

# Approaching the unification and diversity of pottery assemblages: the case of Western Tripolye culture ceramics in the Southern Bug and Dnieper interfluvium, 4100–3600 cal BC

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**ABSTRACT** – *This paper questions the cycling nature of the unification and diversity of pottery forms through a case study of ceramics of the Western Tripolye culture in the Southern Bug and Dnieper interfluvium in modern Ukraine. We identified the cultural cycle representing the transition from more unified ceramic assemblages to more diverse ones, and then back to more unified assemblages. This cultural cycle is disturbed by the increase in the diversity of pottery sets at three of ten subsequent time periods we have analysed. The obtained results are discussed in frames of deterministic explanations and the dynamic behaviour of complex systems.*

**KEY WORDS** – *cultural cycles; unification; diversity; complex systems; pottery assemblages; Cucuteni-Tripolye cultural complex; Western Tripolye culture*

## **Pristop k poenotenju in raznolikosti zbirov lončenine: primer keramike zahodne kulture Tripolye v južnem medrečju Buga in Dnepra v času 4100–3600 pr. n. št.**

**IZVLEČEK** – *V članku se sprašujemo o ciklični naravi poenotenja in raznolikosti keramičnih oblik s pomočjo študijskega primera lončenine iz zahodne tripoljske kulture na območju južnega medrečja Buga in Dnepra v sodobni Ukrajini. Prepoznali smo kulturni cikel, ki predstavlja prehod iz bolj poenotenih keramičnih zbirov k večji raznolikosti ter prehod nazaj k bolj enotnemu zbiru. Ta kulturni cikel zmoti naraščanje raznolikosti lončeninskih zbirov v treh od desetih zaporednih časovnih obdobjih, ki smo jih analizirali. Dobljene rezultate obravnavamo v okviru determinističnih razlag in dinamičnem vedenju kompleksnih sistemov.*

**KLJUČNE BESEDE** – *kulturni cikli; poenotenje; raznolikost; kompleksni sistemi; zbiri lončenine; kulturni kompleks Cucuteni-Tripolye; zahodna kultura Tripolye*

## **Introduction**

The process of cultural unification in prehistory made the world look similar, but not homogenous. This phenomenon may be compared with modern globalisation, although significant difference be-

tween the two processes should be also highlighted. In archaic societies, as opposed to modern ones, cultural unification was much slower and took hundreds and thousands of years (Bauman 2001). In

many cases cultural unification was accompanied by the formation of numerous cultural groups and regional variations characterized by Modderman as “*diversity in uniformity*” (1988).

This paper examines the cycling nature of the unification and diversity of pottery forms through a case study of ceramics of the Western Tripolye culture in the Southern Bug and Dnieper interfluvium in modern Ukraine. First, we will briefly review the concept of cycles in philosophy, natural and social sciences, complementing the earlier review of Detlef Gronenborn and co-authors (Gronenborn et al. 2017). Second, we will present our sample and methodology of approaching unification and diversity. Third, we will discuss the results and their implications for further research in archaeology.

### Cycles in natural and social phenomena

*Cambridge Dictionary (online)* defines a cycle as “*a complete set of events that repeat themselves regularly in the same order, or a regularly repeated period of time*”. The first attempts at the depiction of socio-political and economic events as cycling are known from the philosophers of Ancient Greece (Liddel 2010). Among the most important historians who described the development of the Roman Empire using the concept of cycle was Polybius (Kimla 2009). His ideas, and particularly the elements of degenerationism, were adapted centuries later by the Renaissance thinker Niccolò Machiavelli (Kenny 2005). A systematic approach to history as a series of recurring cycles then started in the 19<sup>th</sup> century. It was assumed that history has a repetitive rhythm, that no historical events are completely unique, as after some time the course of history returns to its starting point, or at least to states similar to those that took place earlier. What happens now is thus not a culmination, but only a transitional stage of the process (Sztompka 2012).

The Russian philosopher Nikolai Danilevskiy, in his work titled ‘*Russia and Europe*’, stated that the issue of development refers not to humankind as a whole but to civilisations. Each civilisation goes through a normal life cycle. The first stage is the occurrence of civilisation as a synthesis of previously scattered cultural elements. The second is the achievement of real cultural and political distinctiveness, the third stage is the blossoming of civilisation, and the fourth is stagnation and apathy. Finally, the fifth is the break-down and the fall of the civilisation (Danilevskiy 1895). A very similar approach was pre-

sented by Oswald Spengler, who claimed that history does not have any universal laws, but that each cultural item has its own laws and goes through certain phases – from the rise and peak, to its fall and destruction (Spengler 2014).

In sociology, the first theory of historical cycles was introduced by Vilfredo Pareto in the 19<sup>th</sup> century. In his view, a social system in constant motion represents a smooth transition from a state of equilibrium to destabilization, and to a collapse of the equilibrium and the re-establishment of a state of equilibrium (Pareto 1975). These four stages of development were also used by Karl Marx and later by Gordon Childe in one of his most important works, titled ‘*Man Makes Himself*’, published in 1936 (Lech 1999). In modern sociology, the most interesting cyclic theory was formulated by Pitirim Sorokin in ‘*Social and Cultural Dynamics*’, published in the late 1930s (Sorokin 1937). According to this, the social world consists of holistic socio-cultural systems. The main element of each system is the *cultural mentality*, on which other elements of the system depend. In other words, the history of humankind is the cycle of changes of cultural mentality. Therefore, the shape of history is not linear, but is defined by the recurring rhythm of cultural changes. The mechanism of changes is regulated by the internal capabilities of each socio-cultural system. Worth highlighting here is that there is a limit to the possibility of cultural development, beyond which a given cultural mentality is exhausted, loses the possibility of expansion and is not able to develop. Then a *syncretic mentality* appears containing both elements of the previous and new cultural mentality in order to give way to the newly emerging cultural mentality, which at that moment has an expansive and creative potential. And so the cycle goes on and on (Sorokin 1937). External factors, such as environment, diffusion or conquest are of secondary importance – those can influence the length of the phases of each cycle, but are not able to replace its endogenous logic (Sztompka 2012).

The humanities and social sciences, including archaeology, consider different concepts of time. The first concept, so-called *event history* is mainly related to political events. Another, *cyclical time*, refers to business cycles (see below). The last concept, *longue durée*, characterizes changes in social structures and the history of civilisations. In this case studies cover a period of several centuries (Braudel 1999). The idea of *longue durée* was used, among the others, by Charles Cobb (1991) to identify the pheno-

mena responsible for cultural changes among prehistoric societies in American Middle West.

Another concept from Fernand Braudel, directly related to the *longue durée*, is based on the idea of *centre* and *periphery* (Braudel 1992). This concept was further developed by Immanuel Wallerstein (1974) in his world system theory. He distinguished three stages of human development. The first is the epoch of 'mini-systems', small self-sufficient communities which are typical of hunter-gatherers societies. The next stage is the 'epoch of empires', and the last one is the 'global system'. It is worth highlighting that these systems consist of central, peripheral and marginal zones which are related to each other. The changes in the centre are mirrored by those in the periphery and *vice-versa*. This concept is often used by archaeologists, especially in research concerning the Bronze and Iron Ages in Europe (e.g., Kristiansen 1994; Sherratt 1994; Kadrow 2001; Kristiansen, Larsson 2005).

The idea of cycles has also been widely adapted by natural scientists to report various phenomena. One of the first was Milutin Milanković, who described long-term climate changes caused by changes in the position of Earth in relation to the Sun, the so-called *Milankovitch cycles*. This theory explains the ice ages that repeatedly occurred in the geological past, as well as the climate changes which may occur in the future (Hays et al. 1976; Campisano 2002). The idea of cyclical phenomena was used to recognize the glacial-interglacial cycle of vegetation changes (Fig. 1; Iversen 1958), solar cycles (increasing sun irradiance every 11 years – Hathaway et al. 1999) and their influences on human disease and adaptability (Davis, Lowell 2006); to identify earthquakes cycles (O'Malley et al. 2017; Galvez et al. 2019) or to explain epidemic cycles (Althouse, Hébert-Dufresne 2014). However, we should also admit that there are critics of cycles in the natural sciences, including the cycling nature of earthquakes (Bak 1996). To a certain extent, human beings 'look for' cycling behaviour in non-cycling phenomena, trying to predict negative

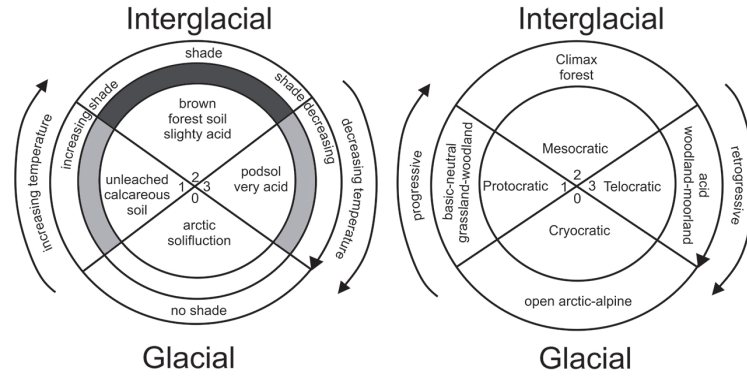


Fig. 1. Glacial and post-glacial cycles (redrawn from Iversen 1958).

events and thus become protected from their impacts (Bak 1996).

The other widely known cycles are business and product life cycles. Both are used by economists to describe fluctuations in economic system and the sales of individual products. Business cycles occurring in the economy represent wide changes in total output, incomes and employment, usually lasting from two to ten years. We can distinguish two main phases of business cycles – expansion and recession – with peaks and troughs marking the turning points (Fig. 2). A key important observation is that there no identical cycles, and the precise prediction of their duration and timing is not possible (Samuelson, Nordhaus 1995).

Very similar to the aforementioned cycle is the product life cycle, characterizing the period in which the product is presented to the market. This case also includes four stages: introduction, growth, maturity and decline (Fig. 3; Altkorn 2004).

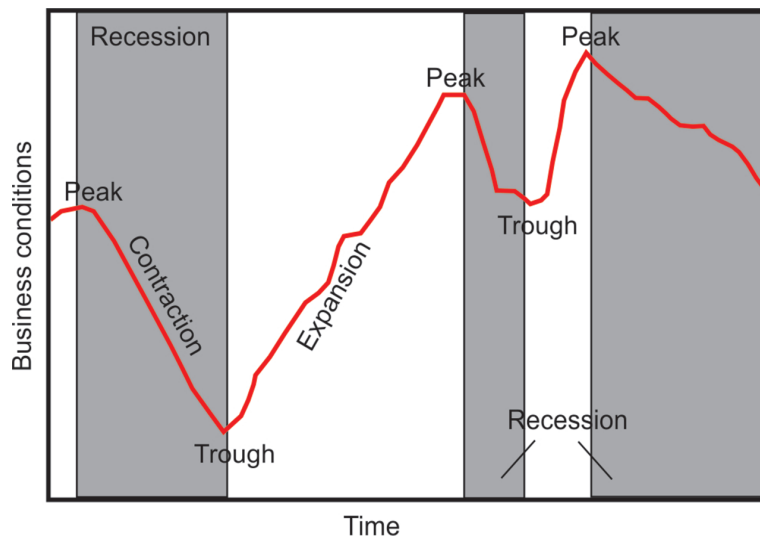
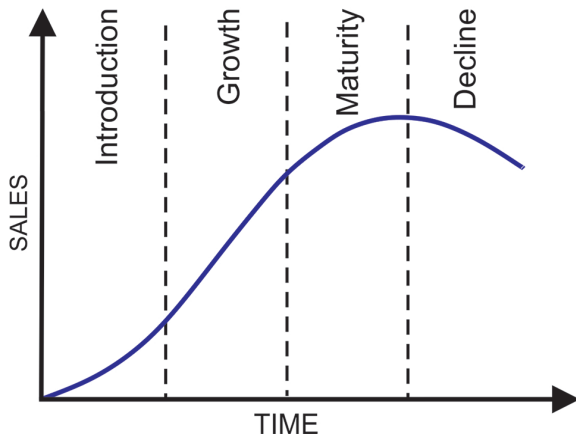


Fig. 2. A scheme of business cycle (redrawn from Samuelson, Nordhaus 1995).

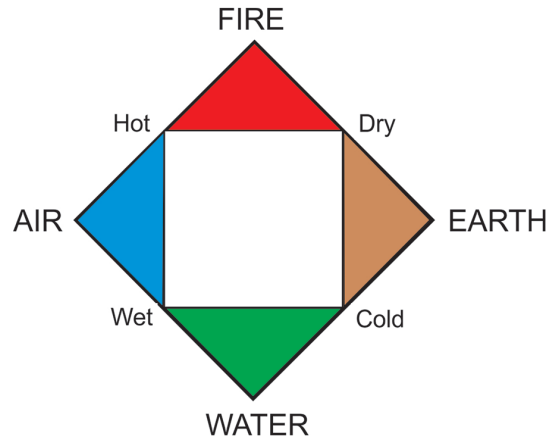


**Fig. 3. Product life cycle curve (redrawn from Altkorn 2004 with modifications).**

It is worth noticing that, regardless of the field the concept of cycle is applied to, four distinct phases of changes are distinguished. This phenomenon resembles the Aristotle's quartet, which he adopted from Plato, although it appears even earlier with Empedocles. This earlier quartet distinguished four elements, namely earth, air, fire and water, which can be set alongside the previous concepts of change presented by Thales, Anaximander, Heraclitus and Xenophanes (Fig. 4; Ball 2004).

Adaptive cycles are also widely applicable to describe patterns of changes in complex systems, both in ecosystems and social systems. Ecologists have noticed that each cycle consists of four phases: *rapid growth, conservation, release* and *renewal* (Fig. 5). The key-point in this case is an assumption about the dynamics of structural and functional properties and also processes. It means we are able to distinguish periods of growth, destruction and decomposition varying over scales of space and time (Angeler et al. 2015). Further development of the idea of adaptive cycles indicates that they mirror the unavoidable dynamics of complex adaptive systems, resulting in the internal process of self-organization and evolution along time (Sundstorm, Allen 2019).

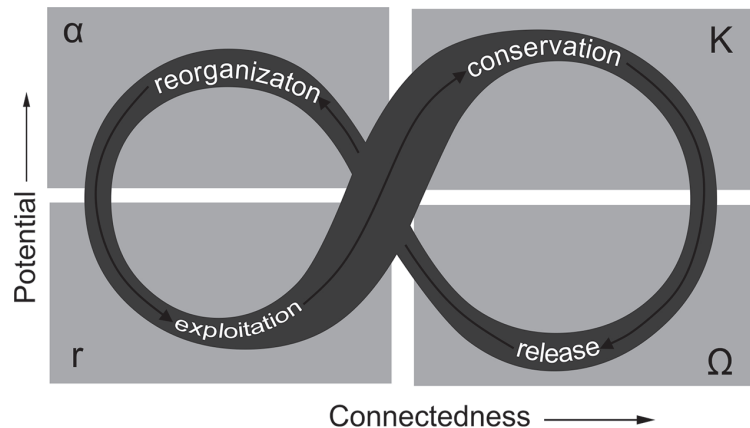
Over the last two decades the concept of adaptive cycles was borrowed from socioeconomics and ecology and applied in many others fields, including social sciences and the humanities. For instance, this concept was used by Jared M. Diamond (2005) to approach the rise and fall



**Fig 4. Aristoteles' quartet. The four elements of Empedocles, imbued with two qualities, by means of which they could be transformed (redrawn from Ball 2004).**

of pre-historic, ancient and modern societies. It can be also applied to recognize changes in current western societies, driven by factors such as technology, industry or digitization (Gilpin 2000).

Adaptive cycles are also being investigated in archaeology. The leitmotif of these studies is the statement made by Gunderson and Holling that "*Resilience is the ability of the system to return to the original state after disturbance*" (Gunderson, Holling 2002). Andreas Zimmermann (2012) proposed using the term cultural cycles to refer to Central European prehistory, especially in relation to agrarian societies. The crucial results of his research are that: (a) cultural cycles caused by internal factors such as the dynamics of social and economic relations are an alternative to external ones, *i.e.* climate fluctua-



**Fig. 5. Graphical representation of the four phases of the adaptive cycles. r rapid growth; K conservation; Ω release; α renewal. The cycles mirroring changes in two properties: Y axis: the potential that is inherent in the accumulated resources of biomass and nutrients; X axis: the degree of connectedness among controlling variables (see Gunderson, Holling 2002.6–8, Fig. 1).**

tions; (b) cultural memory and traditions are pivotal factors that influence the cultural system; (c) cultural evolution is marked by stages and traditions; (d) the complexity of cultural systems is noticeable by the non-linear changes over the middle and long-term time scales. The concept of ‘adaptive cycle’ was also used by Gronenborn and co-authors (2014) in a study of LBK development in Western Europe. More recently, they applied the theory of adaptive cycles to recognize the population dynamics and social resilience strategies in early farming societies of SW Central Europe (Gronenborn et al. 2017; 2018). Following the studies conducted by Gronenborn and his co-authors, our paper focuses at the following questions: (1) are ceramic styles developed in cycles from more unified to more diverse, and then back to more unified? and (2) what factors impact the transitions from more unified to more diverse and from more diverse to more unified pottery assemblages?

## Data input and estimations

### Method

The philosophical connotations suggested for ‘heyday’ and ‘decline’, as broadly presented above, in most cases correspond to widely used archaeological categories of ‘unification’ (approximating ‘birth’ and ‘death’) and ‘diversity’ (approximating ‘growth’). Both of these categories can be quantified with the application of Claude Shannon’s diversity index (Shannon 1948). Providing numerical values for ‘unified’ and ‘diverse’, this approach suggests a gradual transition from one to the other as a reasonable alternative to the widely accepted understanding of the two categories as binary oppositions. The utility of the diversity index is confirmed by its successful applications in archaeology (e.g., Justeson 1973; Dickens Jr., Fraser 1984; Bevan et al. 2012; Furholt 2012; Crema 2015; Gronenborn et al. 2017; 2018; Drost, Vander Linden 2018).

Shannon’s index is estimated as:

$$H = -K \sum_{i=1}^N p_i \log p_i \quad (\text{eq. 1})$$

where  $H$  is the entropy taken for a measure of diversity,  $p_i$  is the proportion of elements belonging to the  $i$ -th type ( $\sum p_i = 1$ ), and  $K$  is the normalizing coefficient (Shannon 1948).

### Data input

We have tested the possible cyclic nature of the development of pottery styles using an example of ceramic assemblages of Western Tripolye culture (he-

reinafter – WTC) sites in the Southern Bug and Dnieper interfluvium, modern Ukraine dated to *c.* 4100–3600 cal BC (Fig. 6). This region is widely known for Tripolye mega-sites, the largest population agglomerations in Neolithic Europe, *i.e.* Nebelevka, Dobrovody, Chicherkozovka, Talianki and Maidanetske (e.g., Menotti, Korvin-Piotrovkiy 2012; Müller et al. 2016b). Materials from the mega-sites of Chicherkozovka and Talianki are included into our sample.

Taxonomically WTC belongs to the Cucuteni-Tripolye cultural complex (hereinafter – CTCC) spread from the Carpathians in the west to the eastern bank of Dnieper in the east, *c.* 5000–3000/2950 cal BC. The internal structure of WTC includes ‘genetic lines’ subdivided into local groups, some of which also include site-types (e.g., Dergachev 1980; Ryzhov 2007). It should be noted that the term ‘genetic lines’ proposed by Dergachev reflects the similarity and change in ceramic assemblages of local groups replacing each other over time (Dergachev 1980). The difference in pottery styles and duration of existence decreases from the top down in this taxonomic hierarchy.

Based on pottery seriation, Sergii Ryzhov (1993; 2000a; 2007; 2015) included the sites which are analysed in this paper into Vladimirovskaya, Nebelevskaya and Tomashovskaya local groups. These three local groups form the Vladimirovsko-Tomashovskaya line of development of WTC. Phases (if not subdivided into stages) and stages of development of local groups include synchronous settlements. Synchronous ceramic assemblages have identical sets of pottery forms, while the percentage of vessels of each type across different sites is similar, varying only up to a few percent. Therefore, significant changes in relative frequencies estimated for pottery of different shapes and ornamentation schemes indicate the chronological difference between the sites. Secondary characteristics, such as modifications in ornamentation schemes or ‘signs’ on pottery, may be considered as markers of either chronological or spatial differences (Ryzhov 1999).

Initially the Vladimirovskaya group settlements were not subdivided into phases of development, while two phases were distinguished in the Nebelevskaya group. The ceramic assemblage of the settlement of Gordashevka 1 indicated its intermediate chronological position between the Vladimirovskaya and Nebelevskaya local groups (Ryzhov 1993). The Tomashovskaya group sites were subdivided into four stages of development (Ryzhov 2000a). Further ap-



the Southern Bug and Dnieper interfluvium, the mega-site of Fedorovka (Ryzhov 2015). Analytical periods 2 and 3, or the second and third stages of the Vladimirovskaya group, were distinguished based on spatial statistics and second-order criteria in pottery seriation (Diachenko, Menotti 2012; Ryzhov 2015). Unfortunately, the data for the precise estimation of pottery types for these analytical periods was not available to us. Therefore, the related values were contingently reduced to zero in our analysis.

Analytical periods 4 and 5 correspond to the first phase and first stage of the second phase of the Nebelivskaya group, respectively. The numbers estimated for analytical period 4 are represented by the mean values which were obtained for pottery types coming from Houses 1, 2 and 3 excavated at the settlement of Peschanoe (Ryzhov 1991; Chernovol, Ryzhov 2006). The numbers estimated for analytical period 5 are the mean values which were obtained for ceramic assemblages coming from Houses 1 and 2 excavated at the large settlement of Glubochek (Ryzhov 2000b).

The subsequent five analytical periods correspond to the first and second phases, the first and second

stages of the third phase, and the fourth phase of the Tomashovskaya local group. The numbers estimated for analytical period 6 are the averages obtained for pottery collections which resulted from the surveys and excavations conducted in the 1920s at the sites Popudnia, Staraya Buda and Sushkovka in the Southern Bug and Dnieper interfluvium (Ryzhov 2000a). The values for analytical period 7 were estimated from the ceramic assemblage coming from House 1 excavated at the mega-site of Chicherkozovka (Ryzhov 2000a). The numbers estimated for analytical period 8 are the mean values obtained from the pottery collections which come from excavations of Houses 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 at Talianki (from excavations in the 1980s directed by Vladimir Kruts; Ryzhov 2000a). Analytical period 9 is represented by the mean values obtained for a set of vessels from the excavations of House 1 at the small site of Moshurov 1, the off-spring of the mega-site of Maidanetske (Ryzhov 2000a). Finally, the numbers for analytical period 10 are the mean values estimated for ceramic collections which come from surveys at the settlements Bondarka 2 and Goncharykha (Ryzhov 1999; 2000a).

The number of pottery fragments at each analytical period in our sample varies from c. 1000–2000 (analytical periods 1, 6, 7, 9 and 10) to c. 4000–6000 (analytical periods 4 and 5). In the case of analytical period 8, the sample includes c. 25 000 pottery fragments. Ordinarily one would normalize the estimated values in order to obtain statistically significant results. However, this is not necessary in our case for the following reasons. Pottery of different shapes is distributed in approximately the same percentages in dwellings at synchronous settlements. Therefore, the relative number of ceramics belonging to different morphological types does not change, when the absolute number of fragments increases with adding an assemblage from a house or two from the same site or some other contemporaneous settlement. For example, the percentages of different pottery types in Talianki estimated as a mean for the assemblages from 11 houses do not

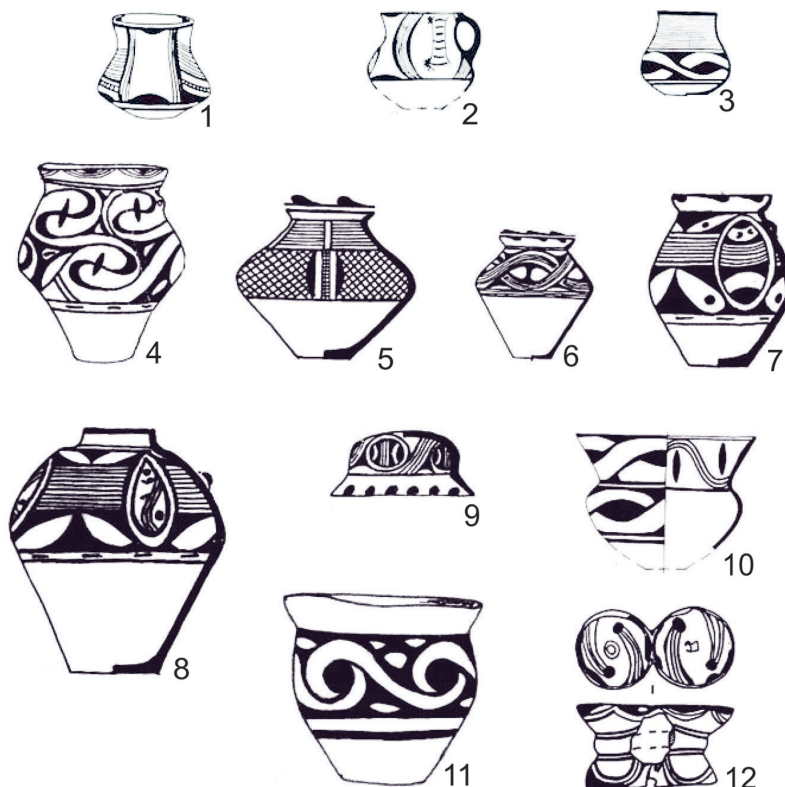


Fig. 8. Western Tripolye pottery shapes: 1, 3 goblets; 2 goblet-shaped vessel; 4, 7 amphorae; 5 sphere-conical vessel; 6 biconical vessel; 8 pear-shaped vessel; 9 lead; 10, 11 craters; 12 binocular-shaped vessel (re-drawn from Ryzhov 2015).

change with excluding ceramic sets from several houses from the sample. In other words, the mean percentage of pottery types from seven, nine or 11 houses remains the same. The relative frequencies of pottery in unbiased surface collections are also similar to the distributions in house inventories. For instance, the percentage of forms estimated from *c.* 2000 ceramic fragments from House 1 in Chichirkozovka corresponds to the percentage of forms estimated from several thousand ceramic fragments from surface collection (the surveys of Ivan Girnyk, with data analysed by Sergey Ryzhov). Moreover, the WTC 'assembly places', which differ from other houses by their size and location in settlement structure are characterized by the same house inventories as other dwellings at particular sites (*e.g.*, *Nebbia et al. 2018; Hofmann et al. 2019*).

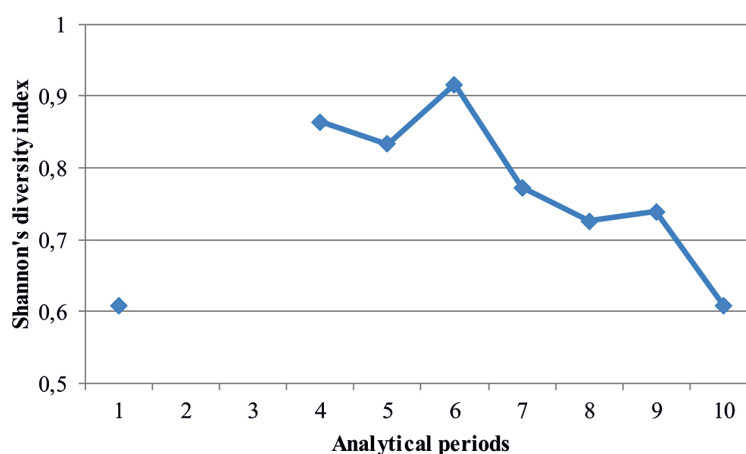
The number of vessels counted for each type was recalculated into relative frequencies. Then we estimated the values of Shannon's diversity index for each analytical period. The results obtained are represented in Fig. 9. The results of the estimations are discussed in more detail below.

## Results

The development of pottery shapes of WTC in the Southern Bug and Dnieper interfluvium corresponds to the cultural cycle representing the transition from more unified ceramic assemblages to more diverse, and then back to more unified (Fig. 9). A possible sample effect on the analysed trend may be assumed considering the highest diversity of ceramics at analytical periods 4 and 5, which correspond to the high number of pottery fragments counted for this time range, while the decrease in diversity from period 4 to period 5 may be explained by the reduction in the number of analysed house inventories from three to two. However, the highest absolute number of pottery fragments counted for Talianki (analytical period 8) corresponds to the lower diversity index than found with the values obtained for Peschanoe and Glubochek (analytical periods 4 and 5, respectively). Moreover, this highest absolute number was estimated from eleven house inventories, significantly exceeding the number of houses analysed from Peschanoe and Glubochek (Fig. 9: analytical periods 4, 5, 8). The diversity index estimated for Talianki is also some-

what lower than the value estimated for a single house inventory from Moshurov 1 (analytical period 9). It should be noted that the values of  $H$  estimated for the first and last analytical period may be somewhat lower than they have to be due to the ceramic collections obtained from surveys, while the highest diversity index estimated for analytical period 6 may be caused by the number of sampled sites. However, the three sites referring to analytical period 6 are located in the same micro-region, while the diversity index estimated for pottery assemblages obtained from these settlements is significantly higher than the diversity index estimated for the set of pottery coming from two settlements located in different micro-regions and referring to analytical period 10 (Fig. 9: analytical periods 6 and 10; see also *Diachenko, Menotti 2012*). Thus, we conclude that the particular values of  $H$  estimated for different analytical periods might be somewhat impacted by the sample effects, but these effects do not change the overall trend in the transition from more unified ceramic assemblages to more diverse, and then back to more unified.

The disturbances in the cultural cycle are represented by significant increases in the diversity of pottery assemblages at analytical periods 4 and 6 and increase in diversity at analytical period 9 (Fig. 9). We should admit that the increase in diversity represents relatively short-term changes in the system, while the subsequent transition to uniformity fits the earlier trends in the development of pottery styles (Fig. 9: analytical periods 4 to 10). Since both cases of the increase in pottery diversity correspond to the initial phases of the Nebelevskaya and Tomashovskaya groups, respectively, the identical distribution of pottery types over time is expected to be identified for Vladimirovskaya group in further studies.



**Fig. 9. Unification and diversity of Western Tripolye pottery shapes.**



Let us now consider the factors which might have impacted the development of pottery shapes represented in the obtained distribution of the values of the diversity index. The usual suspects for the cultural transformations are climate change, migrations, changes in social organization, economic productivity or spatial demography, and the 'isolation by distance' principle. Table 1 summarizes the comparisons between shifts in environmental circumstances, socio-economic and demographic development which might have impacted the changes in ceramic styles and the increase or decrease in diversity of pottery styles of WTC in the Southern Bug and Dnieper interfluvium. In each case changes are compared to the preceding analytical period.

The increase in pottery diversity during analytical periods 4 and 6 correlates with migrations of the WTC population from the Dniester region to the Southern Bug and Dnieper, which are indicated by the demographic estimations and observations of pottery ornamentation (Ryzhov 2007; Diachenko 2016). One more migration of WTC groups from the Dniester and Bug interfluvium to the analysed region occurring in analytical period 9 correlates with the slight increase in ceramic diversity compared to the value obtained for analytical period 8 (Tkachuk 2008; Diachenko 2016). We should note that the number of people involved in the migration in analytical period 9 is also approximated to the smaller values than the number of migrants who came to the Southern Bug and Dnieper interfluvium during analytical periods 4 and 6. Since the new arrivals did not settle separately but mixed with the population of local settlements, it is reasonable to conclude that they contributed to the local pottery assemblages with their traditions. Further on, synthesis of different traditions resulted in more unified pottery styles.

The possible influence of the other listed factors does not correlate with the observed dynamics of the cultural cycle (Tab. 1). Applying the 'isolation by distance' principle suggested by Stephen Shennan and co-authors (2015) to our dataset, one would expect the increase in pottery diversity with the increase of the occupied territory. However, WTC reached its largest territorial extent in the Southern Bug and Dnieper interfluvium during analytical period 5, which is characterized by the lower value of the diversity index than the preceding analytical period 4 and the subsequent analytical period 6. Meanwhile, we cannot exclude that the effect of the 'isolation by distance principle' somewhat increased the

value of the diversity index estimated for analytical period 6.

The settlement dynamics of WTC populations in the analysed region represent two different trends changing one another over time (Diachenko, Menotti 2017). The largest settlements of the Vladimirovskaya and Nebelevskaya groups, Fedorovka and Nebelevka, respectively, are dated to the initial phases of these local groups. Both of these large settlements were formed as the result of migrations to the region. After abandoning Fedorovka, its former inhabitants built the Vladimirovka and Peregonovka settlements, both of nearly equal size and significantly smaller than Fedorovka. Leaving Nebelevka, its former inhabitants built the somewhat smaller settlement of Glubochek and several medium and small size settlements in the region. The settlement dynamics of the Tomashovskaya group sites in analytical periods 6, 7, 8 and 9 are characterized by the increase of the subsequent largest settlements in size, while the number of inhabitants was increasing at the annual rate of 0.3% (Diachenko 2016; Diachenko, Menotti 2017). Both trends do not correlate with the changes in the values of the diversity index estimated for pottery shapes.

According to the available proxies, around the end of the 3800s cal BC (analytical period 6) the climate changed from more arid in the preceding period to warmer and more humid (e.g., Anthony 2007; Diachenko 2010; Harper 2019; Harper et al. 2019). This climate shift probably impacted the increase in agricultural productivity in analytical periods 6–10 compared to analytical periods 1–5. Meanwhile, neither climate change *per se*, nor its economic impacts, influenced the increase in diversity of ceramic styles. Except for the analytical period 6, the values of the diversity index indicate the trend of unification of pottery shapes (Fig. 9; Tab. 1). The available evidence on integrative architecture in Tripolye settlements shows complex decision-making rather than top-down centralized control (Hofmann et al. 2019). Conceptually this fits Anthony Giddens' (2003) structuration theory and Piotr Sztompka's (1991) concept of society as a process, in which social actions are based on human actions making and constantly changing social structures. According to these concepts, we should pay more attention to the daily practices, routines, habits, intentions, sex and age of pottery makers. Considering this variability in intra-social structures and actions, one would also expect an increase in ceramic diversity at least for the analytical periods 6–9 characterized by a number of

Analytical period	Shannon's diversity index	Climate change	Migrations	Changes in economic productivity	Changes in settlement systems	'Isolation by distance' principle
1	N/A	N/A	+	N/A	N/A	N/A
2	?	s	s	s	s	+
3	?	s	s	s	s	S
4	↑	s	+	s	+	+
5	↓	s	s	s	+	+
6	↑	+	+	↑	+	+
7	↓	+	s	↑	s	S
8	↓	s	s	s	s	S
9	↑	s	+	s	s	S
10	↓	s	s	s	s	S

'↑' – increased from the preceding analytical period, '↓' – decreased from the preceding analytical period, '+' – changes occurred, 's' situation remained stable, '?' no data available, 'N/A' not applicable

**Tab. 1. Changes in the diversity of WTC pottery styles in the Southern Bug and Dnieper interfluvium and their possible causing factors.**

chronologically subsequent mega-sites increasing in population size. However, the values estimated with equation 1 demonstrate the opposite trend (Fig. 9).

### Conclusion and discussion

The results obtained in this study indicate that the development of pottery shapes of the WTC in the Southern Bug and Dnieper interfluvium passed through a cultural cycle from unification to diversity and then back to unification. This cultural cycle is disturbed by the increase in diversity of pottery forms at three analytical periods, which may be explained by migrations into the analysed region. However, none of the possible factors which might impact the development of ceramics have shown a correlation with the cultural cycle in WTC pottery styles. At first glance, the discovered cultural cycle conceptually fits the ideas of Danilevskiy, Spengler and Sorokin (*Danilevskiy 1895; Sorokin 1937; Spengler 2014*). Considering the results obtained for the development of Neolithic ceramic assemblages (*Gronenborn et al. 2017; 2018; Gjesfeld et al. 2020*), which are similar to the results of our case study, we question the cyclic nature of cultural development following the stages of 'unification' – 'diversity' – 'unification' in the results of the dynamic behaviour of culture as a complex system. In this respect, it is reasonable to assume that the 'hidden cycling trend' resulting from non-linear complex dynamics may to a certain extent be impacted by different external factors, but remain the same in its main properties. By definition,

the behaviour of complex systems is caused by their internal dynamics (e.g., *Bentley 2003*). Therefore, the modelling of complex cultural dynamics is a crucial issue in further work on prehistoric culture.

Our case study also raises the question of the utility of approaches which include both qualitative and quantitative characteristics of datasets to pottery seriation. This also includes the detailed chronologies produced by data analysis accounting for the relative

frequencies (or percentages) of artefacts belonging to different types which find their confirmation in absolute dating, because the underlying methodology is in fact a truncated version of Shannon's diversity index. With updating such approaches to consider the diversity index, we would expect an increase in the number of cultural cycles identified in archaeological data.

Further work on complex cultural dynamics requires consideration of the cultural hierarchy and corresponding improvements in methodology. We should note that the related studies are being conducted by Ray J. Rivers and his collaborators (as seen in the paper presented by Rivers at the 25<sup>th</sup> Neolithic Seminar in Ljubljana). One of the most important theoretical and methodological challenges behind further studies on complex cultural behaviour is the need to distinguish between complex non-linear behaviour and the changes due to the impact of external factors.

### ACKNOWLEDGEMENTS

*This research was funded by the National Science Center of Poland, grant 2018/29/B/HS3/01201 awarded to Iwona Sobkowiak-Tabaka. We are grateful to Mihael Budja for his kind invitation to present and discuss the results of this study at the 25<sup>th</sup> Neolithic Seminar in Ljubljana, and to the anonymous reviewers for their valuable comments and suggestions. Many thanks are also due to Benjamin Jennings who created the base of map 6 for us.*

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