the stoke hole is located in front, feeding all the channels, here it is located laterally, prolonged as a tunnel, feeding only one channel; the circulation of flue gases throughout the kiln is provided by the openings at the base of the spared wall between the channels.

The novel technical details of the discovery are also very attractive from the perspective of experimental archaeology; given our team's background with experimental installations

¹⁵ Tencariu 2015.

¹⁶ Țerna *et alii* 2019.

inspired by Cucutenian bicameral kilns¹⁷, we are already planning the construction and use of a model with all the features documented in our recent research.

The kiln discovered at Cucuteni-Cetățuie is yet another proof of the circulation of ideas and of a uniform spread of technological innovations towards the end of the Cucuteni-Trypillia evolution, manifested, in this case, by the presence of bicameral kilns throughout the impressive area of the Chalcolithic civilisation. However, there are notable variations between the installations discovered in various settlements, and we are not yet fully clarified whether they are links of an evolutionary chain, visible in the effectiveness of kilns, or simply local innovations. Taking into account the chronology of the discoveries, the grate with perforations seems to be a later innovation, replacing mobile clay plates as a means of separating the two chambers and ensuring uniform and efficient circulation of flue gases. The future discoveries of kilns undoubtedly to appear soon (in both areas of the Cucuteni-Trypillia complex), accompanied by absolute dating, will probably clarify this aspect too. We are convinced, however, that the emergence, development and spread of technological innovations related to the pottery making craft (in this case the two-chambered kilns, but also others), which take place towards the end of the Cucuteni A-B phase and the beginning of the Cucuteni B phase (Trypillia B2C1 and C1 respectively) are in close connection with the accentuation of demographic growth and mobility, with the increasing social and economic stratification, and with the development of human settlements towards the circular mega-sites specific for the east of the Prut river.

Acknowledgements

This work was supported by a grant from the Romanian Ministry of Education and Research, CNCS-UEFISCDI, project number PN-III-P1-1.1-TE-2019-2232, within PNCDI III, TE 14/2020.

The authors wish to thank all of our colleagues and students involved in the excavation, documentation and subsequent processing of the data related to the pottery kiln: Radu Alexandru Brunchi, Viorel-Daniel Cioată, Ioana-Cosmina Hriniciuc, Serina-Daniela Bobe, Ana-Elena Harhăță, Adina Amăriuței, Analisa Ariton, Alina Patriche, Eliza-Ioana Crețu, to name a few. We also thank 'Merlin's Vitamin Aqua' representatives for "energizing" the excavation team.

Bibliography

ASĂNDULESEI A., TENCARIU F. A., MIREA D. A., PÎRNĂU R. G., BALAU R. Ș., 2022. Back to the roots. Ablest prospection techniques for rediscovering the Chalcolithic settlement of Cucuteni-Cetățuie, Romania: short retrospective, novel recent data, prospects for the future. In:

¹⁷ Tencariu *et alii* 2018; Tencariu *et alii* 2021b.

C. Cuenca-Garcia, A. Asăndulesei, K. Lowe (Eds.), *World archaeo-geophysics: State of the art & case studies*, One World Archaeology Series, Springer (in press).

COMȘA E., 1976. Caracteristicile și însemnătatea cuptoarelor de ars oale din aria culturii Cucuteni-Ariuşd. *SCIVA*, 21(1), 23-34.

DIACHENKO A. & SOBKOWIAK-TABAKA I., 2020. Pottery kilns from the Tripolye settlement of Kamenets-Podolskiy, Tatarsky, the 2019 excavation campaign: Regarding the issue of the evolution of Tripolye pottery kilns. *Sprawozdania Archeologiczne*, 72, 147-171. DOI: 10.23858/SA/72.2020.1.007.

ELLIS L., 1984. *The Cucuteni Tripolye Culture: A Study in Technology and The Origins of Complex Society*, BAR Publishing, Oxford.

KORVIN-PIOTROVSKIY A., HOFMANN R., RASSMANN K., VIDEIKO M., BRANDSTATTER L., 2016. Pottery kilns in Trypillian settlements. Tracing the division of labour and the social organization of Copper age communities. In J. Müller, K. Rassmann and M. Videiko (eds), *Trypillia Megasites and European Prehistory, 4100-3400 BCE*. London and New York: Routledge, 221-252.

PETRESCU-DÎMBOVIȚA M., VĂLEANU M. C., 2004. *Cucuteni-Cetățuie. Monografie arheologică*, BMA XIV, Editura „Constantin Matasă”, Piatra Neamț.

RUD V., ZAITSEVA O., HOFMANN R., RAUBA-BUKOWSKA A., KOSAKIVSKYI V., 2019. Unique pottery kiln construction? The interpretation of massive clay objects from the Trostianchuk site of the Trypillia culture. *Sprawozdania Archeologiczne* 71, 11-39. DOI: 10.23858/Sa71.2019.001.

TENCARIU F.-A., 2015. *Instalații de ardere a ceramicii în civilizațiile pre- și protoistorice de pe teritoriul României*, Editura Universității “Alexandru Ioan Cuza”, Iași.

TENCARIU F.A., ȚERNA S., VORNICU D. M., MĂȚĂU F., VORNICU-ȚERNA A., 2018. Experimental (Re)Construction and Use of a Late Cucuteni-Trypillia Kiln. *Arheologia Moldovei*, XLI, 241-256.

TENCARIU F.-A., ASĂNDULESEI A., COTIUGĂ V., BALAU R., VORNICU D.-M., 2019. Cucuteni, jud. Iași. Punct: Dealul Laiu. *Cronica cercetărilor arheologice din România - campania 2018*, 396-397.

TENCARIU F.A., ASĂNDULESEI A., COTIUGĂ V., BODI G., BRAȘOVEANU C., HONCU Ș., BRUNCHI R., LAZANU C., BALAU R., 2021a. Cucuteni, jud. Iași. Punct: Dealul Laiu. In: *Cronica cercetărilor arheologice din România - campania 2020*, București, 551-555.

TENCARIU F.A., BRUNCHI R., ȚERNA S., DROB A., CIOBANU M.-C., VORNICU-ȚERNA A., BRAȘOVEANU C., ADUMITROAIEI D., 2021b. Understanding technological innovations through experiment. Construction and testing of Chalcolithic pottery kilns. *Studia Antiqua et Archaeologica* 27(2), 387-401.

TENCARIU F.-A., ASĂNDULESEI A., COTIUGĂ V., BODI G., BALAUR R., BRAȘOVEANU C., DROB A., BRUNCHI R., CIOBANU M.-C., 2022. Cucuteni, com. Cucuteni, jud. Iași. Punct: platoul Laiu/Cetățuie. *Cronica Cercetărilor Arheologice din România - campania 2021*, București, 789-792.

TSVEK O.V., 2004. Goncharne vyrobnytstvo plemen trypilskoj kultury. In: M. Yu Videiko (ed.), *Entsyklopediya trypilskoj tsyvilizatsii*. Tom 1. Kyiv: Ukrpoligrafmedia, 273-299.

ȚERNA, S., RASSMANN, K., ȚERNA, A. MÜLLER, J., 2019. The evolution of dual-chambered updraught kilns on the Cucuteni-Tripolye mega-sites in the 4th millennium BC: a view from Stolniceni. *Godišnjak* 48, 41-58. DOI: 10.5644/Godisnjak.CBI.ANUBiH-48.116.

ȚERNA A., RASSMANN K., ȚERNA S., 2021. Ștefănești, com. Ștefănești, jud. Botoșani. Punct: Hulboca I. *Cronica Cercetărilor Arheologice din România - campania 2020*, București, 582-584.



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