

The Nebelivka experimental house construction and house-burning, 2014–2015

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ABSTRACT

One of the research goals of the AHRC-funded “Early urbanism in Europe?: the case of the Trypillia mega-sites, Ukraine” Project was the better understanding of how Trypillia houses burned down in order to aid our understanding of the taphonomy of house remains excavated at the Trypillia BII mega-site of Nebelivka. For that reason, the Project decided to build two 2/3 size Trypillia experimental houses – one single-storey and one two-storey – in order to compare the burnt remains of the two types of houses. In the first part of this article, we explain the construction methods of the two 4 x 3m houses and the resources utilized to build them. In the second part, we provide an account of the burning of the two-storey house and explain the principal results of the experiment. In conclusion, we seek to define the specific contribution of the Nebelivka experiment not only to the history of Trypillia house-burning but the wider debate of deliberate house-burning.

KEYWORDS

Trypillia, mega-site, Nebelivka, experimental archaeology, house-construction, house-burning

Introduction

The AHRC-funded project “Early urbanism in prehistoric Europe?: the case of the Trypillia megasites” was a four-year project (with extensions, 2012–2017) designed to understand the phenomenon of the Trypillia megasites – the largest known settlements in 4th millennium BC Europe (Videiko 2013). The project was based on the 238-ha. site of Nebelivka (Novoarkhangelsk District, Kirovograd Oblast), which was set within the spatial and cultural context of the whole Trypillia group (Nebbia 2016) (fig. 1). The fieldwork of the multi-disciplinary project included intensive systematic fieldwalking, geophysical prospection, palaeo-environmental reconstructions, excavations in the megasite and an experimental programme. The geophysical prospection produced what is still the only complete plan of a megasite (fig. 2). The results are published in two media: the detailed data are presented on the York Archaeological Data Service platform (<https://doi.org/10.5284/1047599>), while an interpretative account of the project is published as an open access monograph

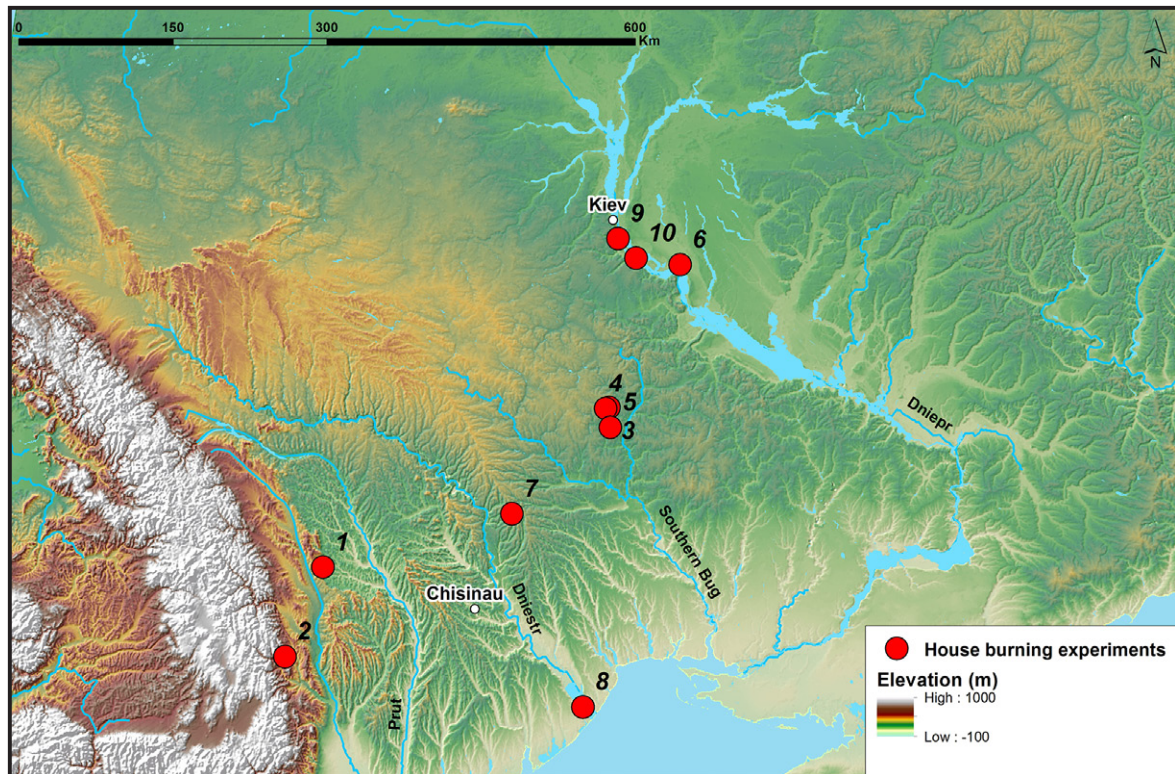


Fig. 1. Map of Cucuteni-Trypillia, with locations where house-burning experiments have taken place: 1. Cucuteni; 2. Poduri; 3. Nebelivka; 4. Legedzyne; 5. Taljanki; 6. Letsky (modern village); 7. Oleksandriivka; 8. Bilhorod-Dnistrovskij (modern town); 9. Chapaivka; 10. Kolomyishchyina (author M. Nebbia)

Обр. 1. Карта на местата, където са проведени експерименти с изгаряне на Кукутенско-Трипилски къщи: 1. Кукутени; 2. Подури; 3. Небелівка; 4. Легедзине; 5. Тальянки; 6. Летски (съвременно село); 7. Олександрівка; 8. Билгород-Дністровски (съвременен град); 9. Чапайвка; 10. Коломийщина (автор М. Nebbia)

(Gaydarska 2019). In this article, we focus on the results of the experimental programme of house-building and house-burning (2014–2015).

Experimental archaeology has a long tradition in Eastern as well as Western Europe (Kulska, Dubitska 1940; Coles 1973, 16-18), with the best results coming in projects with closely-defined research aims and experimental design. The context of this particular experiment was a long-running dispute among specialists of the Cucuteni-Trypillia group (henceforth 'CT') – a large network of over 5,000 known sites distributed across 250,000 km² in modern Romania, Moldova and Ukraine (fig. 1) and covering a time-span of almost two millennia (4800–2950/2900 BC). The dispute concerns the ways in which one of the principal features of the CT group – the dwelling-house – was constructed and the form the house took. The principal remains from house-burning constitute the 'ploshchadka' – a Russian term for the complete burnt daub remains of the house, sometimes translated into English as 'platform'. The deliberate burning of houses would appear to remain the only cultural practice over which most specialists agree. The long-running Ukrainian debate about one- vs. two-storey buildings had twists and turns, with proponents going from one camp to the other, site-based claims gaining wider validity and attempts to ground ideas through appropriate field methodology (Markevich 1964; 1981; Zinkovskiy 1975; 1983; 2013; Shmaglij, Videiko 2003; Kruts 1990; 2003). To-date, there is still no common agreement between scholars arguing for single-storey houses (Kolesnikov 1993), others for exclusively two-storey

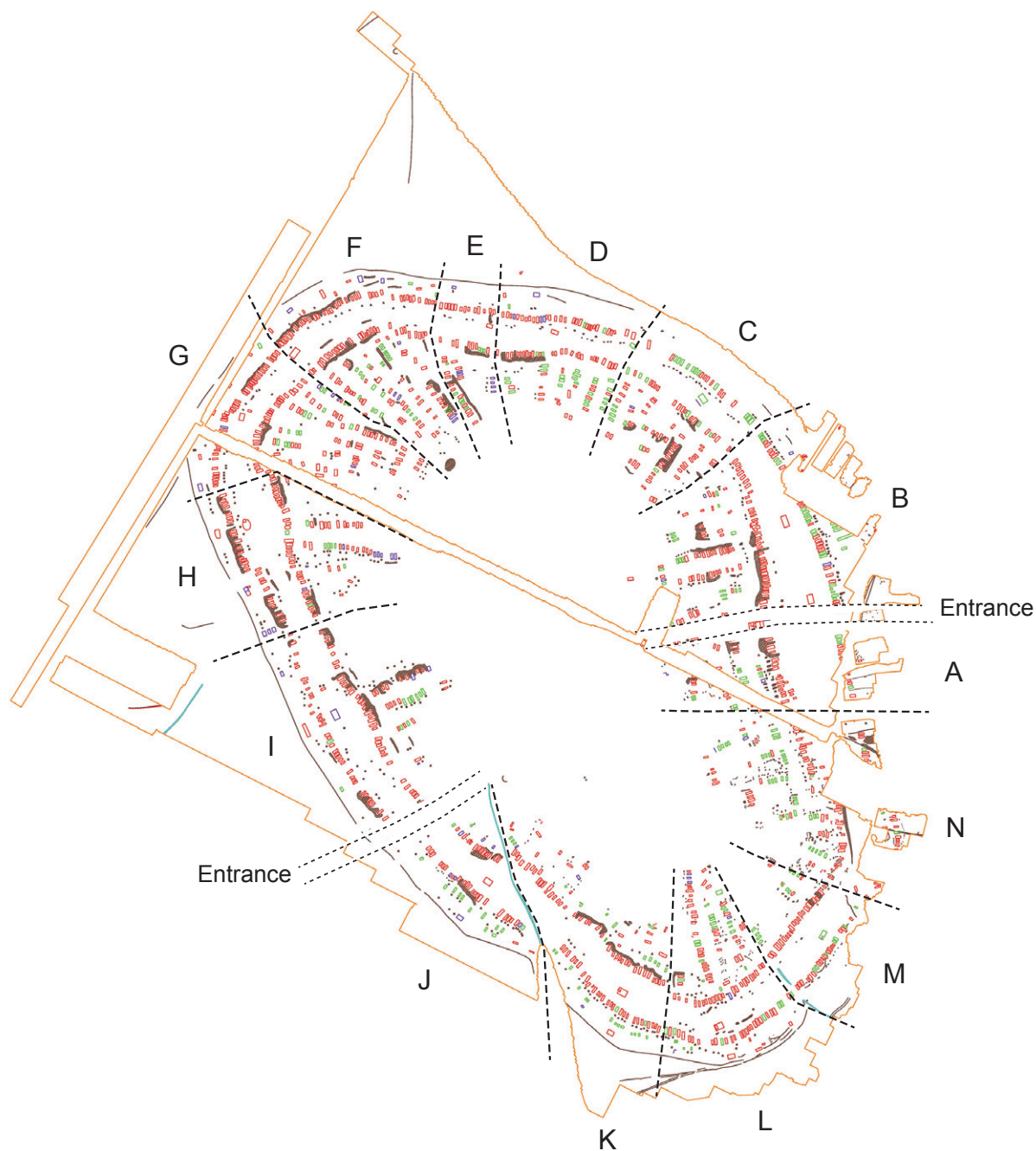


Fig. 2. Geophysical Plan of Nebelivka mega-site, showing (a) fully-burnt houses (red); (b), less burnt / unburnt houses (green); and (c) unclear anomalies (purple). Letters refer to Quarters (author D. Hale)

Обр. 2. Геофизичен план на мега-селището Небеливка, показващ: (а) напълно изгорели жилища (червени); б) по-слабо изгорели / неизгорели жилища (зелени); и в) неясни аномалии (лилави). Буквите се отнасят до кварталите (автор D. Hale)

houses (Chernovol 2012) and still others maintaining the presence of both forms (Kruts 1990 and later; Shumova, Ryzhov 2003; Videiko 2005).

Scholars from Passek (1949) to Korvin-Piotrovskiy (Kolesnikov) (Kolesnikov 1993; Korvin-Piotrovskiy, Shatilo 2008) have maintained that the construction daub of the house was burned in a controlled manner to strengthen what were effectively one-storey structures. This practice has been opposed by others (Burdo 2011; Chabaniuk 2008; Chernovol 2012; Kruts 1990; 2003; Kruts, Chabaniuk 2007; Shmaglij, Videiko 2003; Videiko 2005; 2013;

Zinkovskiy 1975; 1983; 2013), who argued that the burnt daub derived from a more complex, two-storey house form which was universal among CT. Another general problem was the rarity of ash, charcoal and even the traces of house walls in excavated CT houses, in which two reconstructions have been posited: the use of sleeper beams rather than post-holes to support the main vertical posts and the construction of log-cabins (Chernovol 2012; Kruts 2003; Shumova, Ryzhov 2003).

Thus, there were four major issues, as well as many subsidiary issues, to which the Nebelivka house-burning experiment could make a useful contribution:-

- a) Whether fire was used in house construction;
- b) Whether the burning of experimental one- and two-storey houses left traces that would be recognisable in excavations of Trypillia ploshchadki;
- c) The quantity of fuel needed for a successful house-burning; and
- d) the likelihood of deliberate house-burning.

The maximisation of our contributions to the CT house agenda required a comparative research design, in which the Nebelivka Project used the summer 2014 season to construct, with identical materials and technology, two houses of identical ground plan (4 x 3 m) – one single-storey and one two-storey. After leaving them to overwinter, the houses would then be burnt down the following spring. The house-burning sequences would be recorded in real time with video and still photographs, with photogrammetric three-dimensional reconstructions so as to provide an account of the differences between the burning of the two house forms.

Despite the successful construction of the two experimental houses in summer 2014, the Project encountered health and safety, as well as ‘political’, problems in spring 2015. The location of the one-storey experimental house some 10 m from a brick-built kindergarten led the County Fire Officer to question the wisdom of burning this house. Moreover, the Nebelivka village was keen to preserve **both** experimental houses as part of the planned village heritage centre focused on the results of the mega-site project. These difficulties resulted in a compromise solution to burn only one of the experimental houses – the two-storey structure, which was further from modern structures. This decision obviously detracts from the comparative aim of the experimental research design but, nonetheless, enabled the careful recording of one house-burning experiment. An additional experiment conducted by one of the authors (SJ) in Durham in autumn 2014 was designed to test the advantages and disadvantages of Korvin-Piotrovskiy’s hypothesis of constructional burning (for the results, see below, pp. 73 & 79).

While the majority of Ukrainian prehistorians accept deliberate house-burning as a typical Trypillia practice (see above, p. 62), this debate still continues in European prehistory, almost 20 years after the seminal work of Mirjana Stevanović (1997). Opinions such as the following are still rife in Balkan prehistory:

“We could therefore envisage the deliberate burning of a finite group of houses within the tell at Belo Brdo, perhaps similar to the neighbourhood groups of 5–12 houses shown by geophysical survey at the flat settlement of Crkvine, Stubline, some 40km southwest (Crnobrnja et al. 2010, 21). This could leave open the possibility of accidental burnings that got out of hand, rather than deliberate, malicious or otherwise aggressive fire-settings. But the formal chronological models presented here may weigh in favour of a deteriorating social context, with putative, deliberately aggressive burnings repeated within a generation” (Tasić et al. 2015, 1078-9).

“Only one of the (partially) excavated burnt houses at Uivar contained large numbers

of pottery vessels *in situ* (i.e., as one would expect if the burning had been the result of a sudden outbreak of fire). In some cases, differences in the degrees of hardness of floors and walls (caused by varying intensities of burning) might be the result of attempts to extinguish the fire. Current evidence from Uivar, therefore, can neither confirm or refute Tringham's hypothesis of ritual house burning (Tringham 2005)" (Schier 2008, 60).

While it may be thought that a single house-burning experiment cannot make a significant contribution to the overall debate, our results do highlight certain issues which are important in the debate over deliberate vs. accidental burning, especially with respect to the quantity of fuel needed to ensure a successful house-burning in relation to the quantity of timber needed to build the house in the first place.

The house construction

The burning of house models was discussed in the spring of 2014 as part of a possible undergraduate dissertation. Originally the intention was to construct two small models during the 2014 field season in Nebelivka, one single-storey and one two-storey, each with a footprint of 1.5m x 3m, destroy them by burning and carry out comparative analysis of the collapsed remains. The project design was later revised to build two larger house models with a footprint of 3m x 4m (approximately 2/3 size), allow them to dry and weather over the Ukrainian winter before destroying them as the finale of the conference marking the end of the Trypillia Mega-sites Project in the spring of 2015. Judging by the results of previous experiments, it was felt that the larger buildings would produce more realistic collapse patterns and that higher temperatures might be achieved during their destruction.

A three-week window was available for the construction of the house models in late July and early August 2014. This short time frame meant that four compromises had to be made in the choice of construction materials and the tools used; these decisions were made to achieve the desired results without compromising the integrity of the project.

- From the outset, the need to use steel hand tools and power tools was acknowledged if the project was to be delivered on time. The relatively simple wood-working techniques used in the design of the house models meant that the use of modern tools did not achieve results beyond the capabilities of Trypillia people in prehistory but did save time and labour.
- Ideally, the team would have liked to have used oak for the timber framing of the house models as it was the most likely choice in prehistory for construction because of its strength and durability. Unfortunately no oak was immediately available within the timescale required. Instead, pine was procured from a commercial source for the framing. Both types of timber would have been available from the forest-steppe in prehistory (Pashkevych 2012; Albert et al. 2019).
- Initially the intention was to produce daub for plastering manually by treading a mixture of clay, cow dung and straw to a suitable consistency. After discussion with the Mayor of Nebelivka, it became apparent that the amount of labour required in gathering and processing materials would be considerable. It was decided that mechanically-produced daub consisting of only clay, straw and wa-



A



B



C



D



E



F



G



H

Fig. 3. Plate of building sequences: A – Clearing vegetation from the construction site on day 1 of the project; B – Construction of the elements of the timber frames for both buildings on day 3 of the project; C – Erection of the timber frame for the single storey house model on day 8 of the project; D – Weaving the infill panels using hazel withies on day 9 of the project; E - Weaving of wattle panels on the two-storey building and installation of sawn log floors on day 11 of the project; F - Progress with daub plastering at the end of day 14; G - The second (successful) attempt at thatching the single-storey building on day 16; H - Vlad Litkevych finishing the Trypillia inspired designs on the two-storey building (photos A–G – S. Johnston; photo H – A. Aflalo)

Обр. 3. Последователност на строителните дейности: А – разчистване на растителността от строителната площадка на първия ден от проекта; В – изграждане на дървените рамки за двете сгради на третия ден от проекта; С – изграждане на дървена рамка за едноетажното жилище на осмия ден от проекта; D – преплитане на запълващите панели с помощта на леска на деветия ден от проекта; Е – преплитане на запълващите панели на двуетажната сграда и монтиране на пода с помощта на нарязани дървени стъбла на единадесетия ден от проекта; F – нанасяне на мазилка в края на 14-ия ден; G – втори (успешен) опит в построяването на покрива на едноетажната сграда на 16-ия ден; H – Влад Литкевич завършва украсата на двуетажна сграда с дизайни вдъхновени от Трипилски изображения (снимки: А–G – S. Johnston; H – A. Aflalo)

ter as used traditionally by local people¹ would be used instead. Again, the final result was not beyond the capabilities of Trypillia people and the use of modern technology saved time and labour.

- It soon became apparent that the skills available were not sufficient to produce a satisfactory traditional thatch. The method was revised to produce a functional roof through the resourceful efforts of other members of the construction team.

In keeping with current theories of CT house construction, the house models were constructed using a series of sleeper beams resting on levelled ground (Chernovol 2012). These beams were used to locate the vertical structural elements in mortice and tenon joints to create a structure similar to a modern stud partition (Mitchell 1982). All framing timbers were held in place by their own weight unless under tension or warping caused poor fitting of the joint. Three simple types of joint in various combinations were used in the construction of the timber framing. Tee-halving joints and corner halving joints were used to join horizontal timbers together. Mortice and tenon joints, tee halving joints and corner halving joints were used to join vertical timbers to horizontal timbers (Mitchell 1982, 54-55).

Work began on 14th July (day 1) with clearing the site on waste ground in Nebelivka. The following day, plots were cleared and levelled for each of the house models using local labour (fig. 3A). Over the following six days, elements of the timber frames of both the single and two-storey house models were cut and shaped by a small team of reasonably competent woodworkers (fig. 3B). Like many construction projects, little progress was evident until sufficient materials had been prepared for the erection of the single storey house frame on day 8 (fig. 3C). Less skilled labour was employed to weave hazel withies to form the wattle infill panels which freed more skilled workers to concentrate on other tasks (fig. 3D). The two-storey frame was erected on day 10 and sawn log floors were installed on day 11 (fig. 3E). Wattle weaving continued throughout this time. Daub plastering began on day

1 One of our authors (A.D.), whose grand-parents lived not far from Nebelivka for some time, noted that local people used this mix mainly for the construction of walls. Meanwhile, the construction of construction features from clay and water was noted in several cases during the excavations – e.g. Pishchana (Chernovol, Ryzhov 2006).

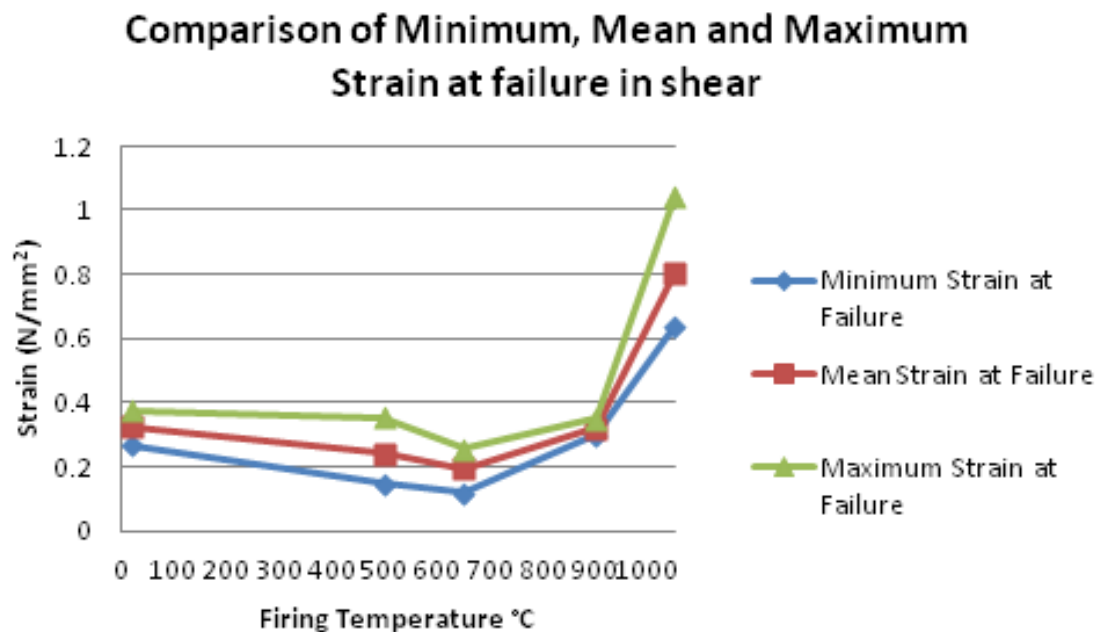


Fig. 4. Comparison of Minimum, Mean and Maximum Strain at failure of daub samples heated to different temperatures in shear. Shear is a twisting force which could replicate the effect of wind on the structure. It is applied to batches of five samples of daub. Each different batch of daub has been heated to a different temperature. The plot shows the largest force needed to break a sample, the smallest force needed and the average of the forces needed to break all five pieces in a given batch and compares it with the batches heated to different temperatures. Initially the strength of the daub decreases on heating but begins to increase as the temperature increases, because the clay molecules are gradually being fused together (author S. Johnston)

Обр. 4. Сравнение на минимално, средно и максимално натоварване на проби от глинена обмазка, нагрявани до различни температури в условия на усукване. Силата на усукване възпроизвежда ефекта на вятъра върху дадена структура. Тя е приложена върху партиди от пет образеца на мазилка. Всяка отделна партида се нагрява до различна температура. Графиката показва най-голямата сила, необходима за счупването на дадена проба, най-малката необходима сила и средната стойност на силите, необходими за разчупването на всичките пет части в дадена партида и ги сравнява с партидите, нагreti до различни температури. Първоначално крепкостта на мазилките намалява при нагряване, но започва да се увеличава с увеличаване на температурата, защото глинестите молекули постепенно се сливат заедно (автор S. Johnston)

12 (fig. 3F) while work began on the erection of gables and roof timbers on both houses. The plastering operation also employed unskilled labour with some supervision.

By day 15, sufficient roof timbers were in place for the first attempt at thatching to be made. The method chosen aimed to reproduce winter reed thatch by stripping leaves from reeds gathered in the summer. This approach did not produce a satisfactory final product, consumed a great deal of material and was labour-intensive. Once this became apparent, the method was altered to make better use of the material available and work continued on thatching until the end of the construction project (fig. 3G). The construction project finished after 18 days (fig. 3H). Some work to complete the thatching of the two-storey building and to decorate both buildings continued after this.

At the same time as the house models were being constructed, a short experiment was carried out to investigate producing paints using milk products and simple pigments. Milk curd was mixed with powdered charcoal and red and white clays available locally. Sam-

ACTIVITY	COMMON	1-STOREY HOUSE	2-STOREY HOUSE
Preparation of site	14		
Sorting of construction materials	71		
Making timber frames		15	25
Weaving wattle panels		8	13
Laying floors/ceilings		3	6
Application of wall plaster		10	11
Thatching		15	15
External decoration		3	5
TOTAL	85	54	75

Table 1. People/days required for the construction of the two experimental houses (data S. Johnston)

Таблица 1. Човекодни, необходими за изграждането на двете експериментални сгради (данни S. Johnston)

Summary

Experimental houses	Single-storey	Two-storey
Total volume of timber (m ³)	2.52	3.44
No of trees of 0.15m diameter and 4m length required	35	48
Total volume of wattle (m ³)	0.29	0.56
Total volume of daub (m ³)	2.95	5.61
Comprising:		
Clay at roughly 80% by volume (m ³)	2.36	4.49
Temper at roughly 20% by volume (m ³)	0.59	1.12
Total volume of roofing material (m ³)	3.00	3.00

Table 2. Estimate of quantities of materials used in the construction of the single- and two-storey experimental houses with a footprint of 3 m x 4 m at Nebelivka, 2014 (data from S. Johnston)

Таблица 2. Изчисления на количествата материали, използвани при изграждането на едно- и двуетажни експериментални сгради с размер 3 x 4 м в Небеливка, 2014 г. (данни от S. Johnston)

ples were painted onto the walls of the two-storey house and evaluated for coverage and opacity. The powdered charcoal pigment did not perform well but the results from the red and white clay pigments were good. More red and white paint was made using the same method and used to decorate both houses with designs inspired by motifs from Trypillia pottery (fig. 3H).

The total time taken for the construction of both houses amounted to 214 eight-hour people/days (Table 1). From the quantities of material used in the construction of the house models (Table 2), it was possible to extrapolate quantities of materials required for full-sized dwellings (Table 3) and subsequently for the construction of a “Nebelivka module” of 100 houses (Table 4). Using data from the United Kingdom Forestry Commission, it is possible to express the timber requirements in terms of the number of trees of required (Forestry Commission 2015).

The following conclusions can be drawn from the construction of the two houses. The production of houses on the scale required to construct a large settlement such as a Trypillia mega-site would have required the careful and co-ordinated management of skills and labour as well as the landscape and its produce. This would extend to the planning of forest management in the forest steppe zone, with its restricted range of tree cover. Particular

Full sized houses of 4.8m x 12.7m (Müller and Videiko, 2015)	Single-storey	Two-storey
Total volume of timber (m ³)	9.65	17.73
No of trees of 0.15m diameter and 4m length required	135	248
Total volume of wattle (m ³)	1.20	2.37
Total volume of daub (m ³)	14.65	28.52
Comprising:		
Clay at roughly 80% by volume (m ³)	11.72	22.81
Temper at roughly 20% by volume (m ³)	2.93	5.70
Total volume of roofing material (m ³)	15.24	15.24

Table 3. Estimate of quantities of materials used in the construction of full-sized single- and two-storey houses with a footprint of 4.8m x 12.7 m at Maidenetske (Müller and Videiko 2016)

Таблица 3. Изчисления на количествата материали, използвани при изграждането на едноетажни и двуетажни сгради в пълен размер – 4.8 x 12.7 м в Майденецкое (по Müller and Videiko 2016)

Nebelivka module of 100 houses	Single-storey	Two-storey
Total volume of timber (m ³)	965	1,773
No of trees of 0.15m diameter and 4m length required	13,509	24,818
Total volume of wattle (m ³)	120	237
Total volume of daub (m ³)	1,465	2,852
Comprising:		
Clay at roughly 80% by volume (m ³)	1,172	2,281
Temper at roughly 20% by volume (m ³)	293	570
Total volume of roofing material (m ³)	1,524	1,524

Table 4. Estimate of quantities of materials used in the construction of 100 full-sized single- and 100 two-storey houses with a footprint of 5m x 15 m (the “Nebelivka module”)

Таблица 4. Изчисления на количествата материали, използвани при изграждането на 100 едноетажни и 100 двуетажни къщи с размери 5 x 15 м (модул „Небеливка“)

Firing temperature	Chemical changes by firing range
<150°C	less than 150°C to represent unburned, air dried daub
500°C	450°C to 600°C to represent initial sintering of clay particles
650°C	600°C to 700°C to represent transformation from Kaolin to Metakaolin and loss of chemically bound water
900°C	700°C to 1000°C to represent formation of Spinel and glass from Metakaolin
1050°C	>1000°C to represent formation of Mullite and glass from Spinel

Table 5. Expected results of re-firing temperatures for compression and shear testing of daub samples (author S. Johnston)

Таблица 5. Очаквани резултати при температури на повторно изпичане в условия на компресиране и усукване на проби от глинена обмазка (автор S. Johnston)

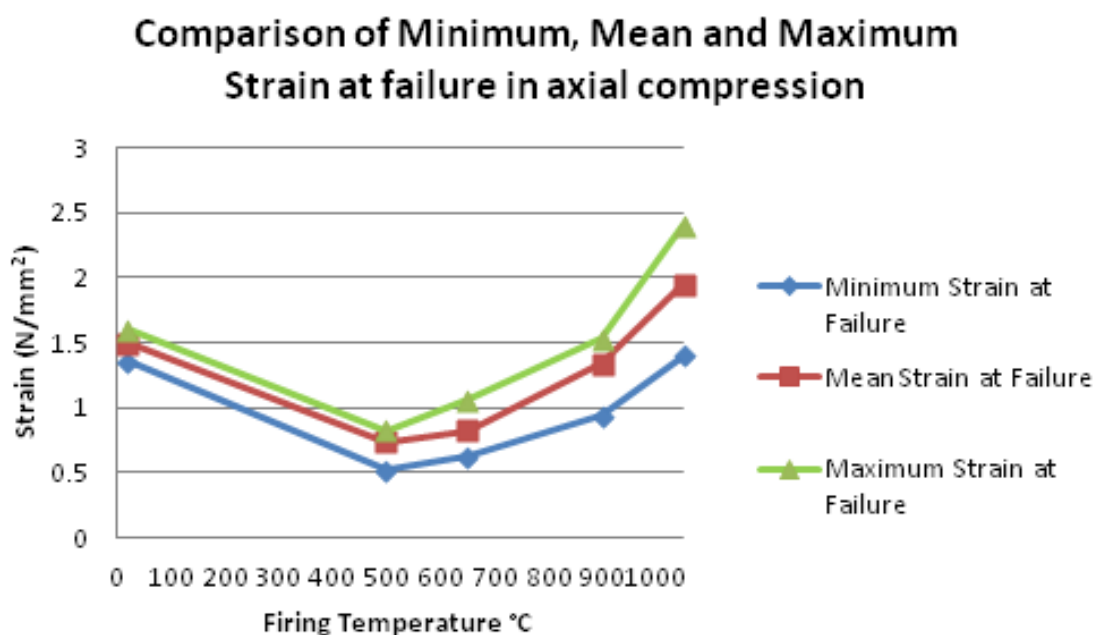


Fig. 5. Comparison of Minimum, Mean and Maximum Strain at failure of daub samples heated to different temperatures in axial compression. The same process as in Fig. 4 but the force is compressing the samples along the centre line, not twisting them (author S. Johnston)

Обр. 5. Сравнение на минимално, средно и максимално натоварване на проби от глинена обмазка, нагрявани до различни температури в условията на осево съгъстяване. Същият процес, както на обр. 4, но силата компресираща пробите по осовата линия, без да ги усуква (автор S. Johnston)

management skills were essential for the coppicing of hazel trees beginning several years in advance to produce withies of suitable size before harvesting for construction, as well as the selection of structural timber, probably oak, from a large area. In the process of constructing a mega-site, the coordination of these activities and the formation and maintenance of a reliable supply chain would have had organisational and administrative effects beyond the comparatively modest efforts necessary to construct a single dwelling or settlement to a level approaching specialised industry.

The production of an individual house can be viewed as a symbolic fusion of the different elements that made up the Trypillia landscape. Creation and fusion was achieved through combining clay from the earth with straw from the steppe or as a by-product of agriculture, wood from the forest and reeds and water from rivers and lakes. The coordinated construction of a mega-site can similarly be viewed as an expression of cohesion, co-operation, obligation and inter-relationship within and outside a larger community than an immediate kinship group.

In summary, it is clear that the increase in the number of construction units from one house to a 'Nebelivka module' of 100 houses to a whole settlement required advances in the scale of social organisation and co-operative labour. These changes in the scale of co-operation would have been related to the increases in the quantities of required materials, whether from nearby or from possibly much further away. There was a three-way management challenge – the woodland management often requiring the coppicing of hazel several years in advance of its use-time and the planting of trees for the next 'generation'; the management of the persons involved in each level of building; and the management of the settlement plan to ensure continuity and cohesion within the overall 'ideal plan'.



Fig. 6. Stages of house-burning: a – at start of burning; b – after 1 minute; c – after 17 minutes; d – after 18 minutes; e – after 30 minutes; f – after 37 minutes; g – after 40 minutes; h – after 41 minutes; i – after 1 hour 19 minutes; j – after 1 hour 20 minutes; k – after 1 hour 48 minutes; l – after 3 hours 15 minutes; m – after 3 hours 21 minutes; n – after 3 hours 25 minutes; o – after 3 hours 29 minutes; p – after 3 hours 34 minutes; q – after 3 hours 50 minutes; r – after 5 hours 22 minutes (author B. Gaydarska)

Обр. 6. Етапи в процеса на опожаряване: а – в началото на опожаряването; б – след 1 минута; с – след 17 минути; д – след 18 минути; е – след 30 минути; ф – след 37 минути; г – след 40 минути; h – след 41 минути; i – след 1 час 19 минути; j – след 1 час и 20 минути; k – след 1 час 48 минути; l – след 3 часа и 15 минути; m – след 3 часа 21 минути; n – след 3 часа и 25 минути; o – след 3 часа 29 минути; p – след 3 часа 34 минути; q – след 3 часа и 50 минути; r – след 5 часа 22 минути (автор Б. Гайдарска)

The Durham experiment

There has been a strong theoretical and practical critique of the idea of construction burning of a house (Cotiuga 2009, 305 – 6; summarized in Burdo 2011; 2013; Videiko 2005). Here, a series of experiments carried out as part of Stuart Johnston's undergraduate dissertation to investigate the physical performance of daub heated to different temperatures provided empirical refutation of the idea. Sixty samples of daub were prepared and some heated in controlled conditions to a range of temperatures (Table 5) (Caple 2014). By adapting test methods used to evaluate the strength of earth-based building materials, the samples were subjected to compressive and shearing forces similar to load bearing and twisting forces which a building would be subjected to in normal use life. When compared to the performance of unheated, air dried daub in the same test conditions, the heated samples performed less well than the air dried samples until temperatures of around 900°C were reached (figs. 4 and 5). Heating the daub actually decreased its performance compared to the unheated material because of the loss of water from the clay structure which binds the material together. At higher temperatures, the silicate minerals in the clay structure begin to melt and fuse together to form a material more like a crude ceramic which performs better in test conditions but is very brittle. Bearing in mind that open fires can be expected to reach a temperature of 650°C, to achieve this improvement in the strength of the daub it has to be heated to 900°C, a temperature that would destroy any woodwork in the structure of the house, thereby rendering it useless as a habitable structure.

Heating daub to temperatures lower than 450°C does not permanently change the molecular structure of the clay and would damage and slightly weaken the straw temper of the daub. Over time, the unmodified clay molecules would re-absorb water vapour from the surrounding atmosphere and eventually return to the same moisture equilibrium, effectively reverting to the state of air-dried daub. Heating the daub to temperatures of 650°C weakens it significantly by removing water molecules from the molecular structure of the clay which hold the clay minerals together by suction (Jaquin, Augarde 2011). At 900°C, the strength gained from the fusing of clay minerals becomes significant enough to make up for the loss of water molecules from the structure. Heating a house or lighting a fire inside it during construction would dry the house but, to make it permanently stronger than unfired daub, the fire would have to reach a temperature of 900°C. It would seem unnecessary to heat the clay in the summer anyway because the clay dries so well. Finally, it would be hard to control a fire in a house, especially if a temperature of 900°C was sought. In summary, the burning of the interior of a dwelling during construction is both unnecessary and impractical, achieving no permanent benefit in the construction process.



a

b



*Fig. 7. House-burning details: (a) opening of a 'door' in the wall; (b) 'sandwich' of fallen wall
(author M. Nebbia)*

*Обр. 7. Детайли от процеса на опожаряване: а) отваряне на „врата“ в стената;
б) „сандвич“ от паднала стена (снимка М. Nebbia)*

The house-burning experiment

The two experimental houses had over-wintered in a good condition, protected by the Nebelivka village authorities; the painted decoration on the houses had also survived. The winter had not been severe, apart from early snow in November, with mean temperatures above 0°C until February and above 10°C in March and April 2015. The snowfall was less than usual and there was relatively dry spring weather, with total precipitation below 40 mm in March and April 2015 (<https://weatherspark.com/averages/33809/Kiev-Kiev-City-Ukraine>).

The basic conclusion reached by Stefanović (1997; cf. Zinkovskiy 1975; Cotiugă 2009) was that additional fuel had to be added to a house for the burnt house to reach the temperatures reflected in the morphology of the resultant daub (Shevchenko, Gaydarska 2019). For that reason, and because several former Trypillia house-burning experiments had failed to reach sufficiently high temperatures to achieve complete combustion (e.g. Chabaniuk 2008), a large quantity of firewood (30 m³, equivalent to 420 trees 0.15 m in diameter and 4m in length) was purchased several days before the burning to fill the house prior to ignition. Thanks to the skills of Vladyslav Litkevych, the firewood was sorted and placed in a criss-cross web of timbers, with a tunnel down the centre of each floor to maintain the oxygen flow from the windows in the far end. Almost all of the 30 m³ of timber was comfortably fitted into the two-storey house within 7 ½ person-hours' work. It is essential to note that almost 10 times the amount of wood was needed to burn a two-storey house as was used to build it, although there is a qualitative difference between timber for fuel and timber for construction, with the latter being increasingly less readily available with time. This conclusion has important implications for the question of deliberate house-burning (see below).

On 14th May 2015 – the day of the burning – the weather was overcast but mainly dry, with a light breeze from the East. The house was ignited at 12.50 pm and continued to burn until mid-afternoon of the following day. A total of 31 stages was recorded for the conflagration (fig. 6), focusing primarily on the main stages in the collapse of the house. Within 40 minutes, the roof thatch had burned and the structure had collapsed. Although burnt debris in the form of small charred plant material was blown to considerable distances of up to 100 m, there was not enough bulky material to set other houses on fire. After 1 hour and 15 minutes, the structure of the loft and its ceiling had burnt down. It took a further five minutes before the first section of one of the walls had fallen out, leaving a hole in the form of a 'door' (fig. 7A), and another five minutes before the North fronton fell inwards. Further sections of the South and West walls slid down during the time interval of 1 ½ and 2 hours. It was not until 2 hours and six minutes had passed that the first section of the East wall collapsed, presumably since it was furthest from the prevailing wind direction. The North wall took even longer, with the fronton falling inwards after 2 hours and 15 minutes and upper parts falling after a further six minutes. A further one hour and 40 minutes elapsed before most remaining parts of the North and East walls had collapsed. Two parts of these walls remained upstanding supported by the ash pile from the fire: a 1.8 m-long central section of the East wall survived to over one metre high, while two low (0.20 m) segments of the North wall were upstanding (fig. 10). This meant that the vast majority of the structural parts of the house had fallen within four hours of ignition. The peak of the resultant ash-pile – at 1.50 m high – was reached at this time and recorded undiminished almost four hours later. With several heavy rain-showers, some of the ash was washed out but a

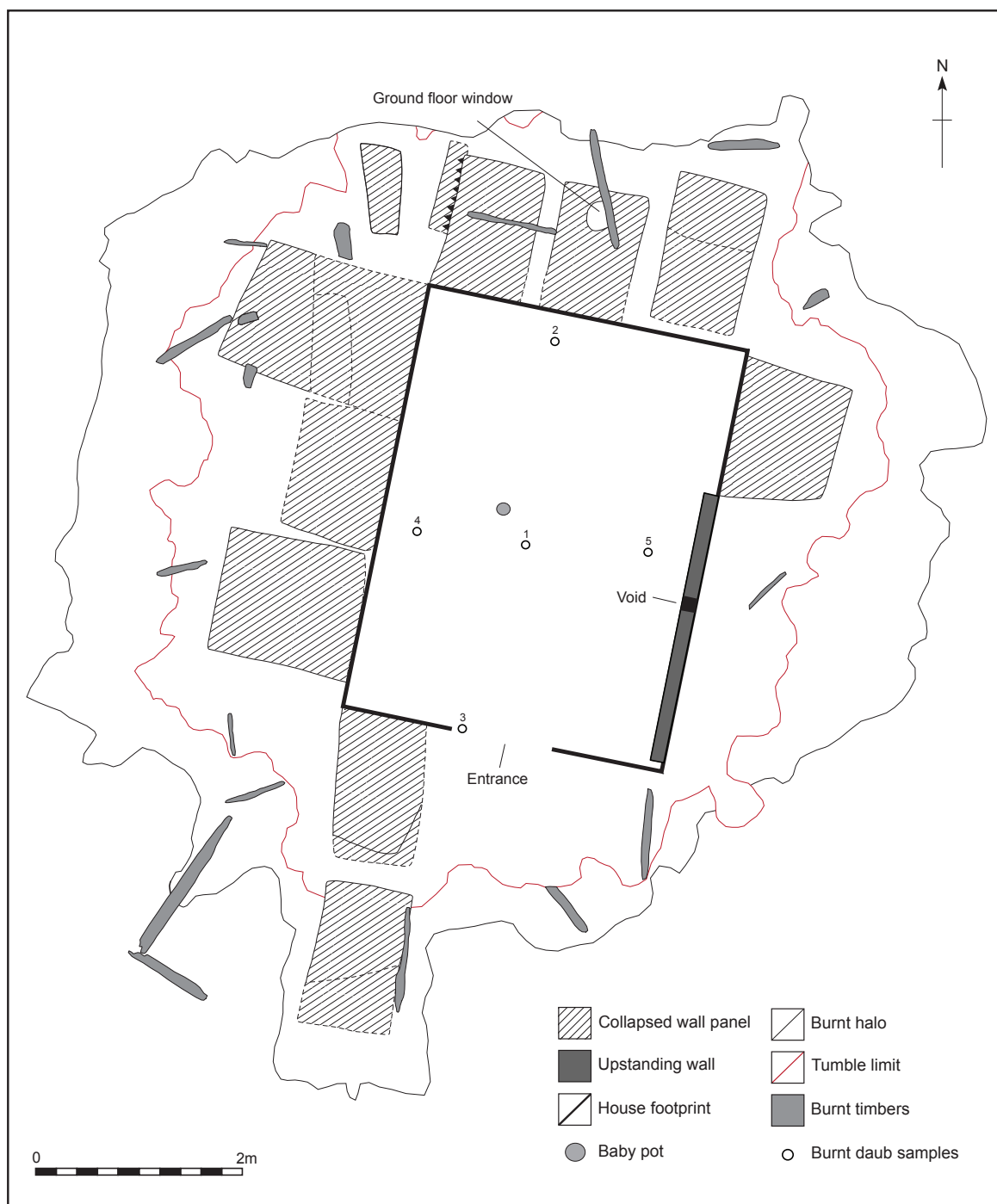


Fig. 8. Plan of remains of house-burning (author P. Voke)
 Обр. 8. План на останките на опожарената сграда (автор P. Voke)

major ash-pile remained to a height of 0.50 m even on the morning of the following day. It was only 29 hours after initial ignition that the ash-pile had sunk to the general level of the house debris.

There were several important observations that could be made about the house-burning sequence (fig. 8). First, the house-burning was a complete success and over 90% of the structure of the house burnt down to the ground. The highest temperatures were found in the centre of the house, just as had been observed on the geophysical plots of many of the

Trypillia houses in the mega-site (Hale 2019; see fig. 2). There was considerable variability in the way that the wall sections fell, provoked by ‘local’ circumstances of construction and timing (i.e., the position in the burning sequence). Only one section – the West section of the South wall – fell outwards as a block c. 1m from the house boundary (fig. 8). The two principal structural features to fall inwards were the two frontons, presumably because there was not enough fuel in the roof to push them outwards. A specific feature that occurred in all walls was the hinging of two segments of the lower parts of the wall along the line of the floor to produce a sandwich-like stratigraphy of the lower wall (fig. 7B). This sometimes followed the sliding-down of the upper part of the wall, so that an inverted stratigraphy was produced of the sandwich of the lower part of the wall above the upper part of the wall (e.g., the East wall: fig. 7B). Very rarely a section of the lower part of the wall fell before the upper wall, as with the middle section of the West wall. This unusual collapse may have occurred because the wattle weaving was not so tight or the daub coating the wall was not so thick.

The temperature of the house-burning has been reconstructed using estimates of the temperatures at which the daub had been fired. Five samples of daub were collected from the burnt house (for locations, see fig. 8) and analysed in the Department of Chemistry, Durham University. The temperatures reached by the daub were consistent with burning at 600–700°C, as established by Thermogravimetric Analysis (TGA) – a method of chemical analysis which measures the changing mass of a substance as a function of temperature when subjected to a controlled temperature programme (Heal 2002, 10–12) (fig. 9)².

What remained as physical evidence of the house-burning was only partly visible; the full picture was to emerge only after excavation of the burnt house remains in 2017 (Johnston et al. 2018). However, the surface remains produced a clear, if partial, picture. There was a halo of burnt grass around all four walls of the house stretching a maximum of 2.50 m (fig. 8) but it was unlikely that this would show up on geophysical plots. A large quantity of ash was produced by the fire but the vast majority of the ash had blown away within 30 hours of the initial ignition (fig. 10). A total of five structural timbers had survived the first day and a half (figs. 8 and 10). However, there were many partially burnt, collapsed wattle-and-daub sections in which the hazel uprights had partially survived. But the overall initial impression was that there was not a large quantity of charcoal produced by the fire. By contrast, there was a great variety of pieces of daub of various colours, all of which had formed from the collapse of the walls. Many fragments of impressed daub could be observed but it was interesting to note that there was little or no relationship between the orientation of the impressions of the fallen daub and the original *in situ* orientation. There were also many fragments of first-floor daub but in poor condition and heavily comminuted through the fall onto the lower building remains. Tellingly, there was no sign of an integrated first floor of clay-coated timber that had survived the fall from above.

Finally, the single-storey house that lay 2 m from the burnt house had no damage to its outside walls, which were warm to the touch but not hot, in contrast to the inner surface of the walls, which retained their normal temperature. Thermal imaging of the interior and exterior of the single-storey house during the fire showed that, for most of the experiment, the outside of the walls was too hot to touch because of the radiated heat from the fire. At the same time, the interior of the single-storey house was comfortable enough to sit in and

² However, the discovery of vitrified daub during the excavation of the burnt house remains in 2017 indicates that higher temperatures were reached (Johnston et al. 2018)

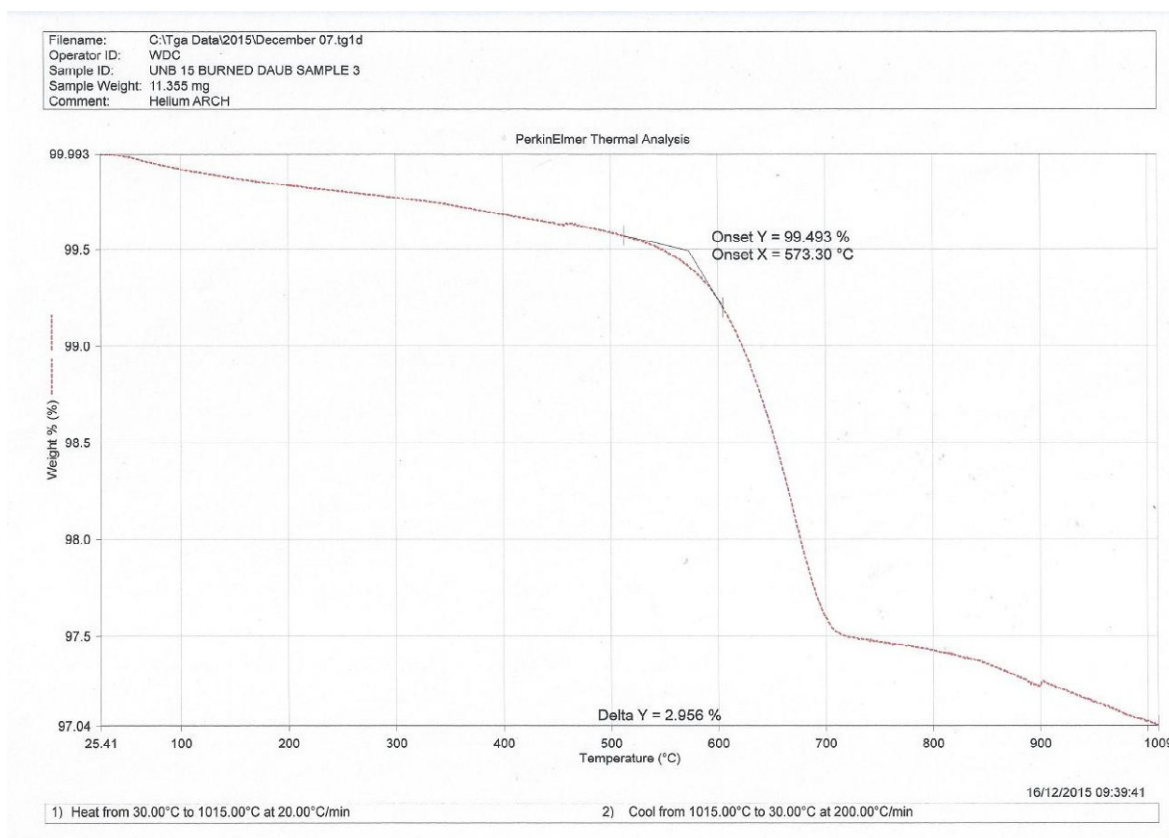


Fig. 9. Plot of Thermogravimetric Analysis (TGA) of a burnt daub sample heated from 30° to 1015° C at a rate of 20°C per minute. On cooling after the initial burning, chemical reactions taking within the daub which resulted in a loss of mass ceased and did not start again until the daub was reheated to the same temperatures during testing. The 2% mass loss between 600°C and 700°C indicates that the daub was previously heated to these temperatures (author S. Johnston)

Обр. 9. Термогравиметричен анализ (TGA) на проба от горяла мазилка, нагрята от 30° до 1015° C при скорост 20°C на минута. При охлаждане след първоначалното изгаряне, химическата загуба на маса се преустановява и процесът не започва отново, докато пробата не се нагрее до същата температура по време на изпитанието. Загубата на 2% маса между 600°C и 700°C показва, че тестото е било предварително загрято до тези температури (автор S. Johnston)

the inside of the wall was only warm to the touch. The thatch would be more vulnerable to spreading fire from windborne sparks and radiated heat but the daub walls remained generally fire-resistant. As with the upstanding section of the East wall of the burnt house, the walls of the first-storey house showed low conductivity – an important factor in the possible spread of a house fire to adjoining structures. The idea of a neighbouring house catching fire very quickly, as has often been assumed in the Balkan literature (Tasić et al. 2015) and Trypillia studies (Burdo 2008; 2011; Kruts 1990; 2003; Videiko 2013), has not been supported by this experiment, although the thatch of the adjacent house would have been the first to catch fire. Nonetheless, if one of a pair of houses built 1 – 2m from each other was deliberately burned, the accidental burning of the second house cannot be completely dismissed (Cotiugă 2009). However, if that second house had not been primed with a filling of dry timber, it would not have burnt down as successfully as a deliberately burnt house, if at all.

The three-dimensional recording of the burnt deposit, made using Structure from Motion (SfM), was completed between 12 noon and 2pm on the day following the main

house-burning. SfM is a multi-image photogrammetric technique that allows the creation of high-resolution 3D datasets from a series of 2D images taken with a normal camera. The technique relies on the principle of reconstructing the camera locations from matching features in overlapping multiple images taken moving around the object of interest (Green et al. 2014). The data collection only took one and a half hour for the burnt remains (160 shots)³. A dense and uniform photo coverage was acquired to record the burnt deposit (fig. 10), with the process of modelling the 3D surface taking c. 12 hours. From the 3D surface of the burnt remains, it is possible to appreciate the micro-topography and overall morphology of the deposit formed after the firing event, as well as to understand the local stacking of the different layers. Moreover, the information derived from the texture highlights the different burning temperatures across the area, thus helping the comparison between the experimental archaeological deposit and the geophysical data from the actual archaeological site. The great detail of the 3D model makes this a good starting point for the elaboration of the 2D plan of the burnt remains (fig. 8). Finally, the two surfaces can be printed in 3D and used in a display in order to have a better sense of what a “reconstructed” Trypillia house might have looked like, both during its use and after its abandonment and destruction.

In summary, our experiment confirms the conclusion of the necessity of adding carefully prepared, additional fuel to guarantee the complete burning of a house. We maintain that the main fuel element was timber, because of the logistical problems of collecting large quantities of animal dung or reeds and their insufficient thermal properties when used alone. The importance of adding additional timber fuel was also suggested by Zinkovskiy (1975), but met criticisms from Kruts on the basis of the estimations of O. Shishov from the Department of Construction Mechanics of the Kiev Engineering and Construction Institute. Kruts noted that the large quantity of timber (25 m³) required for building the first floor and attic of a full-sized Trypillia house became fuel in the process of house-burning (Kruts 1990). This idea later led to Kruts’ assumption of the massive wooden construction of the first storey walls (Kruts 2003; Kruts, Chabaniuk 2007). However, the use of a log-cabin construction would not usually have produced the characteristic *ploshchadka*⁴ found in the vast majority of Trypillia houses.

It was also clear from the surface remains of the burning that walls rather than ceilings / floors had fallen onto the surface of the burned house and were well preserved as daub. These observations require confirmation from the excavation of the experimental burnt house (Johnston et al. 2018). Nonetheless, it is clear that the notion of constructional burning was shown to have no practical significance and can be discarded. Finally, the experimental burning of only one (two-storey) house made it difficult to reach general conclusions about the likelihood of the use of one- or two-storey dwellings, although the presence of daub ‘sandwiches’ was strong circumstantial evidence for a two-storey structure.

Nonetheless, it is important to note that the experiment with the two-storey dwelling also casts light on the burning of one-storey dwellings. This may be exemplified by the recent excavations of the remains of a Trypillia C2 one-storey dwelling in Western Volhynia

3 By comparison, it took about two hours to record all of the parts of the upstanding house that was not burnt (220 shots) The final textured 3D house model can be used to measure and calculate volumes and is also of potential value for exhibition purposes (e.g., the Durham University Palace Green Project exhibition (April 2016).

4 However, the 2003 experiment in Talianki resulted in something like a *ploshchadka*, although the temperature seemed to be lower than was thought necessary for the creation of a burnt daub mass.



Fig. 10. Photogrammetric reconstruction of burnt remains of two-storey experimental house, Nebelivka
(author M. Nebbia)

Обр. 10. Фотограметрично възстановяване на изгорелите останки от двуетажната
експериментална сграда в Небелівка (автор М. Nebbia)

(Diachenko 2016). The reason for the interpretation of a single-floor building was that no fragments of an upper floor, or its fittings, had been preserved. Similar to the Nebelivka experimental house, only one long wall was fired enough to be preserved in a form of burnt daub, probably showing the direction of the prevailing wind. Meanwhile, a clay feature with a grindstone over it was found on the ground floor (Diachenko 2016). Considering the close fit between this excavated one-storey dwelling and the burnt house experiment, we may question if the so-called ‘unburnt or eroded dwellings’ found on the geomagnetic plans could be the remains of one-storey dwellings (Chapman et al. 2014; Rassmann et al. 2014; here, fig. 2). This issue remains to be solved by further excavations and experimentation.

Archaeological implications

We wish to emphasise that the decision to burn only one of the two experimental houses meant that the Project could not fulfil its stated comparative aim of defining the differences in outcome of burning a one- and a two-storey Trypillia house. Although definitive conclusions are rarely possible on the basis of a single case, this house-burning experiment has demonstrated some important aspects of the ‘behaviour’ of two-storey houses which prompt general discussion.

Experiments in Trypillia house-construction and house-burning have been conducted since 1935, with eight house-burning experiments featuring 10 Trypillia and Cucuteni experimental houses (summarised in Burdo 2011; Kruts, Chabaniuk 2007; Korvin-Piotrovskiy et al. 2012)⁵. With the exception of the current experiment, not a single experiment

⁵ These experiments are as follows: 1. Kulska, Dubitska 1930s (Kolomyishchyna); 2. Zinkovskiy in the 1970s (Oleksandrivka and modern town of Bilhorod-Dnistrovskiy); 3. Kruts and Zagnij (Chapaivka) and 4. Korvin-Piotrovskiy (modern village of Letsky) – both were noted in Kolesnikov 1993 and Kruts, Chabaniuk

with one-storey dwellings was successful in terms of the production of remains identical to Trypillia ploshchadka⁶ (Korvin-Piotrovskiy et al. 2012; Kulska, Dubitska 1940; Kruts, Chabaniuk 2007; Zinkovskiy 1982). All experiments confirmed the destruction firing of houses (Kruts, Chabaniuk 2007). Small-scale models appeared to be inappropriate for the aims of experiments in Trypillia house construction and burning – it is possible to fire anything made of clay at relatively low temperatures (e.g., the one-storey model in Talianki: Korvin-Piotrovskiy, Shatilo 2008; cf. the criticisms of this experiment by Burdo 2011). Meanwhile, previous experiments left unanswered issues such as the mode of house construction (log cabin vs. wattle-and-daub house), the presence of an upper floor and the firing of interior fittings (Chabaniuk 2008).

The report on the Cucuteni Archaeological Park experiment involving the burning of four houses, with two accidental and two deliberate firings, has also produced one of the most thorough evaluations of the different hypotheses purporting to explain the phenomenon (Cotiugă 2009). The author concluded (2009, 319) that accidental burnings could not produce the burnt traces of walls and floors repeatedly found in excavations and that large quantities of firewood were required to produce high-temperature daub (2009, 311-2).

The Nebelivka experiment has moved the debate on in five ways:

1. This was the first experiment in which the temperature was high enough to burn the house to produce daub looking like Trypillia daub. There remains the question of whether the fuel on the second storey was necessary for a successful burning. At Dobrovody, preservation of significant fragments of walls of the upper floor (Chernovol 2012; Kruts et al. 2005) would seem to confirm the use of additional fuel on the upper floor. However, Kruts (2003) believed that the temperature of the ground floor fire was sufficient to solidify the upper floor into the resulting ploshchadka, even without fuel on the upper floor. We cannot adjudicate on this question on the basis of the Nebelivka experiment.
2. The destruction of the walls produced remains similar to those found in excavations of what have been considered as floors. Because the floor of the upper storey caught fire quite fast, it divided the walls into two parts. The length of the better-fired upper parts of walls (especially, the Western long wall) corresponds well to the archaeological observations of walls, as in dwelling 4 in Dobrovody, where the high temperature of the walls was notable (Kruts et al. 2005) and the Eastern wall seemed to be preserved for the future as large numbers of small pieces of daub, forming the so-called Greben (Kruts 1990).
3. The upper floor did not fall, in either one piece or in several large fragments, but piecemeal, as small lumps of daub, because the supporting wooden structure had been destroyed by the fire. This result of the Nebelivka experiment goes against Zinkovskiy's (1975; 1983; 2013) unproven assumption of the falling of the upper floor as a single, integrated entity. What Zinkovskiy and others believed was the upper floor was in fact the mixed remains of the floor of the lower storey (the 'ground floor') and parts of the walls. The misleading impression of super-

2007, but without many details . 5. Three small models in Talianki by Kruts. 6. One 1:1 model in Talianki (Kruts, Chabaniuk). 7-8. Two more small-scale models in Legedzyne (Korvin-Piotrovskiy, Shatilo); 9. Cucuteni (Cotiugă 2009); 10. Poduri (Cotiugă 2009); and 11. Nebelivka (this article).

6 Some of the Trypillia experiments, such as in Talianki 2003, produced remains which bore a resemblance to a ploshchadka.

imposed floors in *ploshchadka* excavations, suggesting an upper floor above a ground floor, was most likely the mixed remains of the lower floor and walls, as attested in the Nebelivka experiment.

4. During the discussion regarding the number of storeys, the issue of charcoal was raised on a regular basis. It is notable that the fuel turned into ash, as suggested by Kruts (Kruts 2003; Kruts, Chabaniuk 2007). Moreover, the high amount of ash that could cover ceramics, flint and bone tools could preserve these artefacts from high temperatures, thereby answering one of the main criticisms of Korvin-Piotrovskiy (Kolesnikov 1993) based on the lack of secondary firing of tools. Another explanation for the lack of secondary burning on artefacts could be that the temperature at which the house was burnt was variable across the *ploshchadka*, with some temperatures too low to produce these traces. Until we excavate the burnt remains of the house at Nebelivka, we cannot adjudicate between these two explanations (Johnston et al. 2018)

There were several criteria which could be used to differentiate single- versus two-storey buildings. First, the crumbled, comminuted daub from the fall of a first-floor ceiling would not be found in a single-storey house, where the loft ceiling would have been far less solid. For easier and safer handling, the loft ceiling of the experimental house was constructed with tangentially sawn logs half the thickness of the ceiling below. After burning, it was possible to differentiate between the daub plaster from each ceiling because of the impressions formed by the differently shaped timbers, although there is no evidence to suggest different construction techniques in the archaeological record. Secondly, there would be far fewer cases (if any) of a 'sandwich' of two parts of the lower floor in a single-storey house since the fault-line acting as a hinge would be formed by the line of the ceiling. During excavations, the 'sandwich'-type debris would be manifested as unusually thick overlaying clay blocks which, although known, are extremely rare. Thirdly, the quantity of wall daub in a two-storey house would have been far greater than in a one-storey house. Another important point arising from the comminution of an upper-floor ceiling would be that the absence of the floor falling in a single piece, rather than the sliding-down of the upper floor as proposed by Zinkovskiy (1975), means that none of the hypothesized upper-floor interior fittings and features – whether hearths, platforms, podia or fired clay bins – could have possibly survived a fall of almost 2m intact; in other words, the discovery of intact built features indicates ground-floor interior fittings rather than upper-floor features. However, transformed fittings and features found upside down, or at unusual angles, or in a partial state, may well represent a fall from an upper floor. The view of many Ukrainian archaeologists is that most houses were two-storey and that surviving daub features found superimposed above supposed ground floor segments demonstrate the upper floor. While two-storey houses were certainly common on Trypillia megasites, the Nebelivka experiment showed that this must be proved rather than assumed, since there are alternative ways of producing what appears to be the remains of a two-storey burning (*viz.*, the successive collapse of upper-floor walls or ceilings onto the ground floor).

An important result of the experimental Nebelivka house-burning was the discovery of preserved walls both on the surface outside the house and on the surface inside the house. This settles a long-running debate on Trypillia houses – the presence or absence of

preserved walls (Kolesnikov 1993; Kruts 1990, 2003) – in favour of their presence.⁷ While some incompletely burnt walls may well have disintegrated over millennia, leaving no trace for the archaeologist, there were clearly some areas of walling that had been burnt to such a high temperature as to form a ceramic-like material. The discovery of vitrified daub may be predicted from the observation of a high-temperature blue flame⁸ but awaits confirmation from the future excavation of the burnt house (Johnston et al. 2018). The daub samples so far measured do not confirm firing temperatures high enough for vitrification. What is harder to estimate is the proportion of the original timber and clay which survived to become incorporated into ‘archaeological’ sediments.

A more general issue concerns the reasons for house-burning. While the primary reason for house abandonment – leading to house-burning – would have concerned either preservational factors or social practices, the effects of the decision to burn would have led to the production of some charcoal in the case of well-burnt houses, timber well enough preserved for future building use in poorly burnt or unburnt houses (also conceivably one-storey houses) and timber for firewood in intermediate cases. Given that the Nebelivka IB pollen diagram shows cyclical variations in the rise and fall of arboreal pollen (Albert et al. 2019), the value of building timber may well have increased in periods of reduced forest cover. The location of a new house adjacent to an unburnt house may well have made good locational sense in terms of the recovery of timber from an unburnt house. The alternative to permanent, large-scale occupation of the mega-site would be a smaller and/or a seasonal occupation, in which less dramatic forest clearance and longer periods of forest regeneration, amounting to many decades, may have changed the requirements for building (Gaydarska 2019).

One of the most provocative results of the experiment was the conclusion that many times the quantity of timber was required to achieve a complete burning down of a house as compared to building it. This result extends the significance of the conclusions of the Cucuteni house-burning experiment (Cotiugă 2009: see above, p. 81) by emphasising the sheer quantity of timber fuel required for successful high-temperature combustion. This conclusion has major implications for the management of the landscape and the labour investment required for a complete burn. An estimate of the timber fuel required to fill a full-sized single-storey house based on Müller & Videiko (2016) was just over 150 m³ of timber (4.8 × 12.7 × 2.5 m = 152.4 m³) or over 2,000 trees of standard size. While it could be argued that each of the 100 households in a Nebelivka “Module” could have contributed 1.5 m³ of **firewood** to fill a single house, the collection of fuel would still have been a major logistical operation at a communal level. The combustion of only five full-sized houses at the same time would have required the felling, transport, storage and drying of over 10,000 trees – covering an estimated area of 0.05 km² (after Kruts 1989)⁹. If the community of 100 families living at Nebelivka had made the decision to make a temporary, short-term aban-

⁷ Excavated examples of walls have been found at Nebelivka in House A9 and the mega-structure (see <https://doi.org/10.5284/1047599> sections 5.1 and 5.2.1). The best published example of the preserved wall is *ploshchadka 4* in Dobrovody (Kruts et al. 2005)

⁸ However, the colour of the flame is not only an indication of the temperature but is also affected by the elements being burnt (<http://www.webexhibits.org/causesofcolor/3BA.html>)

⁹ Kruts (1989) estimated the availability of 300 cubic meters of wood from each ha of forest. Hence, 5 houses × 150 m³ of wood means the exploitation of 2.5 ha or 0.025 km². Considering Kruts’ assumption of 50% of forested areas in a mega-site hinterland, this means doubling the area of forest required to 0.05 km² for 5 dwellings (excluding daily needs).

donment of the site and therefore burn down all of the 100 houses on the mega-site, this operation would have led to a massive human impact on the local landscape, in terms of both deforestation for fuel and a massive fire event – the cutting down of two million trees and the production of huge quantities of charcoal – neither of which have actually been witnessed in the pollen/microcharcoal diagram (Albert et al. 2019). Even the planned and simultaneous combustion of 10 houses would have required a major act of social cohesion and mobilisation of labour, which some archaeologists would associate with higher-level decision-making in a complex Trypillia society (Rassmann et al. 2014).

By the same token, unburnt or less burnt houses may have been a result of insufficient fuel, wood that was not dry enough or other variants on the poor or rushed planning of a house-burning. The high proportion of structures which produced weaker magnetic anomalies at Nebelivka (put at 1/3rd: Hale 2019: here, fig. 2) has been previously interpreted as a sign of deliberately not burning a house (Chapman et al. 2014) but may in fact have been caused by one or more kinds of shortcoming in fire management. This alternative interpretation still implies a deliberate decision to burn the house down, even if this may not have been fully successful. There is also a possibility that the geophysical anomalies of lower strength represent one-storey dwellings. We would not exclude any of these possibilities, predicting that structures of different types, in terms of both house-construction and house-burning, will be found in further excavations.

Conclusions

The Nebelivka experimental house-burning has produced a number of important results which sheds light on the overall debate over deliberate house-burning. The experiment demonstrated beyond any doubt that it was possible to burn down a Trypillia-like house given the addition of a sufficient mass of dry timber fuel. This result confounded the general scepticism of many Ukrainian archaeologists present at the performance as to whether we could contrive the burning of the house at all. The quantity of timber fuel was far more than the amount of construction timber – perhaps as much as by a factor of ten. This means that, in the past, we have underestimated the significance of house-burning in terms of the resources and mobilisation of the labour required to complete a successful house-burning. Co-operation between households was even more necessary for house-burning than for house-building. While we can never rule out some cases of non-deliberate burning, our view is that this was usually a rare event in comparison with the most common social practice of deliberate house-burning on Trypillia settlements and on sites in other parts of South East and Central Europe; furthermore, the resultant appearance of accidentally-burnt houses would not have resembled a *ploshchadka*. The large quantities of fuel required and the lack of evidence for a massive fire event in the Nebelivka pollen/microcharcoal diagram (Albert et al. 2019) demonstrate clearly that a widespread, if not whole-site, burning at the end of the mega-site occupation was not feasible and indeed did not occur. By contrast, the continuous microcharcoal curve throughout the mega-site occupation indicates that low levels of house-burning were the norm for the entire period. The implications of the quantity of fuel required for burning a house have provided a possible explanation for the variety of geophysical anomalies detected on recent mega-site excavations – and not only Nebelivka – in terms of a variety of failed or partly successful attempts at still deliberate house-burning which had been thwarted by different kinds of poor fire management. The combustion experiments conducted at Durham showed that there was

no good reason for the practice of construction burning. Although the Nebelivka experiment did not allow a comparison of the burnt remains from one- and two-storey buildings, there are nonetheless some forms of daub remains which can be strongly associated with two-storey buildings and which have been identified in *ploshchadka* excavations.

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References

- Albert, B., Innes, J., Kremenskiy, K., Millard, A. R., Gaydarska, B., Nebbia, M. & Chapman, J. 2019. What was the ecological impact of a Trypillia megasite occupation? Multi-proxy palaeo-environmental investigations at Nebelivka, Ukraine. *Vegetation History and Archaeobotany* 2019. (<https://doi.org/10.1007/s00334-019-00730-9>).
- Burdo, N.B. 2008. *Sacred Space of the Trypillian Civilization*. Kyiv: Nash Chas.
- Burdo, N. B. 2011. Rekonstruktsii domov i poselenij tripolskoj kultury: ot risunkov V. Lhvoiki k 3D modelyam. *Archaeology and Ancient History of Ukraine* 5, 38-52.
- Burdo, N.B. 2013. K.V. Zinkovskiy – issledovatel Tripoliady. *Stratum Plus* 2, 15-23.
- Caple, C., 2014. *Conservation Theory: Ceramic Decay and Conservation*. Durham: Durham University.
- Chabaniuk, V. 2008. New experimental data on the Tripolye house construction techniques. In Korvin-Piotrovskiy, A., Menotti, F. (eds), *Tripolye Culture in Ukraine: The Giant-Settlement of Talianki*. Kiev: Institute of Archaeology of the NAS of Ukraine, 218-226.
- Chapman, J., Videiko, M., Gaydarska, B., Burdo, N., Hale, D., Villis, R., Swann, N., Thomas, N., Edwards, P., Blair, A., Hayes, A., Nebbia, M., Rud, V. 2014. The Planning of the Earliest European Proto-Towns: A New Geophysical Plan of the Trypillia Mega-Site of Nebelivka, Kirovograd Domain, Ukraine. *Antiquity Gallery*: <http://antiquity.ac.uk.ezphost.dur.ac.uk/projgall/chapman339/>

- Chernovol, D. 2012. Houses of the Tomashovskaya local group. In Menotti, F., Korvin-Piotrovskiy, A. G. (eds) *The Tripolye Culture Giant-Settlements in Ukraine: Formation, Development and Decline*. Oxford: Oxbow Books, 182-209.
- Chernovol, D., Ryzhov, S. 2006. Doslidzennya trypils'koho poselennya bilya s. Pishchana. In Gavriliuk, N. A. (ed.) *Archeologichni Doslidzennya v Ukraini 2004 – 2005 gg.*, 373-376.
- Coles, J. M. 1973. *Archaeology by experiment*. London: Hutchinson.
- Cotiugă, V. 2009. Experimental archaeology: the burning of the Chalcolithic dwellings. In Cotiugă, V., Tencariu, F. A., Bodi, G. (eds) *Itinera in praehistoria. Studia in honorem magistri Nicolae Ursulescu*. Iași: Editura Universității 'Alexandru Ioan Cuza', 303-342.
- Diachenko, A. 2016. Tripolskie ploshchadki poselenij Novomalin-Podobanka i Kurgany-Dubova na Zapadnoj Volyni. In Diachenko, A., Krol, D., Kyrylenko, A., Rybicka, M., Verteletski, D. *Novomalin-Podobanka i Kurgany –Dubova –Poseleniya tripolskoj kultury na Zapadnoj Volyni*. Rzeszow: Zimowit, 19-33.
- Forestry Commission 2015. *Rough Guide to Calculating Timber Volumes* [http://www.forestry.gov.uk/pdf/TimberVolumeCalculator.pdf/\\$FILE/TimberVolumeCalculator.pdf](http://www.forestry.gov.uk/pdf/TimberVolumeCalculator.pdf/$FILE/TimberVolumeCalculator.pdf)
- Gaydarska, B. (ed.) 2019. *Early urbanism in Europe: the Trypillia mega-sites of the Ukrainian forest-steppe*. Berlin: De Gruyter.
- Green, S., Bevan, A., Shapland, M. 2014. A comparative assessment of structure from motion methods for archaeological research. *Journal of Archaeological Science* 46, 173-181.
- Hale, D. 2019. Geophysical Investigations and the Nebelivka Site Plan. In Gaydarska, B. (ed.) *Early urbanism in Europe: the Trypillia mega-sites of the Ukrainian forest-steppe*. Berlin: De Gruyter, Section 4.2.
- Heal, G. R., 2002. Thermogravimetry and Derivative Thermogravimetry. In Haines, P. J. (ed.) *Principles of Thermal Analysis and Colorimetry*. Cambridge: The Royal Society of Chemistry, 10-12.
- Jaquin, P., Augarde, C. 2011. *Earth Building: History, Science and Conservation*. Bracknell: IHS BRE Press.
- Johnston, S., Diachenko, A., Gaydarska, B., Nebbia, M., Voke, P., Bondar, Ks., Litkevych, V., Chapman, J. 2018. The experimental building, burning and excavation of a two-storey Trypillia house. In Turcanu, S., Ursu, C.-E. (eds) *Materiality and identity in pre- and proto-historic Europe. Homage to Cornelia-Madga Lazarovici*. Suceava: Karl Romstorfer, 397-434.
- Kolesnikov, O.G. 1993. Trypilske domobudivnytstvo. *Archeologiya* 3, 63-74.
- Korvin-Piotrovskiy, A.G., Chabaniuk, V., Shatilo, L. 2012. Tripolian house construction: conceptions and experiments. In Menotti, F., Korvin-Piotrovskiy, A. G. (eds) *The Tripolye Culture Giant-Settlements in Ukraine: Formation, Development and Decline*. Oxford: Oxbow Books, 210-29.
- Korvin-Piotrovskiy, A., Shatilo, L. 2008. Experimental modelling on Tripolian houses of the Tomashovska local group. In Korvin-Piotrovskiy, A., Menotti, F. (eds) *Tripolye Culture in Ukraine: The Giant-Settlement of Talianki*. Kiev: Institute of Archaeology of the NAS of Ukraine, 199-210.
- Kruts, V. 1989. K istorii naseleniya tripolskoj kultury v mezhdurechje Yuzhnogo Bugu i Dnepra. In Berezanskaya, S. S. (ed.) *Pervobytnaya archeologiya: Materialy i issledovaniya*. Kiev: Naukova dumka, 117-32.
- Kruts, V.A. 1990. Tripolskoe poselenie u s. Talianki i nekotorye voprosy tripolskogo domostroitelstva. In Zbenovich, V. G. (ed.) *Rannezemledelcheskie poseleniya-giganty tripolskoj kultury na Ukraine*. Tezisy dokladov 1 polevogo seminara. Talianki: Institut Archaeologii AN USSR, 43-47.

- Kruts, V.A. 2003. Tripolskie ploshchadki – rezultat ritualnogo sozhzheniya domov. In Korvin-Piotrovskiy, O. G., Kruts, V. O., Ryzhov, S. M. (eds) *Tripolian Settlement-Giants: The International Simposium Materials*. Kyiv: Korvin-Pres, 74-6.
- Kruts, V.O., Chabaniuk, V.V. 2007. Doslidy z trypils'kogo domobudivnytstva. *Materialy ta doslidzennya z archeologii Prykarpattya i Volyni* 11, 30-37.
- Kruts, V.A., Korvin-Piotrovskiy, A.G., Ryzhov, S.N., Buzian, G.N., Ovchinnikov, E.V., Chernovol, D.K., Chabaniuk, V.V. 2005. *Issledovanie poselenij-gigantov tripolskoj kultury v 2002 – 2004 gg.* Kiev: Korvin-Pres.
- Kruts, V., Korvin-Piotrovskiy A., Ryzhov, S., Chernovol, D. 2008. The 2005 – 2006 research in Talianki. In Korvin-Piotrovskiy, A., Menotti, F. (eds) *Tripolye Culture in Ukraine: The Giant-Settlement of Talianki*. Kiev: Institute of Archaeology of the NAS of Ukraine, 82-108.
- Kulska, O.A., Dubitska, N.D. 1940. Budivelni materialy trypils'koi kultury (khimiko-tekhnologichnyj analiz). In Yachmeniov, M. I., Passek, T. S., Slavin, L. M. (eds) *Trypilska kultura. Tom 1*. Kiev: Vydavnytstvo AN URSR, 325-34.
- Mitchell, G. 1982. *Carpentry and Joinery*. London: Cassell.
- Müller, J., Videiko, M. 2016. Maidenetske: New Facts of a Mega-Site. In Müller, J., Rassmann, K., Videiko, M. (eds) *Trypillia-Megasites and European Prehistory 4100-3400 BCE* (EAA Monograph No. 2). Wakefield: Maney, 71-94.
- Nebbia, M. 2016. *Early cities or large villages?: settlement dynamics in the Trypillia group, Ukraine*. Unpublished Ph.D. thesis, Durham University.
- Pashkevych, G., 2012. Environment and economic activities of Neolithic and Bronze age populations of the Northern Pontic area. *Quaternary International* 261, 176-182.
- Passek, T.S. 1949. Periodizatsiya tripolskikh poselenij (III–II tys. do n.e.). *Materialy i issledovaniya po archeologii SSSR* 10. Moskva: Nauka.
- Rassmann, K., Ohlrau, R., Hofmann, R., Mischka, C., Burdo, N. Videjko, M. Yu., Müller, J. 2014. High precision Tripolye settlement plans, demographic estimations and settlement organization. *Journal of Neolithic Archaeology* 16, 96-134.
- Shevchenko, N., Gaydarska, B. 2019. Building material analyses. In Gaydarska, B. (ed.) *Early urbanism in Europe: the Trypillia mega-sites of the Ukrainian forest-steppe*. Berlin: De Gruyter, Section 4.9.
- Shmaglii, N., Videiko, M. Yu. 2003. Maidanetskoe – tripolskij proto-gorod. *Stratum plus* 2, 44-140.
- Shumova, V.O., Ryzhov, S.M. 2003. Trypillia culture in Podillia in the light of new data. In Zalizniak, L., Carter, J. C. (eds) *Archaeology in Kyiv-Mohyla Academy*. Kyiv: Kyiv-Mohyla Academy, 88-106.
- Stevanović, M. 1997. The age of clay: the social dynamics of house-construction. *Journal of Anthropological Archaeology* 16, 334-395.
- Schier, W. 2008. Uivar. A late Neolithic-early Eneolithic fortified tell site in western Romania. In Bailey, D. W., Whittle, A., Hofmann, D. (eds) *Living Well Together ? Settlement and Materiality in the Neolithic of South-East and Central Europe*. Oxford: Oxbow Books, 54-67.
- Tasić, N., Marić, M., Penezić, K., Filipović, D., Borojević, K., Borić, B., Cook, G., Reimer, P., Bayliss, A., Barclay, A., Gaydarska, B., Whittle, A. 2015. The end of the affair: formal chronological modelling for the top of the Neolithic tell of Vinča-Belo Brdo. *Antiquity* 89, 1062-84.
- Tringham, R. 2005. Weaving house life and death into places: a blueprint for a hypermedia narrative. In Bailey, D., Whittle, A., Cummings, V. (eds) *(un)settling the Neolithic*. Oxford: Oxbow Books, 98-111.

- Videiko, M.Yu. 2005. Architektura trypil'skykh poselen VI–III tys. do n.e. In Videiko, M. Yu., Terpylovskiy, R. V., Petrashenko, V. O. (eds) *Davni poselennya Ukrainy*. Kyiv: Instytut archeologii NANU, 10-80.
- Videiko, M.Yu. 2013. *Kompleksnyj analiz krupnykh poselenij tripolskoj kultury (V – IV tys. do n.e.)*. Saarbrücken: Lambert Academic Publishing.
- Zinkovskiy, K.V. 1975. Do problem trypil'skogo zhytlobuduvannya. *Archeologiya* 15, 13-22.
- Zinkovskiy, K.V. 1982. Znachenie modelirovaniya v issledovanii ostatkov postroek na poseleniyah tripolskoj kultury. In Dzis-Raiko, G. A. (ed.) *Archeologicheskie pamyatniki Severo-Zapadnogo Prichernomorja*. Kiev: Naukova Dumka, 19-32.
- Zinkovskiy, K.V. 1983. K protsedure issledovaniya domostroitelstva tripolskikh plemen. In Dzis-Rajko, G. A. (ed.) *Materialy po archeologii Severnogo Prichernomorja*. Kiev: Naukova Dumka, 16-22.
- Zinkovskiy, K.V. 2013. Zhilishcha plemen tripolskoj kultury. *Stratum Plus* 2, 27-100.
- Web References: <http://www.webexhibits.org/causesofcolor/3BA.html>

Експериментално построяване и опожаряване на жилище в Небеливка, 2014–2015 г.

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(резюме)

Статията дискутира резултатите от експерименталната програма на англо-украинския проект „Ранен урбанизъм в праисторическа Европа?: Трипилските¹⁰ мега-селища“ (2009–2017 г., с прекъсвания), финансиран от Съвета за изследвания в областта на изкуството и хуманитарните науки. Този многогодишен проект цели по-добро цялостно разбиране на феномена на трипилските мега-селища, които засега остават най-големите селища в Европа през IV хил. пр. Хр. Основната изследователска дейност на проекта е свързана със селището Небеливка (238 хектара), Новоархангелск, Кировоградска област, което пространствено и културно се свързва с праисторическата мрежа Трипилие (известна в по-старата литература като култура Триполие). Полевият аспект на този интердисциплинарен проект включва интензивни и систематични обходи, геофизични измервания, палео-екологични изследвания, разкопки и експериментална програма. Геофизичните измервания произведоха единствения за сега цялостен план на трипилско мега-селище. Резултатите от проекта могат да бъдат проследени чрез две медии – подробно представяне на суровите данни на архивната платформа, поддържана от Университета на Йорк (York Archaeological Data Service) (<https://doi.org/10.5284/1047599>), и дигитална интерепретативна монография с отворен достъп.

¹⁰ Терминът „Трипилие“ (вместо традиционно използвания в българската научна литература „Триполие“) е въведен по изрично настояване на авторския коректив, в който има български и украински представители (бел. ред.)

Тази статия представя част от резултатите от експерименталната програма, по-специално построяването на две жилища в мащаб 2/3 от нормалните размери – едно едноетажно и едно двуетажно, и опожаряването на двуетажното жилище (2014–2015 г.). Украинската и румънска археология (в чиито модерни граници е разпространена праисторическата мрежа Кукутени–Трипилие) имат традиции в експерименталното построяване и опожаряване на жилища, но степента до която резултатите от експериментите отговарят на археологическите данни сериозно варира. По тази причина бе решено в рамките на проекта да се построят и опожарят две жилища за целите на последващ сравнителен анализ. По-конкретно, експериментът бе замислен да допринесе в следните четири направления:

- а) възможността огънят да е част от процеса на построяване на жилищата;
- б) разлики в опожарените останки на едноетажното и двуетажното жилище, които биха могли да служат като индикатор за подобно разграничаване в археологически контекст;
- в) количеството гориво, необходимо за успешно опожаряване;
- г) вероятността опожаряването да е преднамерено.

Особено важен е приносът в последното направление. Докато повечето украински и някои румънски и молдовски праисторици са на мнение, че кукутенско-трипилските жилища са изгаряни нарочно, голяма част от европейските (вкл. балкански) праисторици изразяват сериозни съмнения за по-широкото разпространение на тази практика (напр. Tasić et al. 2015; Schier 2008).

Двете жилища бяха построени за 214 човекодни, или с други думи в рамките на 3 седмици, като броя и уменията на работната ръка варира. Употребата на модерни инструменти до известна степен обяснява сравнително бързото построяване, но е много важно да се посочи, че конструкцията не съдържа метал (напр. пирони) и всички свързки за от дърво или коноп. Единствено дървеният материал за основното скеле на конструкциите бе закупен и готово нарязан (2,52 м³ за едноетажното и 3,44 м³ за двуетажното). Всички останали компоненти (камъш, глина и т.н.) бяха набавени на местна основа с помощта на местното население. Този процес доведе до осъзнаването на очевиден, но пренебрегван факт, че праисторическите постройки са своеобразен микрокосмос на окръжаващата среда – земята, водата, дърветата, тръстиките формират материален ансамбъл, наречен дом.

Съпротивата на местните власти относно опожаряването на експерименталните жилища, независимо от първоначалното съгласие, доведе до компромисния вариант да се изгори двуетажното жилище, докато едноетажното да остане като културен паметник. Почти 30 м³ дървен материал бе внимателно нареден на двата етажа на постройката (от пода до тавана), като специално внимание бе обърнато подреждането да осигурява достъп на кислород. Огънят бе запален в 12,50 ч. на 14 май 2015 г. и продължи да гори до средата на следващия следобед. Бяха документирани общо 31 етапа (Таблица 6, обр. 6), фокусирани главно върху основните фази на разрушаване на къщата. По-голямата част от конструктивните елементи на къщата паднаха в рамките на четири часа от запалването.

На базата на наблюденията, направени по време на този експеримент и подобен, извършен в ботаническата градина на Университета на Дъръм, се стигна до следните заключения относно поставените по-горе цели:

- а) по практически причини, огънят не би могъл да е част от процеса на постро-

яване на жилищата;

б) независимо че едноетажното жилище не бе опожарено, бяха документирани редица особености, които биха могли да служат като показател за разграничаване на едноетажни и двуетажни жилища в археологически контекст;

в) едно от най-шокиращите открития е голямото количество гориво, необходимо за успешното опожаряване на експерименталното жилище и изводите за количеството гориво за жилище с нормални размери, както и за комплекс от 100 такива жилища, което носи сериозни последици за околната среда;

г) с оглед на почти идентичните останки на експерименталното опожаряване и археологическите контексти не може да има съмнение, че опожаряването на Трипилските жилища е било преднамерено.

Експериментът в Небеливка постигна редица важни резултати, които хвърлят светлина върху дебата за преднамереното изгаряне на жилища. Той показва без всякакво съмнение, че е възможно да се изгори трипилска къща, при условие че е добавена достатъчна маса сухо дърво като гориво. Количеството дървесина за опожаряване е почти десет пъти повече от количеството дървен материал за построяване. Това означава, че досега ресурсите и усилията за организирането на работата, необходими за успешното изгаряне на жилището са били сериозно подценявани. Сътрудничеството между домакинства вероятно е било по-необходимо за изгарянето на жилищата, отколкото за тяхното построяване. Въпреки че не може да се изключат случаи на неумишлено изгаряне, по наше мнение, това обикновено се случва рядко в сравнение с най-често срещаната социална практика на преднамерено опожаряване на жилища в Трипилски селища и в други части на Югоизточна и Централна Европа.