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The evolution of dual-chambered updraught kilns on the Cucuteni-Tripolye mega-sites in the 4th millennium BC: a view from Stolniceni[1]

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Abstract: Four complex dual-chambered pottery firing kilns have been recently systematically excavated at the Cucuteni-Tripolye mega-site of Stolniceni in Northern Moldova. The data obtained from these investigations are corroborated with older and newer evidences from other sites and allow us to address wide problems such as technological and social context for specialized pottery firing on large Cucuteni-Tripolye settlements from the 4th millennium BC.

Key words: Cucuteni-Tripolye culture; mega-sites; pottery production; pottery firing kilns; geophysics; labour division; technological innovation

Introduction

In the last decade, large-scale geophysical surveys performed with high-resolution equipment led to the discovery, and therefore opened the possibility, for targeted archaeological investigation of numerous pottery firing kilns on the so-called "mega-sites" of the Chalcolithic Cucuteni-Tripolye culture.[2] These findings resulted in a vast discussion in the archaeological literature regarding the use of dual-chambered updraught kilns for the firing of high-quality painted pottery which is characteristic for Cucuteni-Tripolye site assemblages.[3]

The multidisciplinary investigations carried out, since 2015, in the large Cucuteni-Tripolye settlement of Stolniceni in Northern Moldova, in the Prut river basin,[4] provided new data on this particular type of installation. The fieldwork included both non-intrusive surveys (geophysics and airborne photography) and excavations.[5] One of the main research objectives of the project has been the multifold investigation of pottery firing installations, four such kilns being excavated between 2016 and 2018. The data from Stolniceni, combined with both recently excavated kilns in Ukraine and information regarding older findings from Romania, Moldova and Ukraine, allows us now to broadly address the question of kiln typology and chronological dynamics on Cucuteni-Tripolye settlements from the 4th millennium BC.

[1] We are honored to dedicate this article to our colleague and friend Blagoje Govedarica – a scientist who contributed substantially to the Copper Age research in the North-Western Black Sea region.

[2] Rassmann et al. 2014; Müller / Rassmann / Videiko 2016.

[3] See Korvin-Piotrovskiy et al. 2016; Черна / Рассманн / Рудь 2017; Видейко 2019 with further bibliography; cf. Tencariu 2015.

[4] The research at Stolniceni is carried out within a cooperation between "High Anthropological School" University (Chișinău), RGK DAI (Frankfurt am Main) and Kiel University.

[5] Țerna et al. 2016; Черна / Рассманн / Рудь 2017; Scholz / Rassmann / Țerna 2018; Țerna et al. 2019.

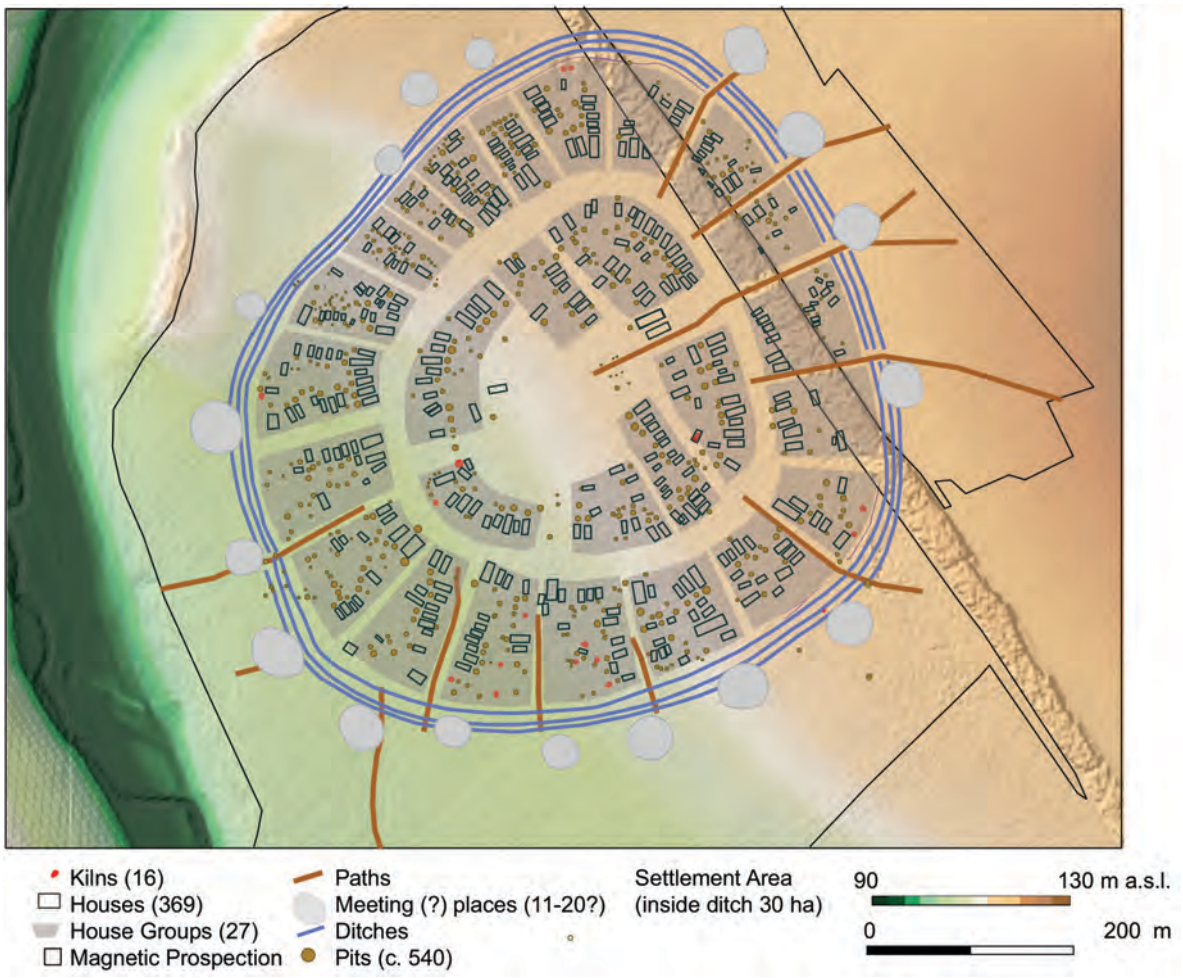

Fig. 1. *Stolniceni. The interpretation of the magnetic map. DEM based on UAV images and their SFM processing* (K. Rassmann / S.Țerna)

Pottery kilns from Stolniceni – spatial distribution and geophysical data

The magnetic surveys in Stolniceni in 2015 and 2017 revealed detailed data regarding the layout of the Cucuteni-Tripolye settlement. In 2015, the northeastern part of the settlement (23 ha) was surveyed with a 5-channel magnetometer. The system was mounted on a push-cart fibreglass array. The gradiometers were set at a 0.5 m interval.[6] The magnetometers used were FGM-650B tension band fluxgate vertical gradiometers with 650 mm sensor separation, a ±3000 nT measurement range and 0.1 nT sensitivity. Precise georeferencing with an accuracy of *ca.* +/- 0.05 m was similarly achieved through the utilisation of a Leica RTK-DGPS (base/rover). In November 2017 the survey was completed with a 16-channel magnetometer system mounted on a vehicle-towed, non-magnetic array of fibreglass. This time, the gradiometers were set at 0.25 m intervals. The array was therefore 4 m wide. The 16 magnetometers used were FGM-650B, like those on the 5-channel magnetometer. A Trimble RTK-DGPS systems consisting of a base station and a rover was used for precision georeferencing of the magnetometer data.

The prospected area covered 70 ha, including most of the settlement territory (30 ha) and a large sector outside it. The magnetic data enabled us to gain an insight into the general structures of the settlement (fig. 1). Around 370 burnt houses are visible, an enclosure system composed of three ditches and a palisade, around 540 settlement pits and 19 pottery kilns. With a lower contrast, some linear anomalies indicate paths,

[6] Țerna et al. 2016.

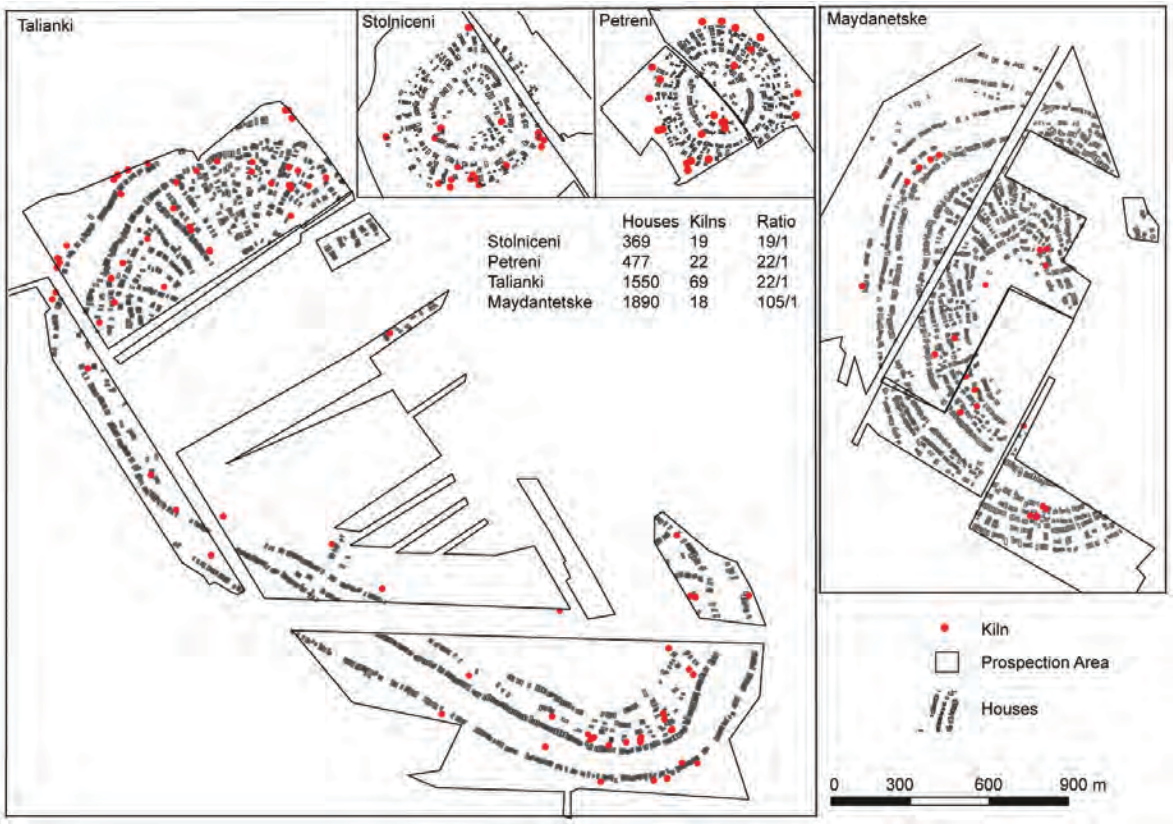

Fig. 2. *Schematic map of the location of kilns in the settlements of Maidanetske and Talianki (both Talne district, Ukraine), Petreni* (Drochia district, Moldova) *and Stolniceni* (Edineț district, Moldova). *The identification of the pottery kilns is based on the geomagnetic data. The correct identification as kilns of five anomalies at Maidanetske and Talianki was established by excavation in 2013 and 2014, while another four kilns were excavated at Stolniceni* (excavations 2016–2018) (illustration K. Rassmann)

clearly visible in the southern and northern periphery of the settlement. The course of the paths is connected with gaps in the ditches and with the arrangement of the house rows. Outside the enclosed area, multiple circular anomalies with a diameter of 25–30 m are regularly distributed all around the settlement, corresponding to house groups. Those are areas where large amounts of fragmented domestic material was discarded probably as a result of collective activities by the inhabitants associated with the house groups.[7]

Thanks to the settlement research of the Romano-Germanic Commission in Moldova and Ukraine,[8] the data regarding the kilns identification and distribution within the settlement of Stolniceni can be considered in a wider, comparative perspective (fig. 2).

The Ukrainian mega sites are remarkable through their extraordinary size (Talianki with nearly 340 ha and Maidanetske with 270 ha), whereas the Moldavian settlements of Petreni and Stolniceni are slightly over 30 ha. Nonetheless, the ratio between houses and kilns at Petreni and Stolniceni, i.e. 1:22 and 1:19 respectively, is around the same value as that recorded for the giant settlement of Talianki. However, at Maidanetske, the situation is completely different, as the ratio is 1:105. Most probably, this is due to the location of a high number of kilns on the as yet unprospected part of the site.

A closer look at the spatial distribution of the kilns reveals further differences between the settlements mentioned above. At Petreni and Talianki the kilns are regularly distributed, whereas the kilns in Stolniceni and Maidanetske are clustered, with large parts of the settlements displaying no kilns. An explanation could be that in Talianki and Petreni more social groups (house

[7] Țerna et al. 2019, 246-248.
[8] Rassmann et al. 2014; Rassmann et al. 2016a; Rassmann et al. 2016b.

groups?) were engaged in ceramic production, while in Stolniceni and Maidanetske the labour division is more advanced and limited to specific social units. Before drawing wider conclusions let us evaluate the archaeological data in detail.

Pottery kilns from Stolniceni – archaeological data

At Stolniceni, four pottery kilns have been excavated in the 2016, 2017 and 2018 campaigns, both in the northern and southern parts of the settlement (fig. 3).

The first two kilns (trenches 3/2016 and 5/2017) located in the northern area of the settlement have been briefly described in previous publications[9] and were part of what has been interpreted as a pottery firing complex which also included a house, four pits and various features on the prehistoric step-surface, such as an agglomeration of unfired pottery and polished stone tools.[10] Both kilns had a similar construction and belonged to the dual-chambered updraught type (fig. 4); the combustion chambers had been dug into the prehistoric step-surface and consisted of two parallel, oval channels on which clay slabs would have been subsequently placed, serving as stands for the pottery load. In both cases, the upper part of the kiln's construction (firing chamber or dome?) was not preserved, but its presence is indicated by the discovery of few scattered fragments of burnt clay, smoothed on the outer side and bearing imprints of twigs on the inner side. Two successful experimental reconstructions of pottery kilns of the type discovered at Stolniceni[11] proved the extraordinary firing capacity of such constructions and validated the interpretation of the kiln remains from archaeological contexts, especially the presumed use of clay slabs covering the channels as both stands for the pottery load and regulators for the firing process.[12] The radiocarbon determinations obtained for animal bones recovered from the kilns' fill allow us to date the two constructions to the first two centuries of the 4th millennium cal BC.

Two other kilns have been subsequently investigated in the southern part of the site (trenches 14/2018 and 15/2018) (fig.3). As they have not yet been published, we will give a more detailed description of the two pottery firing installations in the following.

Trench no. 14 was placed over two distinct anomalies, namely one of the kilns and, to the west of it, another one, which, based on the geomagnetic data had initially been interpreted as a pit. The step-surface level was reached at a depth of 55-60 cm and consisted of agglomerations of finds that formed two distinct areas – the western one with pottery and burnt clay corresponding to the anomaly next to the kiln, and the eastern one containing pottery, bones and daub corresponding to the upper part of the kiln. The kiln structure itself was revealed further below, at a depth of circa 5-20 cm from the step-surface level. It had a round shape with the opening in the south, a diameter of circa 210 cm and a total area of 3.9 m^2. From an architectural point of view, the kiln differed from other kilns excavated at Stolniceni by the fact that the two-channeled combustion chamber had an addition of six air holes located on its perimeter (fig. 5). The holes where connected to the main channels via funnel-like openings covered by arch-shaped partition walls built on a frame of parallel bent twigs (imprints from which have been preserved in the clay) (fig. 6). Two larger air holes with diameters of 25-28 cm were placed in the back of the combustion chamber, at the extremities of the channels, while the other four, with diameters of 12-17 cm were located laterally, two on each of the channel's outer side. The channels had a U-like profile and were about 38 cm high, 45 cm wide in the upper part and 27 cm wide, at the bottom. They were divided by a longitudinal partition wall which had a height of circa 40 cm and a width of 40-42 cm.

An interesting find was made at a distance of circa 2 m to the west from the kiln, in the area of the magnetic anomaly initially interpreted as a pit. Here, an agglomeration of pottery, animal bones and clay fragments had been cleaned on the step-surface level; further investigation of this feature revealed several concentrations of crumbly burnt clay scattered within an area of circa 4.5 m^2. The burnt clay fragments were circa 5 cm thick and smoothed on the outer side. On

[9] Черна / Рассманн / Рудь 2017; Țerna et al. 2019.
[10] See Țerna et al. 2019.
[11] Tencariu et al. 2018; Scholz 2019.
[12] See also Видейко и др. 2016.

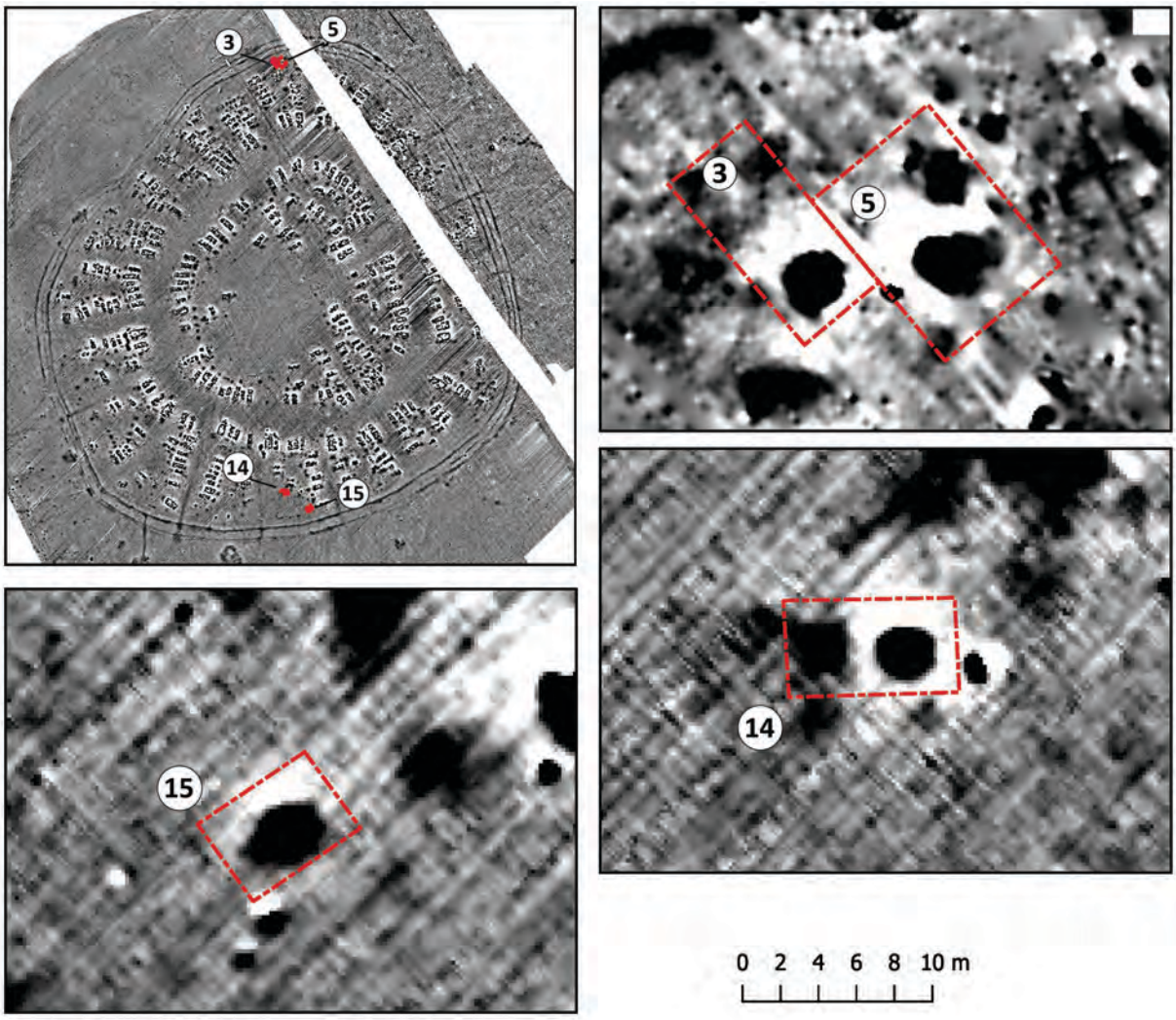

Fig. 3. *Location of excavation trenches 3/2016, 5/2017, 14/2018 and 15/2018 with the investigated pottery kilns on the geophysical plot of Stolniceni settlement* (geophysics – K. Rassmann)

Fig. 4. *The kilns from trenches 3/2016* (left, photo D. Topal) *and 5/2017* (right, photo S. Țerna)

Fig. 5. *The kiln from trench 14/2018 viewed from the north* (photo J. Liebscher)

the inner side they had imprints of twigs of 3 cm diameter (fig. 7 and 8). We interpret these clay fragments as remains of the dome of the kiln, which had been removed after the last (?) firing and discarded near the kiln. The area on which the dome remains were scattered corresponds roughly to the area of the kiln.

As regards the building process of this particular type of kiln, we were able to reconstruct the *chaîne opératoire* starting from the information provided by the multiple sectioning of the archaeological feature. Thus, the first operation consisted in digging the kiln's pit from the pre-

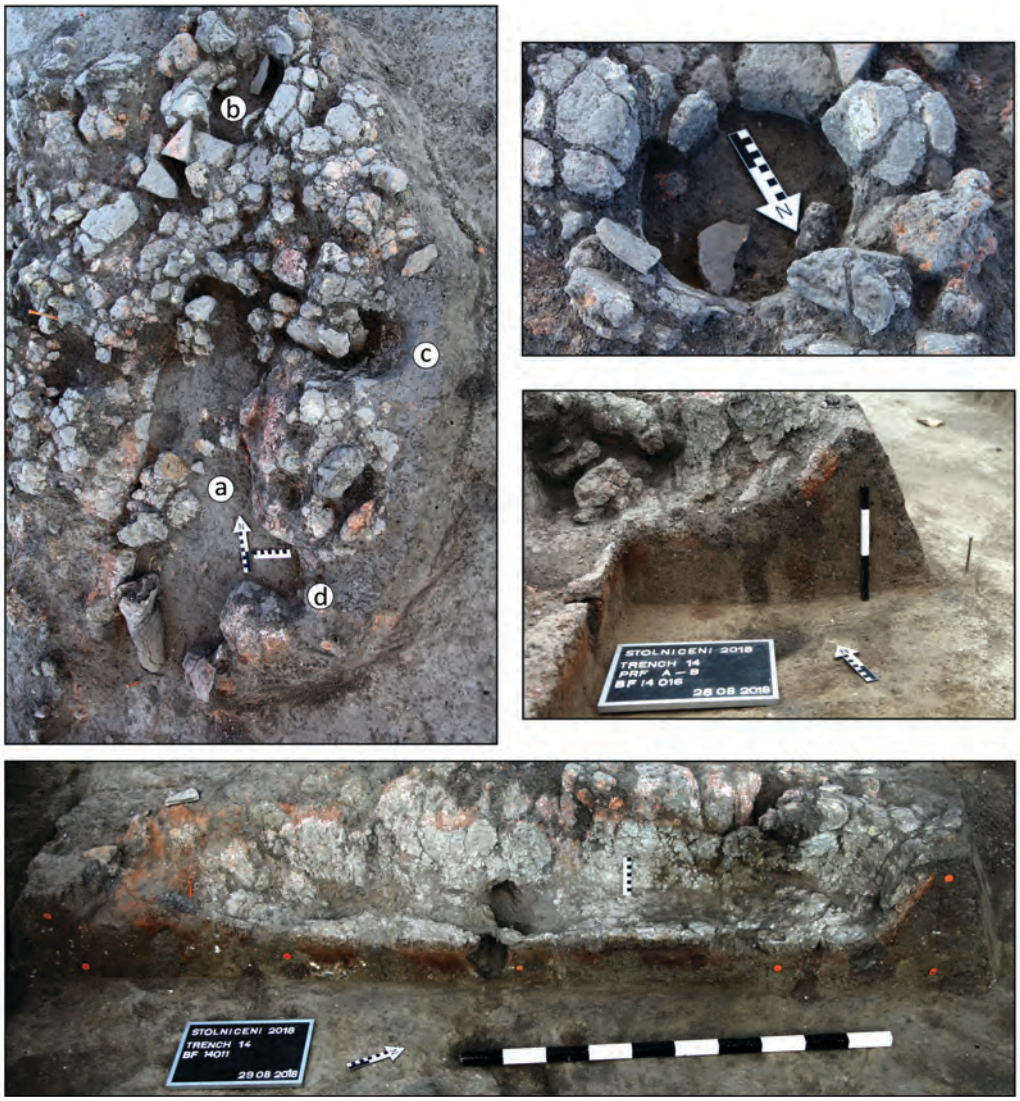

Fig. 6. *Construction details of the kiln from trench 14/2018. Top left: a – eastern channel; b – larger air hole at the extremity of the channel; c and d – lateral smaller air holes* (photo S. Țerna). *Top right – the larger air hole from the extremity of the eastern channel* (photo S. Țerna). *Middle right – section through one of the smaller lateral air holes* (photo A. Vornicu-Țerna). *Down – section through the eastern channel of the kiln and the larger air hole at its northern extremity* (photo J. Liebscher)

Fig. 7. *Remains of dome within the pottery and bone agglomeration located to the west of the kiln, in trench 14/2018* (photos S. Țerna)

Fig. 8. *Daub fragments interpreted as remains of kiln dome in trench 14/2018* (photos J. Liebscher)

historic step-surface, into the yellow soil. Then, the two main channels were excavated, leaving a partition wall in the middle; perpendicular to the external side of the channels, short narrow corridors were dug out. Subsequently, the construction was coated with a layer of fine-tempered clay with no vegetal admixture. Immediately after that, when the coating was still wet, small twigs were bent and inserted into the channel walls, at the northern extremity as well as into the walls of the four narrow corridors, in order to build arch-shaped partition walls which would partly separate the air holes from the main combustion channels. This twig frame was subsequently coated with the same clay as the base of the kiln. Afterwards, the frame for the dome was built of interwoven twigs, placed on top of the combustion chamber, coated with clay and left to dry before the first firing event (fig. 9).

Trench 15 was opened over a kiln anomaly, with the objective to remove *en bloc* such a construction and conserve it for museum display. In order to achieve this, the research process had to be adapted for this objective, thus some of the final methodological stages in the investigation, such as the sectioning of the feature, which could have yielded further details about the kiln's construction and duration of use, were not completed.

The kiln belongs to the same dual chamber up-draught type as those excavated in the previous years (fig. 10). It had an almost round shape, with the opening in the east, a diameter of 170 cm, and together with the clay *platform* at the entrance occupied an area of 3 m^2.

Similar to the case from trench 3, the building of the pottery firing installation investigated in trench 15 implied the digging of two connected pits, one for the construction of the dual-chamber kiln and the other serving as the potter's pit.

The kiln's pit was around 20 cm deep from the prehistoric step surface. From this level, the two channels were dug 38-44 cm into the yellow clayish soil, leaving a partition wall in the middle. The channels had a U-shaped profile, a width of 48 cm in the upper part and 27 cm at the bottom; the dividing wall was 39-54 cm wide. In front of the kiln's entrance, the firin clay-coated platform was partially preserved.

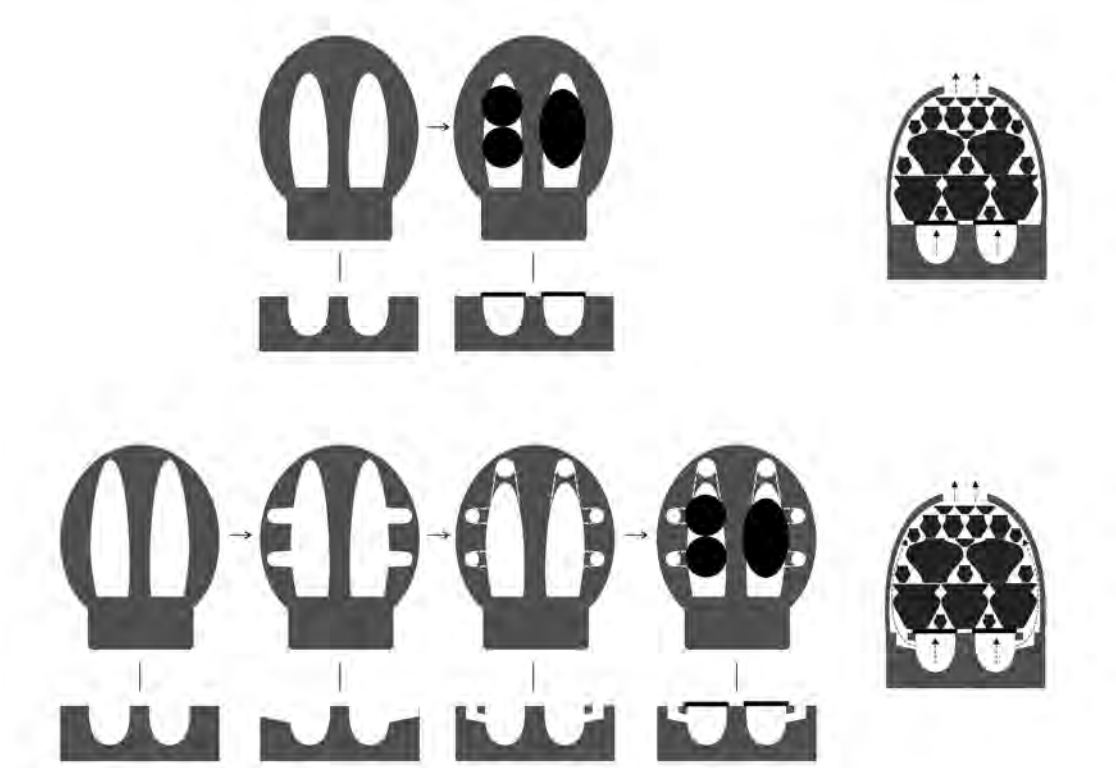

Fig. 9. *Schematic illustration of the construction stages of the two pottery kiln types from Stolniceni – the simple two-channelled (above) and the two-channelled with air holes (below). Each stage is illustrated twofold, with a conventional section from above and another one perpendicular to it, showing the profile through the channels and the partition wall. Black colour (in the views from above) marks the discoid and shield-like clay slabs* (illustration S. Țerna, A. Vornicu-Țerna)

Fig. 10. *View from the west over the pottery kiln in trench 15/2018 and the pit located in front of it* (photo A. Vornicu-Țerna)

Fig. 11. *Fragments of clay slabs from trench 3/2016* (photos S. Țerna)

The potter's pit, connected to the kiln through the firing platform, contained in the upper part – at the platform's level – vitrified shards, fragments of clay slabs, charcoal and several bones. Towards the east, the pit went deeper, forming a rectangular cavity of c. 60×70 cm, which probably served as a protective niche from which the potter would have controlled the firing process.

After it went out of use, the pit of the kiln was filled with fragments of burnt clay. Of these, 13 were identified as being parts of slabs; they were found concentrated right above the western wall of the kiln.

Material derived from activities related to the kiln use were found on the step surface, c. 80-90 cm to the west and north-west of the construction. These are large fragments of pottery, several animal bones and two concentrations of burnt clay. The latter comprised mainly fragments of uncertain origin, several pieces of slabs and one fragment with twigs imprints (22-25 mm diameter), probably a fragment from the dome.

Clay slabs, firing management and kiln relative chronology

A few years ago, the discovery and investigation of a pottery firing kiln at the Tripolye large site of Nebelivka in Ukraine allowed the researchers to presume that the so-called clay slabs played an important role in the technological process by, fragments of which had been found both in the kiln area and in the adjacent pit.[13] Thus, according to the authors mentioned above, the discoid flattened greenish clay objects may have been placed onto the channels of the kiln combustion chamber in order to support the load of unfired pottery which would have been placed on top of these slabs. This interpretation was later confirmed at Stolniceni, both archaeologically (by finding of a complete shield-like clay slab which had fallen into one of the channels of the kiln in trench 3/2016 – see above, fig. 3) and experimentally, during the reconstruction of a similar kiln in 2017.[14]

At Stolniceni, fragments of clay slabs (fig. 11) accompanied all of the four excavated pottery kilns. Thus, in trenches 3 and 14 they are concentrated generally within the remains of the abandoned kilns, while in the other two trenches (5 and 15) they are scattered both within the remains and on the surrounding area, sometimes at a distance of several meters (fig.12). What are the implications of these two patterns? We should emphasize once again that the features excavated at Stolniceni belong to certain groupings or agglomerations of kilns and – as we pointed out in other studies[15] – it is likely that the kilns within such an agglomeration were not all in use at the same time, but there was rather a successive use of kilns within one specialized pottery firing complex, probably based on knowledge transfer between generations. The absolute dating from trenches 3 and 5 seem to support this assumption since the "post kiln" event in trench 5 started later than the backfill of the kiln in trench 3.[16] If so, the technological waste including the slab fragments from trench 3 would come from the later use of the kiln in trench 5 and this could be an explanation for the various patterns of slab occurrence – when the kiln in trench 5 (and therefore the entire pottery production complex) went out of use, it had been abandoned without subsequent cleaning of the area and the slab fragments were just left scattered across the surface. In contrast, the older kiln (and the adjacent area) could have been cleaned before subsequent deposition of waste.

If we apply the same scenario to the kilns excavated in 2018, the two-channeled one from trench 15 would have functioned later than the one in trench 14, with two channels and air holes. Furthermore, this assumption seems to be supported by the intensity of finds on the step-surface: in trench 14 much more waste was found above the kiln than in trench 15. This waste probably comes from one of the three kilns located nearby, possibly including the one in trench 15.

Based on the distribution of clay slab fragments and other technological waste, we can therefore conclude that the kilns in trenches 3 and 14 do not belong to the latest kiln generations from the site. The kiln in trench 3 is among the earliest features in the settlement so far, while the exact chronological position of the one in trench 14 (with air holes) is not yet known; it is, however, quite likely that this kiln is earlier than the kiln investigated in trench 15. Future research and the results of absolute dating of kilns excavated in 2018 should provide clarification in this matter.

A further possible indicator of relative chronology of kilns is their size. If pottery firing is one of the earliest activities organized in the settlement, then the initial production volume should have been pretty high in order to cover the demand for ceramic ware during the first, construction phase of the settlement and its

[13] Видейко и др. 2016; Видейко 2019; cf. Korvin-Piotrovskiy et al. 2016.
[14] Tencariu et al. 2018.
[15] Черна / Рассманн / Рудь 2017; Ţerna et al. 2019.
[16] Ţerna et al. 2019, Fig. 50.

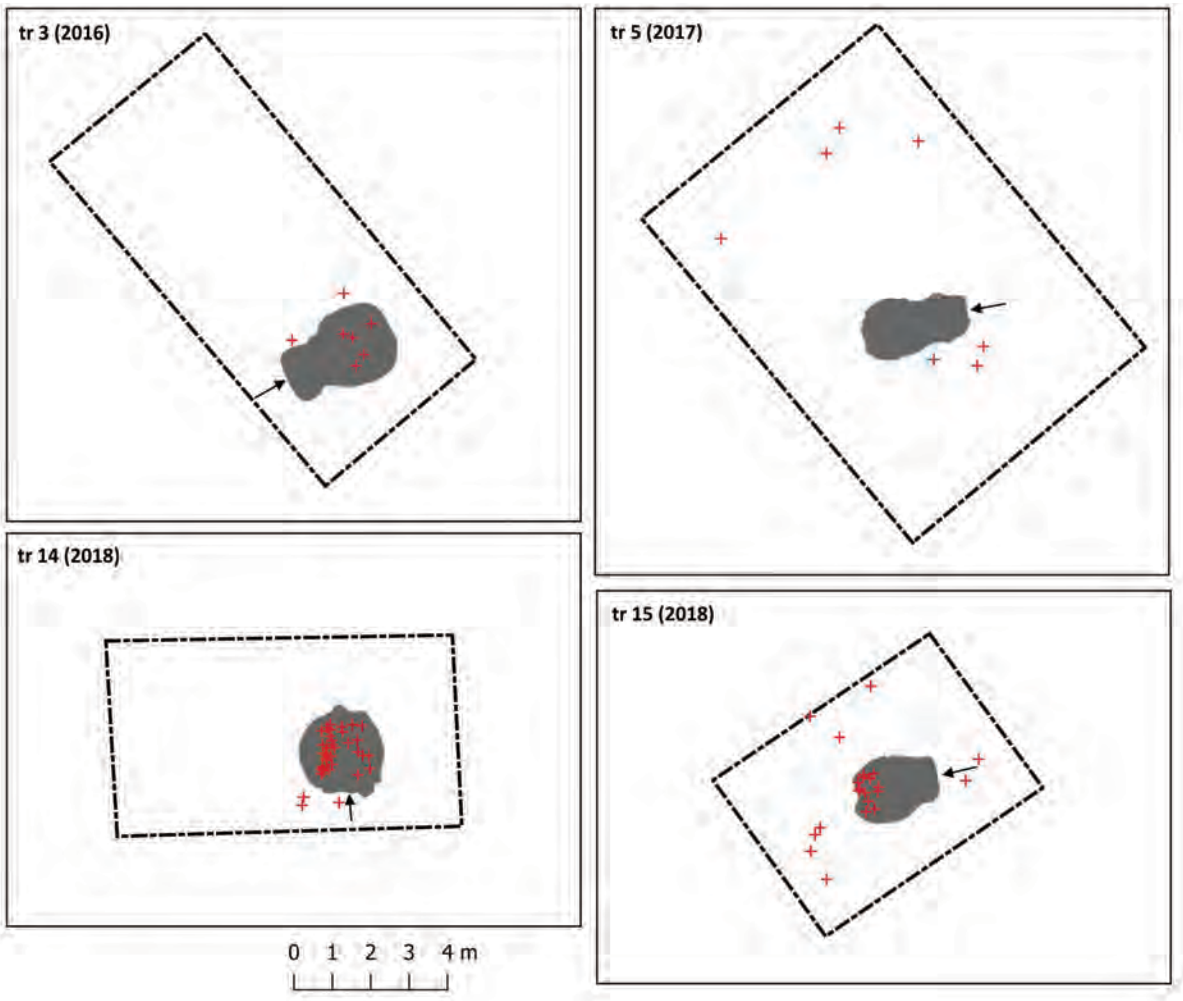

Fig. 12. *Distribution of fragments of clay slabs in the trenches with pottery kilns investigated at Stolniceni* (illustration S. Țerna). *Red crosses indicate locations of slab fragments discovery, grey contours mark the outlines of pottery kilns and black arrows point the location of access to the kilns.*

households. Subsequently, the pottery demand decreases as the potter shall basically just supply "renewal" ware to the existing households and provide ceramics for new households at the site. A decrease of the quantity of pottery to be fired should result in a decrease of kiln capacity which is reflected in its dimensions. Indeed, at Stolniceni, there is a clear size reduction of circa 23-29 % from the earliest to the latest kilns; in the first case (trenches 3 and 5) the kilns' relative chronology is supported by absolute dates while in the second (trenches 14 and 15), chronological relation of the kilns is deduced from distribution of waste, slab fragments and, as we can see, the size (table 1).

Table 1. *Area of kilns excavated at Stolniceni*

Kiln no.	Area (m^2)
3/2016	4.8
5/2017	3.4
14/2018	3.9
15/2018	3

Dual-chambered kiln typology in the 4th millennium BC

In the 4th millennium BC, the dual-chambered updraught pottery kiln with two- or three channeled combustion chamber became a part of the package of technical innovations in the Copper Age to the east of the Carpathians. To this mo-

Table 2. *Cucuteni-Tripolye kilns of the 4th millennium BC. Techniques of managing the hot air and gas inflow from combustion to firing chamber*

No.	Site	Relative chronology	Technique	Literature
1	Chirileni	Tripolye C2	grate	Бикбаев 2016
2	Costești IX	Tripolye C2	grate on cones	Маркевич 1981; Сырбу, Бикбаев 2017
3	Dobrovody	Tripolye C1	air holes	Корвін-Піотровський та ін. 2016
4	Glăvăneștii Vechi	Tripolye C1C2	grate on cones	Comșa 1976
5	Hancăuți I	Tripolye C2	grate on cones	Бикбаев 1990; Bicbaev 2009
6	Kamianets – Podilskyi	Tripolye B2C1	slabs	Дяченко та ін. 2019
7	Maidanetske	Tripolye C1	slabs	Відейко та ін. 2015; Korvin-Piotrovskiy et al 2016; Видейко 2019
8	Nebelivka	Tripolye B2	slabs	Видейко и др. 2015
9	Novomalin – Podobanka	Tripolye C2	?	Дяченко 2016
10	Ostrog – Zeman	Tripolye B2C1	?	Позіховський 2016
11	Stolniceni	Tripolye B2C1	slabs and air holes	-
12	Talianki	Tripolye C1	air holes	Круц и др. 2015; Korvin-Piotrovskiy et al 2016; Корвін-Піотровський та ін. 2016
13	Trinca – Izvorul lui Luca	Tripolye C2	grate on cones	Сырбу 2015
14	Valea Lupului	Tripolye C1C2	grate on cones	Dinu 1957
15	Zhvanec – Shovb	Tripolye C2	grate on cones	Мовша 1971

ment, there are 15 Cucuteni-Tripolye settlements from which such kilns have been published (Table 2); all of these sites belong to the Tripolye B2 – C2 interval, or the entire 4th millennium. The first dual-chambered kilns with channeled combustion chamber appeared probably earlier[17] and accompanied the formation and spread of large centripetal settlements (= Cucuteni A-B / Tripolye B1B2 stage or roughly the last quarter of the 5th millennium BC) as suggested by the available data from Vesely Kut.[18] Even though the Vesely Kut information is not complete, the growth of settlement sizes driven by the agglomeration of population in radial settlements presented new demands to the size of pottery production due to an increased number of inhabitants. We expect, therefore, the discovery of dual-chambered kilns on Cucuteni A-B / Tripolye B1B2 sites in the nearest future.

There are several differences among the dual-chambered pottery kilns from various settlements, such as size or number of channels. In our opinion, the main one is however the technique of managing the hot gas inflow between the two chambers: combustion and firing. Generally, this problem was solved by placing a deck on the lower compartment (combustion chamber) which had a twofold function: it directed the influx of hot air and gases upwards into the firing chamber and served as a support for the pottery load. We can now distinguish three types of kilns based on the construction of the combustion chamber and its cover (figure 13; cf. fig. 9):

A – the two- or multi-channeled combustion chamber is covered by discoid or shield-like slabs on which the unfired pottery was subsequently placed;

[17] Traditionally, the earliest Cucuteni-Tripolye dual-chambered pottery kiln is considered to be the one found at Luka-Vrublevetskaya, on a Pre-Cucuteni – Tripolye A settlement from the mid 5th millennium BC (cf. Бибиков 1953). In our opinion, the kiln from this site is more likely to be attributed to one of the two chronological horizons which overlapped the Copper Age layer, namely the occupations from first centuries AD and the Middle Ages.

[18] Unfortunately, this pottery (?) kiln located in a house has never been extensively published (Цвек 1994, 77); we should however emphasize here that the placement and subsequent use of a dual-chambered firing construction in a dwelling would not be safe. All of the other pottery kilns of such types have been found outside houses, on large inter-dwelling spaces or even on the periphery of the settlements. Therefore, the real function of the feature from Vesely Kut remains questionable at least until thorough publication of the excavation data.

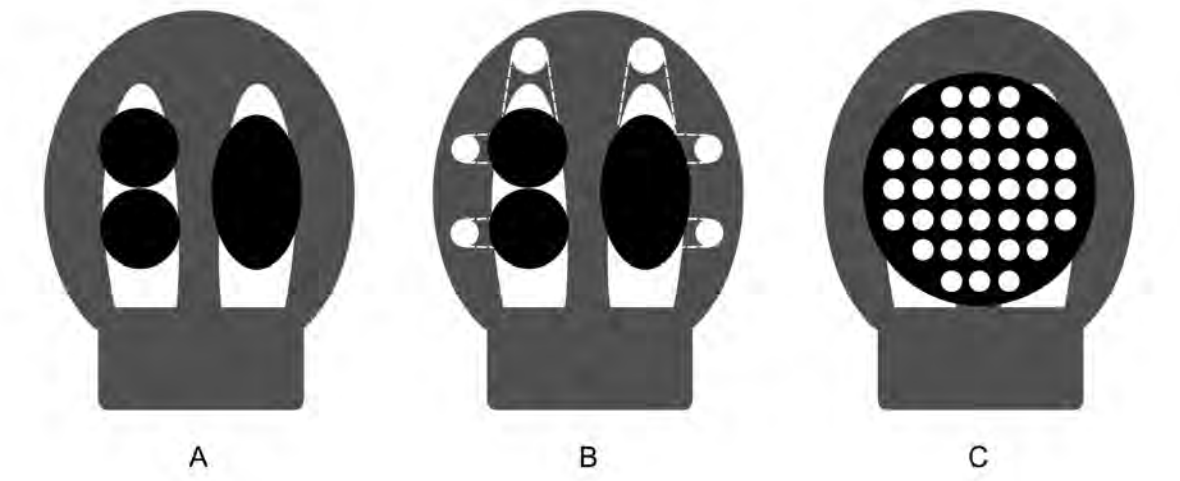

Fig. 13. *Three techniques of managing the hot air and gas inflow from combustion to firing chamber within the Cucuteni-Tripolye dual-chambered updraught pottery kilns. A – channels covered with discoid or shield-like slabs; B – channels complemented by air holes, both covered with discoid or shield-like slabs; C – channels covered by grate* (illustration S. Țerna)

B – the two- or multi-channeled combustion chamber with air holes on its perimeter is covered by discoid or shield-like slabs on which the unfired pottery was subsequently placed;

C – the two- or multi-channeled combustion chamber is covered by a grate on which the unfired pottery was subsequently placed. The grate often lies on clay cones arranged vertically on the perimeter of the combustion chamber.

These three types have a certain spatial and chronological trajectory in the 4th millennium BC (figures 14-15). Type A appears at the Tripolye B2 stage (4000/3900 BC) and lasts throughout the climax of mega-site evolution until approximately 3600 BC. Type B seems to be a further improvement of type A, by adding air holes on the combustion chamber's perimeter, and had a time span from 3900 to 3600 BC. Type C appeared at circa 3600 BC and has been encountered throughout both Tripolye C1C2 and the entire Tripolye C2 stage till the end of the 4th millennium.

In most of the cases, there is a single type of kiln for each settlement. Here, the only exception so far is the Stolniceni case where kilns of types A and B have been found in groups close to a standalone dwelling which may be interpreted as "potter's house": the northern agglomeration of kilns displayed two A-type features while the southern one included an A-type and a B-type kiln. This technological variability together with the spatial arrangement of the two pottery production complexes – located in opposite parts of the site – raises important questions related to the emergence and spread of a technological innovation within a specific, specialized socio-economic group such as pottery makers. Were both kiln types (A and B) already known to Stolniceni potters when the site was founded, or has the use of air holes for firing management been discovered and implemented at Stolniceni after a certain period of use of type A kilns? The available radiocarbon data for kilns from the north of the settlement (trenches 3/2016 and 5/2017) shows a remarkably early dating within the settlement's inner chronology. This means that the firing of pottery in two-channeled dual-chambered kilns had been organized from the very beginning of the site's occupation and "filling" of its preconceived geometrical structure. One could therefore expect that the B-type kiln in trench 14/2018 should either have a later date and display a local innovation or, if not, belong to a technological package which reached Stolniceni from elsewhere; in this case, the emergence of kilns of type B would have happened before 3900 BC. As pointed out above, the distribution of technological waste and clay slab fragments would indicate that the B-type kiln from Stolniceni is probably not a "last generation feature" since the A-type kiln in trench 15 seems to have been used later. Does it mean that both types of

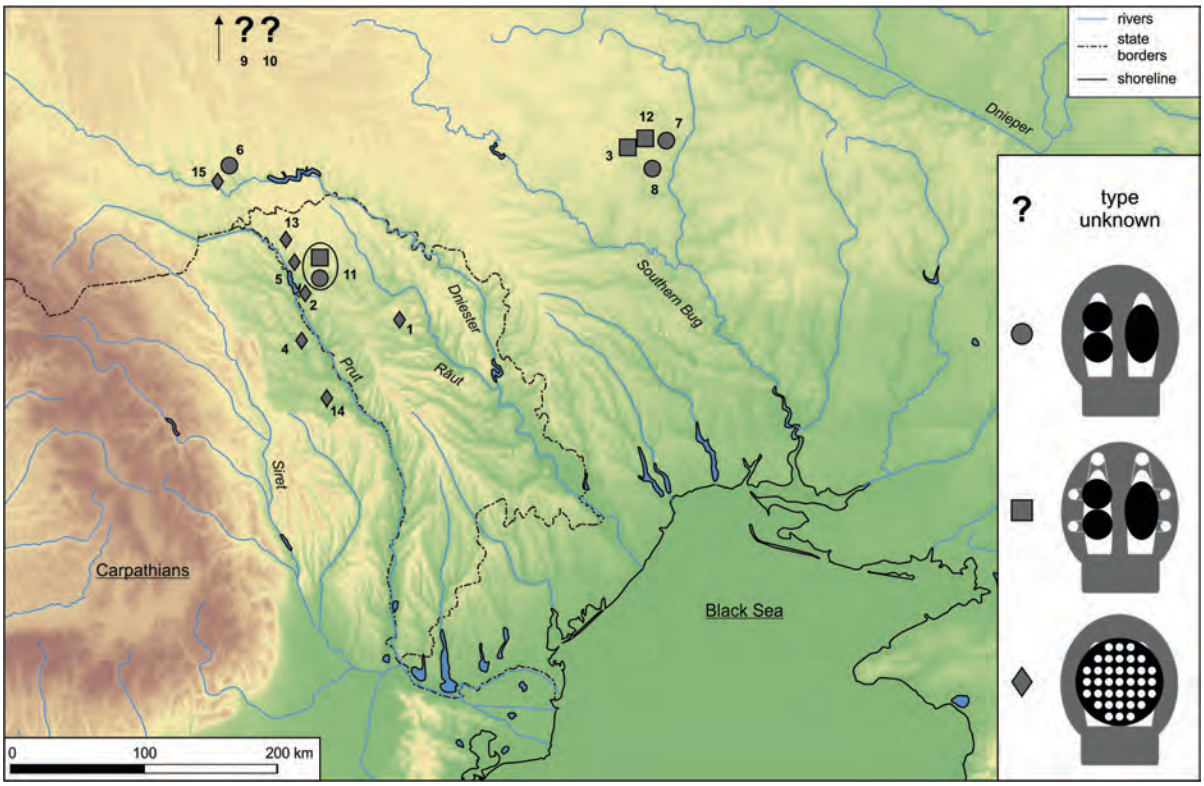

Fig. 14. *Geographical distribution of the three techniques of managing the hot air inflow from combustion to firing chamber within the Cucuteni-Tripolye dual-chambered updraught pottery kilns in the IVth millennium BC. Numbers correspond to the ones from Table 2* (illustration S. Țerna)

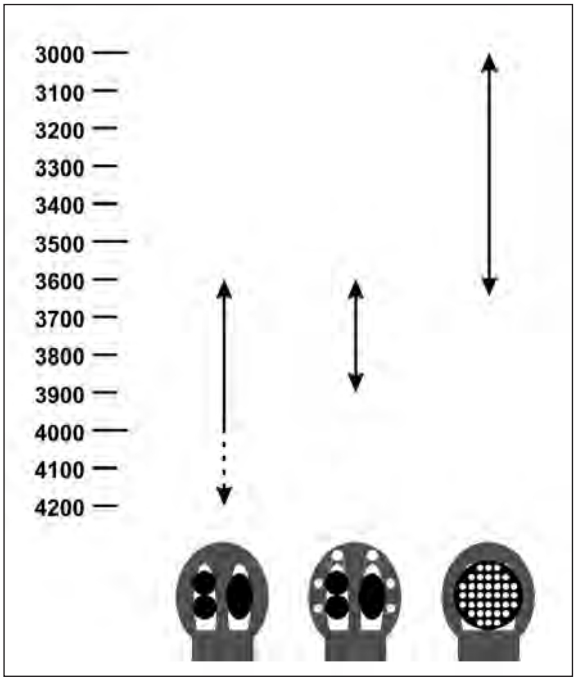

Fig. 15. *Chronological distribution of the three techniques of managing the hot air inflow from combustion to firing chamber within the Cucuteni-Tripolye dual-chambered updraught pottery kilns* (illustration S. Țerna)

kilns were known to the Stolniceni potters from the very beginning of the settlement's development? Though it seems to be a plausible scenario, a firm answer should be provided in the future, when more data on the inner chronology of the site will become available.

Spread of technological innovations

Another research problem is the spatial dissemination of kiln-related technological innovations. The available informations suggest that the spread of Cucuteni-Tripolye radial settlements followed a West–East geographical vector, from North-Eastern Romania towards the Bug-Dnieper basin in modern-day Ukraine;[19] therefore, the roots for the constructive elements of the pottery kilns from such huge settlements as Talianki, Maidanetske, Nebelivka or Dobrovody should be sought in the Western part of the Cucuteni-Tripolye area. Indeed, at Stolniceni we witness kilns of both A and B types in a chronological setting

[19] Țerna / Vornicu-Țerna / Rassmann 2018.

slightly younger than Nebelivka and slightly earlier than the Ukrainian mega-sites of the Tripolye C1 stage.[20] Did innovations in pottery manufacturing spread as part of the gradual movement of people and settling of the Eastern territories in Bug and Dnieper basins which manifested itself in large radial settlements, or did such technological peculiarities as the use of air holes in kilns of type B travel across already existing sites? There is evidence for mutual exchange of pottery between the Prut and Uman regions such as, for example, the discovery at Stolniceni of fragments of bowls made of caoline, which is considered to be an import from the eastern area, where caoline pottery is widespread. Obviously, imported pottery does not imply the existence of direct contacts among potters; on the other hand, it reflects a certain degree of population mobility and one could expect that potters could have been a part of this process, ensuring "transfer of knowledge" between distinct mega-sites.

The origin of type C kilns, with such a complex innovational element as the grate, remains unclear. In technological terms, a grate would represent a radical improvement over the "air hole" idea, with hot air and gas flowing through multiple circular holes made in a large clay slab which covers the entire bottom of the firing chamber, replacing thus the rows of discoid and/or shield-like slabs of type A and type B kilns. All of the known C-type kilns are concentrated in the Prut and Dniester basins, with the earliest examples coming from Tripolye C1C2 (= Cucuteni B2) settlements from the right bank of the Prut. Although still awaiting new data, we may now presume that the grate in dual-chambered pottery kilns appeared by the end of the mega-site phenomenon and represented a development of the "slab and air hole" principle documented in kilns from Stolniceni and Talianki.

Pottery making and labour division

An interesting aspect is the distribution of kilns within settlements. Both from the chronological analyses of the kilns in Maidanetske[21] and the dating of the Stolniceni kilns we know that the installation of kilns (as a part of the settlements infrastructure) and the demarcation of the area by an enclosure were part of the first activities at the sites. Also the long duration of some kilns[22] indicate the stability of these infrastructural devices, which is important until the recently socially explained collapse of mega-sites.[23] In this respect it is tempting to link the spatial distribution of the kilns within the sites[24] with the question of socio-economic developments.

As also stated above, there seem to be two distinct patterns: the "regular" one, where the kilns are more or less distributed over the entire site and most of its structural units (like house groups or "quarters"), and the "clustered" one, where the kilns form distinct agglomerations and are not present in all or most of the settlements' structural units. The first model has been recorded at Petreni and Talianki, while the second one has been revealed by the geophysical plots of Stolniceni and Maidanetske.

Obviously, these spatial distribution patterns indicate differences in part-time or full-time specialization within the settlement. Presumably, a "clustered" pattern indicates reduced access to the technology of pottery firing with just several structural units (such as house groups) involved in ceramic production while a "regular" one would mean broader access to technology with most of the structural units producing pottery.

In principle we could link this observation with questions about urbanization and social differentiation. As Stolniceni and Petreni are contemporary, and Talianki dates partly younger then Maidanetske, a simple chain from disperse to a concentrated distribution of kilns is not the case. Nevertheless, the concentration in one quartier in two of the mentioned sites might indicate a development to "proto-urban" divisions of work, which would indicate a combination of certain craft specialization with spatial separation.

Beside these non-directed processes "potter-quarters" not necessarily indicate processes of vertical social differentiation. We are dealing with societies, in which, like in every society, such specializations could result both in the strengthening of reciprocal relationships between non-stratified actors with different

[20] cf. Müller et al. 2016.

[21] Ohlrau 2020.

[22] Ibid.

[23] Hofmann et al. 2019.

[24] As documented by Rassmann et al. 2014; Rassmann et al. 2016a.

production ties, or in the development of social stratification by the restriction of the access to resources – in this case high quality pottery products. But, in consequence, only with the evaluation of the development of other aspects of the mega-sites, these questions regarding the social consequences might be answered.

Conclusion

Of course, the available data from recent excavations based on geophysical plots (kilns excavated at four sites in the Uman region and one single site in the Prut basin) are still insufficient to draw far-going conclusions about the emergence and spread of innovations related to pottery firing within the Cucuteni-Tripolye large and complex settlements of the 4th millennium BC. They only allow us to point out some research problems and questions for future work. Identification and excavation of pottery kilns on diachronic radial sites on the right bank of the Prut, Dniester and Bug basins should be a research task for further investigation of pottery manufacturing and, on a wider scale, spread of innovations and knowledge in the vast and intriguing world of the Cucuteni-Tripolye mega-sites.

Sažetak

Evolucija dvokomornih produvnih keramičkih peći na Cucuteni-Tripolje mega-lokalitetima iz 4. milenija pr. n. e.: pogled iz lokaliteta Stolniceni

Četiri složene dvokomorne produvne keramičke peći nedavno su sistematski iskopane na mega-naselju Cucuteni-Tripolje kulture na lokalitetu Stolniceni u Sjevernoj Moldaviji. Podaci dobijeni ovim istraživanjima, upoređeni sa starijim i novijim dokazima sa drugih nalazišta, dozvoljavaju nam razmatranje niza pitanja, kao što je tehnološki i društveni kontekst za usavršavanje pečenja keramike u okviru velikih Cucuteni-Tripolje naselja od 4. milenija pr. n. e. Raspoloživi podaci iz nedavnih istraživanja bazirani na primjeni geofizičkih mjerenja (peći su iskopavane na četiri lokaliteta u regionu Uman i na jednom lokalitetu u dolini rijeke Prut) još su uvijek nedovoljni za izvlačenje konačnih zaključaka o pojavi i širenju inovacija vezanih za pečenje keramike u okviru velikih i kompleksnih naselja Cucuteni-Tripolje kulture u 4. mileniju pr. n. e. Dobijeni rezultati nam dopuštaju samo da ukažemo na određene istraživačke probleme i otvorimo pitanja za budući rad. Identifikacija i iskopavanje keramičkih peći na dijahronijskim i zrakasto postavljenim lokalitetima na desnoj obali Pruta, u dolinama Djestra i Buga, trebali bi biti naučni zadatak za istraživanje manufakture keramike, kao i, na višem nivou, širenja inovacija i znanja u širokom i intrigirajućem svijetu Cucuteni-Tripolje mega-lokaliteta.

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