LIETUVOS ARCHEOLOGIJA. 2019. T. 45, p. 145–167. ISSN 0207-8694
https://doi.org/10.33918/25386514-045004

A UNIFIED MODEL FOR THE GOVERNING DYNAMICS OF AGRICULTURAL FRONTIER ZONES

CHRISTOPHER BARBER TROSKOSKY[1, 2], JONATHAN MARK WHITE[1, 2], LUKAS GAIŽAUSKAS[3]

[1] University at Buffalo Department of Anthropology, 380 Fillmore Academic Center Ellicott Complex, North Campus, Buffalo, NY 14261-0026 716-645-2414, e-mail: cbtrosko@Buffalo.edu, jmwhite2@Buffalo.edu
[2] University at Buffalo Anthropology GIS Social Systems Laboratory, 380 Fillmore Academic Center Ellicott Complex, North Campus, Buffalo, NY 14261-0026 716-645-2414.
[3] Laboratory of Bedrock Geology, Nature Research Centre, Akademijos 2, Vilnius, 08412, Lithuania, e-mail: lukas.gaizauskas0@gmail.com

We present a unified model for the movement of agricultural frontiers based on the construction of the parallax shift and its relation to normalizable science. The model is based on data from the Baltic Basin, where for thousands of years, complex and semi-complex hunter/gatherer/fishers and agriculturalists remained in an equilibrium state. When agriculturalization occurred, it occurred in a punctuated equilibrium manner, which defies current models of agricultural frontier movement, and by extension, current understandings of the underlying dynamics of social change.

This new model is a modification of Structuration (Giddens 1984), with the emerging field of self-organized criticality within Physics (Bak et. al 1988; Brunk 2002b). These modifications require two additional governing dynamics not included in Giddens's original formulation.

When joined to an agricultural frontiers model with selective information permeability, these governing dynamics allow for societies to undergo punctuated equilibrium change under stress affect conditions. This results in critical behavior without the need for chaotic state change (Bak et. al 1988). This results in the creation of new material culture assemblages, reflecting new societal structures which are in equilibrium with the social and environmental landscape.

The model is scale independent in both space and time, presenting some interesting conclusions.

Keywords: SubNeolithic, Corded Ware, Agricultural Frontier, Dynamic Model, Self Organized Criticality.

Straipsnyje pristatome bendrą modelį, kuris paaiškina agrokultūrinių pasienių judėjimą ir yra sukurtas remiantis paralakso poslinkio principu bei jo santykiu su normalizuojamu mokslu. Modelis grindžiamas Baltijos baseino, kuriame pusiau išsivysčiusių bendruomenių lygio medžiotojų-rankiotojų-žvejų bei žemdirbių grupės per tūkstantmečius gyvavo pusiausvyros būsenoje, duomenimis. Prasidėjus agrikultūrizacijai, jos plėtra vyko punktualizmo principu, todėl yra nepaaiškinama dabartiniais modeliais apie agrokultūrinių pasienių judėjimą ir iškelia dabartinio supratimo apie socialinius pokyčius lemiančias varomąsias jėgas trūkumus.

Naujasis modelis yra struktūracijos (Giddens 1984) ir fizikos moksle besivystančio save reguliuojančio kritiškumo, kritinės elgsenos (Bak et al. 1988; Brunk 2002b) tyrimų lauko modifikacija. Į pastarąją būtina įtraukti dvi papildomas valdančias dinamikas – varomąsias jėgas – kurių nėra originalioje Giddenso formuluotėje.

Taikomos su agrokultūrinių pasienių modeliu, lemiančiu aktyvų bendruomenių keitimąsi informacija, šios valdančios dinamikos paaiškina, kaip bendruomenės pereina punktualizuotus pokyčius sustiprėjusio streso sąlygomis. Pokyčiai pasireiškia kritine elgsena be chaotiškų būsenos perėjimų (Bak et al. 1988). Dėl šių pokyčių išsivystę kiti materialiosios kultūros rinkiniai rodo naujas bendruomenines struktūras, pasiekusias pusiausvyrą su socialiniu ir fiziniu kraštovaizdžiais.

Modelis gali būti taikomas įvairiu mastu tiek erdvėje, tiek laike ir leidžia daryti kelias įdomias išvadas.

Reikšminiai žodžiai: subneolitas, Virvelinės keramikos kultūra, agrokultūrinis pasienis, dinamiškas modelis, save reguliuojantis kritiškumas.

INTRODUCTION

This paper proposes for the first time a unified model for the transmission of the knowledge required for the adoption of agriculture across space.

The paper is constructed as a six part argument: four arguments leading into the model, the model itself, and an argument concerning the adoption of unrecognised governing dynamics. The article will conclude with a final discussion of the arguments and model.

The first argument works to clarify misconceptions about the nature of change in the social sciences, specifically as they relate to paradigm shifts and their limitations. These clarifications are necessary for the formation of a unified model for the movement of agricultural frontiers. A unified model needs to be based on the construction of a parallax as opposed to a paradigm shift and its relation to normalisable science.

The second argument concerns supposed outliers in the archaeological record of agricultural adoption in Europe. The model as a whole is rooted in data from the Baltic Basin, where for thousands of years the relationship between complex and semi-complex hunter gatherers and agriculturalists remained in a relatively static state. There were only a few major agriculturalisation events, all of which were of a seemingly punctuated equilibrium nature. These interactions defy current models for the governing dynamics of agricultural frontier movement and, by extension, current understandings of the underlying dynamics of social change (Giddens 1984).

The third argument concerns self-organising criticality. We will discuss the development of the concept in other disciplines and how the self-organised critical nature of human systems has been received within anthropology and archaeology.

The fourth argument is for a new universal societal model driver. This driver is *stress affect,* which is a general and indefinite index which measures the expectations of the residents of a society compared to their lived reality. It is directly linked to their environment in a cohesive and comprehensive social and physical sense and incorporates both subsistence and non-subsistence aspects of society. This means that changes to either the social or environmental landscape can cause stress affect within a population, as expectations are affected by either changing climatic or social landscape conditions. These landscape conditions must be treated holistically in order to avoid misconstruing cause and effect in the driver of complex anthropogenic systems of systems (Brunk 2002a, pp. 33–34). A complex system can be seen to have exceeded stress affect thresholds when emergent behaviour occurs. Emergent behaviour in human systems can be identified by a rapid change in the material culture related to rapid changes to societal structural principles. This is the equivalent of a self-organised criticality, 'sandpile model' cascade (Bak 1996, p. 52; Brunk 2002a) in an anthropogenic system.

The fifth argument is the model itself, with its complete list of definitions and assumptions. The unified model is a version of structuration (Giddens 1984) with modifications from self-organised criticality, a field emerging recently in the hard sciences, most prominently in physics (Bak 1996).

The sixth argument is for the adoption of unrecognised governing dynamics in the behaviour of linked systems following a self-organised critical approach. These modifications require the construction of two additional governing dynamics for model behaviour not included in Giddens's original formulation. These governing dynamics allow for societies to undergo punctuated equilibrium change under certain stress affect loading conditions, which produce critical or phase change behaviours in non-chaotic states (Bak *et al.* 1988).

ARGUMENT 1

Paradigm Shifts vs Parallax Shifts

We will spare the reader the many citations that exhaustively detail the paradigm concept or paradigm shifts in archaeological thought and go directly to the source. How the discipline speaks about trends within the discipline of archaeology is often done in a manner which is inaccurate with regard to the original literature. This paper therefore opens with a treatment of Kuhn's 'paradigm' concept, the issues with paradigms in the Social Sciences, and the 'Normal Science' concept (Kuhn 1962, p. 2). An alternative is proposed which allows for an analysis of disciplinary change in archaeology, in a manner which more closely resembles the normative meaning of the English words 'trend' or 'viewpoint'.

ipsius naturae mutatione – η ίδια η φύση της αλλαγής

The notion of change we have adopted in the science of archaeology is very historically contingent, very romantic, and very specific. The subtitles of this section have identical meanings. However, we can only understand them as having the same meaning within a normative framework of linguistic translation. With the publication of *The Structure of Scientific Revolution* in 1962, Thomas Kuhn outlined a project to determine the discrete temporal periods in which unambiguously, unqualified, and self-contained science was operating in a 'normal' science mode or was undergoing a paradigm shift or radical change in thinking. Kuhn had a brilliant idea, summarised with great buzz words, and they spread like wildfire throughout nearly every academic discipline, changing the academic landscape, at least in the West, for generations starting in the late 1960s. This pattern in scholarship is not in question, but how many of these disciplines Kuhn himself would have understood to have undergone legitimate paradigm shifts is a far more interesting question (Ezra Zubrow 2019, personal communication).

Peter Galison (1997), in his *Image and Logic,* put forward a new theory of scientific revolution brought on by technological advancement as an alternative to Kuhn's metaphysical driver and which more accurately describes the changes in social sciences scholarship. We acknowledge that Galisonian shifts may occur in the hard sciences, but they are essentially still paradigmatic in nature and therefore more closely align with the way the Kuhnian terminology has been applied to the social sciences. Regardless, Galisonian shifts still use the paradigm concept and do not necessarily describe theoretical shifts in archaeology. To understand if archaeology can really claim to have undergone a paradigm shift (either Kuhnian or Galisonian), one needs not only to understand Kuhn's aims and end project goals, but also what he explicitly did to construct his grand project of theorising scientific revolution. Once this has been understood, the particulars of the various modes of archaeological thought on agriculturalisation can be evaluated as they relate to each other in reality.

Kuhn (1962) explicitly reduces the term 'paradigm' to its original Greek formulation, *παράδειγμα,* with the constricted literal meaning of 'example'. This hearkened back to a perceived original Greek meaning that was direct and unambiguous. It implies that the only way that scientific revolutions could be mapped is in terms of examples of paradigms, normal science lying between these anomalies.

There are, however, alternative, if not outright better ways to phrase a concept similar to Kuhn's and with identical goals but using a slightly different notion of the semantic way in which scientific change happens in disagreement with Kuhn. *Παράλλαξις* literally translates to 'alteration' in the original Greek and far better describes events in the history of archaeology.

In Modern English, the word is rendered 'parallax' and is used to describe how something

appears different when viewed from a different position, for example, a needle-style speedometer in a car might appear to be showing slightly different speeds depending on whether it is viewed from the driver's seat or the passenger seat. In theory, this means that we should view theoretical movements in archaeology as *perceived differences in the position of a single object of study derived from new and different fixed respective viewpoints of the object* (parallaxes) rather than *movement of the object itself or, to be even more explicit, looking at the same object in a new light or through a new lens* (paradigms). This would result in a non-revolutionary shift in discipline focus which retained aspects of previous foci and the potential maintenance of the good while disposing of the bad without revolutionary change. 'Parallax shift' far better fits the social sciences and humanities than Kuhn's concept of 'paradigm shift'.

'Normal' science under a parallax system would imply that 'normal science' never stops; it merely changes the form and focus of enquiries within a stable metaphysic. Paradigm shifts 'may only' occur if they are generally not normalisable to previous modes of science. The classic example is Newtonian Gravity being a special case of General Relativity operating in a single reference frame in which nothing moves at subliminal speeds. This makes Einstein's revolutionary ideas of gravity non-paradigmatic by Kuhn's definition, since new paradigms should be irreconcilable with the old (Kuhn 1962, p. 79). It also explains why Newtonian Gravity and, by extension, Newtonian Mechanics still work just fine for applications within its boundary conditions, such as predicting the motion of bodies within the solar system or measuring the mass of the earth if a projectile is launched from it.

The classic example of an actual paradigm shift is the original formulation of the Standard Model of Quantum Mechanics, which cannot be normalised with General Relativity. There were several previous 'paradigm shifts' in physics, all of which were eventually normalised under either the Standard Model or General Relativity even if they were revolutionary at the time. Paradigm shifts happen infrequently in the hard sciences, where they can actually be shown to exist. Biology has not surpassed the Paradigm of Darwinian/Mendelian Evolution and genetics in over 150 years. Even the discovery of the DNA molecule by Crick and Watson only further refined (as opposed to changed) this original metaphysic. The case for chemistry is more complicated, as it exhibits at least three real paradigm shifts. These are the metaphysical shift from alchemy to chemistry, the development of inorganic chemistry, and the discovery of organic chemistry. Only the first of these paradigm shifts has been fully normalised.

However, by definition, parallax shifts occur virtually constantly in science: every time someone decides to examine the same corpus of information in a new light or from a new viewpoint, it is a different parallax. We undertake one (if we read critically) with every scientific article we consume as philosophers of anthropology and aspiring philosophers of anthropology. Meltzer's axiom holds just as true today as when he first wrote it, stating that it is only when a new metaphysic is introduced, which cannot fit on the same continuum of normal science, that revolution (a paradigm shift) results (Meltzer 1979, pp. 652–653).

Using this understanding, archaeology has never had a non-normalisable shift in its metaphysic. Although we had a shift from antiquarianism to proper archaeological science, it was almost immediately normalised. We dig things up and examine them empirically. We have always done so; our external viewpoints of the archaeological data have changed or expanded to include empirical data not understood by the antiquarians, and even non-empirical analyses of ultimately empirical material. We will likely continue to dig things up and analyse them. With no change in our metaphysic, we have undergone parallax, not paradigm shifts.

ARGUMENT 2

The Agricultural Frontier as a Concept

Different parallax shifts within archaeology have resulted in different approaches to the agricultural frontiers, usually with different models driving the advance of agricultural or explaining hiatuses in that spread. Generally, they have followed the trajectory of the sciences over the same period of time, eventually leading to cross-disciplinary and transdisciplinary research. Many of these methods and interpretations (models and drivers) have found their way into mainstream archaeological science as explanations for the agriculturalisation of Europe (Milisauskas 2011, pp. 159–162; Robb 2013, pp. 660–662).

Although these models and drivers have changed, the idea of an agricultural frontier has not. A zone in which agriculturalists interacted with non-agricultural societies is a necessary geographic reality in a world not totally occupied by agriculturalists. Not all of the models and drivers that have been proposed require this frontier to be present at the beginning of agriculturalisation, but they inevitably require it to be present during at least part of the endless series of events which cause the transmission of agriculture over space and time.

Specific examples of historical theorisations of the agricultural frontier and its drivers will be discussed below following the definition of the model put forward in this paper.

The Baltic Basin

The Baltic Basin as used here comprises, in respect to the geological definitions, both the Baltic Sedimentary Basin and its entire watershed drainage basin. The authors feel that using political as opposed to geologic designations for geographic areas carves up the past in a manner which is not conducive to a realistic understanding of the palaeoenvironment. The drainage basins of the Baltic which lie to the East, specifically the Nemunas Basin and its immediate environs, including the Šventoji palaeo river delta system, form the geographic locus of this study.

Broader readings of events, which occurred throughout the Baltic Basin and are mentioned in the paper, do in fact cover events throughout the entire history of the Baltic Basin, including the Western Baltic Basin watersheds, but these events are outside the temporal scope of the paper. These include additional large scale punctuated equilibrium agriculturalisation events such as the formation and spread of the Funnel Beaker Groups, the influx of Corded Ware Culture groups into great swaths of Hunter/Gather/Fisher territory in the Scandinavian Peninsula, and the widespread replacement of transhumance with cereal agriculture communities during the Nordic Bronze Age. However, these events do not form the core argument in this paper. They merely illustrate that the archaeologically documented events in the Nemunas Basin do in fact fall within a continuum of punctuated equilibrium events following the arrival of agriculture to the Baltic Basin until it was fully converted to agriculture almost 10 000 years later.

Mesolithic and sub-Neolithic groups of the Baltic Basin persist both longer in time and, more importantly, longer in cultural contact with agriculturalists and agro-pastoralists than any other hunting and gathering populations in Europe (Milisauskas 2011, pp. 227–232; Piličiauskas *et al.* 2017b). The eventual spread of agriculture among these populations also took on a different character than the generally and apparently steady migratory or diffusionistic spread of agriculture from the Middle East. Regardless of its veracity, migratory or diffusionistic spread from the Middle East has characterised the development of archaeological models for the majority of Europe as well (Bogucki 2017, pp. 15–18; Piličiauskas *et al.* 2017a; Piličiauskas *et al.* 2017c; among others). However, in the Baltic Basin,

a distinctly different pattern for the dissemination of the necessary agricultural, technical, and social knowledge, as well as the technological components, is necessary for an agricultural lifestyle into hunter/gatherer/fisher groups. Alternatively, this pattern may apply to the integration of specific traditions of knowledgeability and technical components of hunter/gatherer/fisher groups into agricultural groups, but either way, it is apparent throughout the entire agriculturalisation period throughout the Basin and as a whole throughout the entire Neolithic.

Shifts to agriculture, specifically meaning the adoption of the pool of knowledge necessary to utilise to any extent domestic animals or plants and to perpetuate that way of life generationally, among hunter/gatherer/fisher groups in the Baltic Basin are marked by periods of long-term stability in intercultural interaction with agriculturalists in a highly conservative agricultural frontier.

This pattern is punctuated by short periods of very rapid sweeping cultural change over large areas. This can occur with or without the hybridisation of complex hunter/gatherer/fishers and agriculturalists into fusion cultures. The phenomenon of agriculturalisation appears to operate at approximately the drainage basin scale. This overall trend is best represented as a model of punctuated equilibrium as it relates to the adoption of agriculture within the region over time.

This pattern of punctuated equilibrium has not been observed in archaeological or ethnological records as it pertains to hunter/gatherer/fisher interactions with agriculturalists, with the exceptions of planned agricultural imposition situations in the archaeological record and colonialist/globalisation cash crop situations in Early Modern and Modern ethnographies. Instead, current research suggests an ultimately diffusionistic spread, with emergent agriculturalisation at the end of the Neolithic filling the geographic gaps (Zvelebil 2005; Robb 2013) during agriculturalisation. A gradual diffusionistic model, even with late period emergent behaviour, does not satisfactorily explain the punctuated equilibrium nature of the Baltic Basin cases in which emergence appears to be the normal operational mechanism, rather than a late phase phenomenon.

Nemunas Basin (Lithuania) (3200–2000 BC)

This case was selected from several others in the Baltic Basin because the geologic drainage divide between the lower Nemunas River and the basins of the North Polish Plain formed both geographic and cultural barriers to the agriculturalisation of the Eastern Forest Neolithic (EFN) groups. The formation of the Funnel Beaker culture (TRB) at approximately 4200 BC (Adamczak *et al.* 2017, p. 77) allowed for the widespread availability of agricultural technology and information in the region. However, this adoption did not occur among the EFN groups for approximately 1100 years. The Nemunas basin developed as a major periglacial drainage element during the retreat of the Fennoscandian Ice Sheet. The region is marked by a complex coastal geology representing the various phases of the Baltic Ice Lake. The surficial geology consists of very young soils, developed in pro-glacial and post-glacial fluvial and lacustrine environments. The region is also marked by a series of morainal positions demarcated by tectonic ice marginal kame and kame terrace deposits which represent different retreat phases of the Nemunas Lobe of the Fennoscandian Ice Sheet (Bitinas *et al.* 2004; 2012; Rinternecht *et al.* 2008).

The Narva culture (an EFN group) was similar to the Ertebølle (a Western Forest Neolithic group (WFN)) in terms of ceramic material culture. Both cultures received pottery technology via the so-called Hyperborean Stream (Gibbs, Jordan 2013), a maritime exchange route in which very distinct pointed-bottom vessels and shallow blubber lamps form the majority of the diagnostics in the base assemblage (Gibbs, Jordan 2013). Both cultures maintained a Mesolithic economy and had pottery

from the same non-agricultural source before they began to interact with agriculturalists. However, while the classical pottery-bearing Narva EFN culture emerged in what is today Estonia in the late 6th or early 5th millennium BC (Kriiska *et al.* 2017, pp. 69–74), pottery reached eastern and western Lithuania in the mid-5th millennium, and the Lithuanian coast around 3900 BC (Piličiauskas 2016, p. 45, fig. 6). By that time, Narva pottery groups to the north were being replaced by EFN Comb Ware groups. EFN communities in Lithuania continued to produce pottery that was technologically and functionally similar to the original Narva, but with regionally distinct morphologies. Hence the term 'Narva' was most often used to classify rather diverse EFN communities in the East Baltic that produced porous pottery with organic temper, commonly crushed shell, as opposed to Comb Ware, which is mostly mineral tempered. See Figure 1.

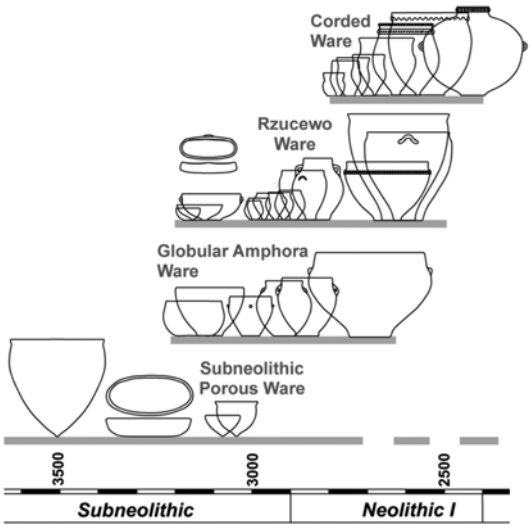

Figure 1. The pottery sequence in Lithuania covering the period under study. Note the Bowl or Boat-shaped Lamps associated with EFN influence. Modified from Robson et al. (2019).

The first interactions between EFN peoples and agro-pastoralists likely first took place in what is today southeast and coastal Lithuania. Currently, a more detailed picture of the Neolithisation process exists in the coastal region, as most of the recent research has been carried out there. The site complexes at Šventoji, and later Nida, have yielded EFN material from c. 4000 BC. Prior to this shift, the coastal region was occupied by Mesolithic groups. These sites represent an at least partially sedentary complex with a hunter/gatherer/fisher way of life and a primary focus on freshwater resources fished and gathered from the Curonian lagoon and other freshwater bodies along the Baltic Sea coast to the north of it (Piličiauskas *et al.* 2017a, pp. 535–541; Piličiauskas *et al.* 2017b, pp. 1431–1435; Piličiauskas *et al.* 2017c). If they operated similarly to their contemporary neighbours to the north at Šventoji, they practiced a delayed return economy and invested heavily in the improvement of their wetland landscape to intensify yields (Piličiauskas *et al.* 2012). A secondary economy in the collection and rendering of seal fat or fish oil for the lamps, found ubiquitously in both WFN and EFN cultures, was of seasonal importance and a major long-distance trade good year round. Among groups who were not located on the coast it has been suggested that eels or other oily fish were seasonally procured in the same manner. See Figure 2 for a diagram of Neolithic influence and routes over time in the study area.

Circa 3200 BC, a cultural fusion event resulted in the creation of the Rzucewo Culture (RC) on the Southeast Baltic coast. This culture is marked by the addition of low intensity agro-pastoralism to the existing hunter-gatherer-fisher way of life, a transition to globular amphora style vessels, and a slight intensification of landscape usage of all types. The intensity of the fishing, sealing, and pastoralism increased along with a consummate increase in the raw percentages of non-domesticated ungulate remains (Piličiauskas *et al.* 2017a). There is also a coincidental rise in population density further north along the coast at the EFN site complex in Šventoji which most likely represents the immigration of a number of Narva EFN people from the Nida region to their nearest contemporary EFN neighbours. The

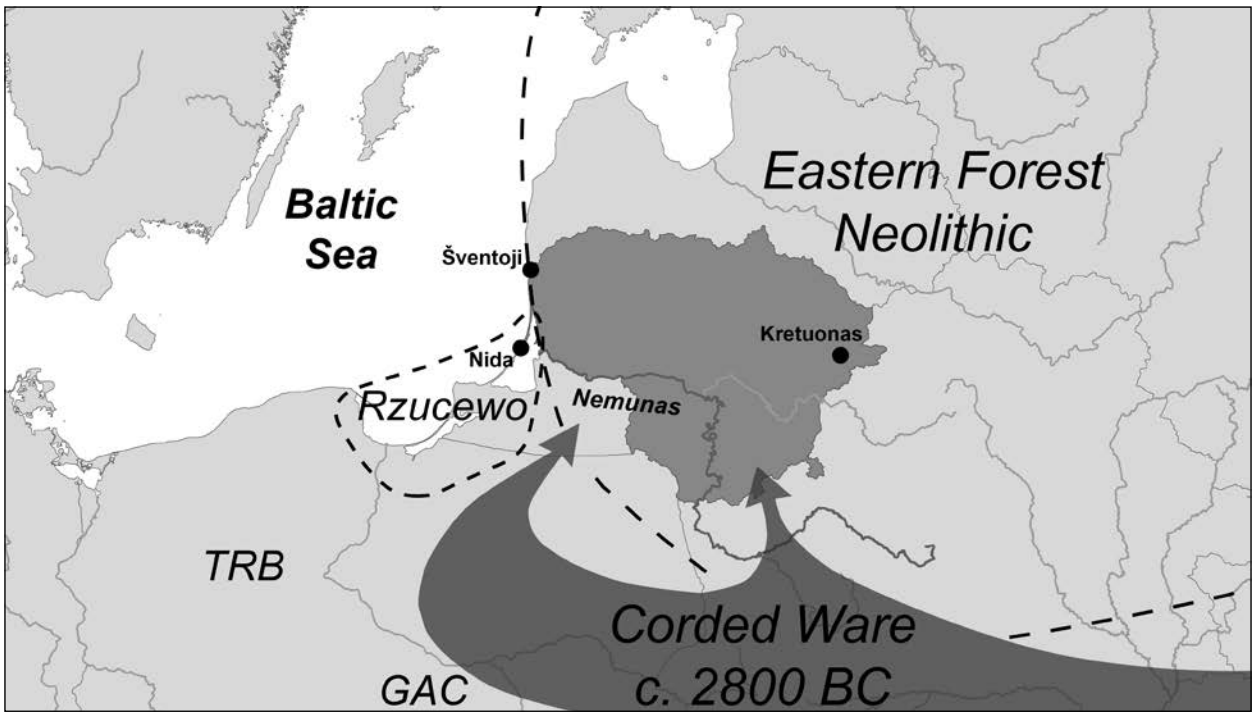

Figure 2. The archaeological sites and cultural units mentioned in the text. Shaded arrows indicate the possible directions of CWC movements across the EFN frontier c. 2800 BC. TRB and GAC culture areas are shown. GAC interactions with southern Lithuanian EFN groups began before 2800 BC. *Drafted by L. Gaižauskas, 2019.*

details of the intercultural interaction leading up to the RC cultural fusion/creolisation are currently unknown (Piličiauskas 2018).

There is slightly less information available for the initial Globular Amphora Culture (GAC) and the subsequent Corded Ware Culture (CWC) 'migration' through Lithuania some 300 years later. Outside the coastal corridor, reliable radiocarbon dates for the timing of this are scarce and mostly come from CWC burials, but it seems that CWC interaction and the adoption or replacement of EFN cultural signatures was underway in both Eastern and Western Lithuania by the early 3rd millennium BC. This change is shown the most clearly by the adoption of domestic animals, but also by other markers. It is currently unknown if there was a single direction for the advance of the CWC peoples into Lithuania, or if there were multiple vectors. However, the current distribution of radiocarbon assays indicates that, whatever the paths taken, CWC peoples had integrated into or displaced EFN groups in Northern Lithuania by 2700 BC, moving from a source region somewhere to the north of the Pontic Steppe, which extends nearly to modern Georgia (Piličiauskas 2018).

The EFN cultures at Šventoji appear to have been integrated or replaced very abruptly, first by GAC people and then by CWC groups by 2700 BC. The RC showed remarkable resilience to CWC influence, but even though they persisted in the presence of gradual contact, the CWC cultural-technical markers increased steadily until 2600 BC (Piličiauskas *et al.* 2017c). It should be noted that this is still a scale of less than a dozen generations. It is simply less rapid than the replacement happening elsewhere, which is likely a function of the RC and CWC cultures reacting to integrated environmental and cultural stressors during this time. Interactions between CWC groups and EFN groups appear to have been both intensive

and brief in the coastal zone and inland Western Lithuania, resulting in complete replacement within a relatively brief window of time in most places.

In inland Lithuania, it is apparent that in some regions, CWC culture groups integrated or displaced EFN groups very quickly, judging from the radiocarbon dating of CWC burials and abundant finds of CWC pottery in places of previous EFN settlement (Piličiauskas *et al.* 2018). However, to date, archaeological research in most of inland Lithuania has been unable to confirm whether both cultures could have persisted side by side until the middle of the third millennium BC. Interestingly, there appears to have been a migration of what has been termed 'Late Narva' EFC groups into Eastern Lithuania in the Late Neolithic and Early Bronze Age, c. 2400–1800 BC, as CWC influence fades in the region. These late EFC groups possessed a hybrid material culture, such as flat-base ceramic vessels tempered with crushed shell (Brazaitis 2002, pp. 64–66), but their settlements are found only next to wetlands rich in freshwater resources, such as Lake Kretuonas (Girininkas 2013, p. 64). It is unclear at this juncture whether this is actually a migration back into occupied territory, or if EFC cultures merely persisted, albeit with changed aspects of their material culture, in some inland regions until the beginning of the second millennium. Similar EFC sites with post CWC materials are found to the north in modern Latvia, around Lake Lubans (Лозе 1979).

These cases represent only those present in the Nemunas Basin during the time period in question and additional research throughout the Eastern Basins of the Baltic Basin Watershed will be necessary to assess whether they represent a normative response to CWC contact or not. Within the Nemunas Basin it is freely acknowledged that they represent examples of punctuated equilibrium change that did not mark the entire EFN population. This, however, does not detract from their explanatory power with regard to the proposed model or its applicability, merely that different groups suffered different levels of Stress Affect during this period of time. As new data from other regions of the Eastern Baltic become available, it will be possible to assess the disruption caused by the influx of the CWC into those regions over time.

ARGUMENT 3

The self-organised Critical Nature of Human Systems

In the late 1980s, physicists recognised that open dissipative systems could undergo critical (phase change) behaviour if they were tuned to the proper frequency noise ratios. This led to the realisation that many physical systems follow a distribution nearly identical to the Richter Law (Bak 1996, pp. 12–26). This is the same law that governs how we classify the magnitude of earthquakes: against the log frequency of their distribution. Earthquakes have a perfect 1/f noise, which means that their log intensity plotted against their log frequency forms a perfect 1:1 curve over 8 orders of magnitude. It was discovered over the next dozen years, through experimentation, that a number of phenomena (including human phenomena) follow this same distribution, with 1/f noise ratios of between 1 and 2. These are the frequencies which physicists find 'interesting' because they imply that those systems exist in a self-organised critical state, that is to say, they enter that state without external tuning (Bak 1996, pp. 28–32).

Gregory Brunk published a series of papers (Brunk 2002a; Brunk 2002b) about the applicability of self-organised criticality in human systems and found that it was both widely applicable (Brunk 2002b) and that it could be used to normalise statistical outliers which had plagued the study of societal collapse (Brunk 2002a). It is now fairly widely established that both the synapse system of the human brain and human systems exist in self-organised critical

states. Recently a transdisciplinary paper entitled *Mechanisms of self-organised criticality in social processes of knowledge creation* (Tadić *et al.* 2017) was published in 'Physical Reviews'. This paper makes the claim that:

> '...besides determining a fine structure of the developing knowledge networks, ...the values of scaling exponents and the geometry of large avalanches...we find that the level of the activity of the communities that share the knowledge correlates with the fluctuations of the innovation rate, implying that the increase of innovation may serve as the active principle of self-organisation.' (Tadić *et al.* 2017)

It is clear that physicists and mathematicians believe that human systems exhibit self-organised criticality even if the majority opinion in Anthropology is still unclear on the matter. We, as archaeologists, are already about 20 years behind the curve. The authors believe we need to catch up, and catch up quickly, as the research potential is potentially as great as the development of radiocarbon dating or the incorporation of ancient DNA study into archaeology.

ARGUMENT 4

Stress Affect as the Model Driver

If the affective stress levels within a society become too high, habitus replaces validated agency as the primary mode by which societal structures are modified. Because habitus does not require structural validation, this can be viewed as an event cascade from a self-organised Criticality standpoint (Bak *et. al.* 1988; Sewell 1992, pp. 13–19), resulting in rapid cultural change until stress affect is reduced to acceptable levels and the event cascade ends in a stable configuration. This results in cultural changes of various scales depending on the amount of stored entropy in the form of unexploited unintended consequences which are involved in a given cascade (Bak 1996, pp. 192–198). The system will return to normal operation with validated agency and habitus co-governing modification of cultural structure once acceptable levels have been reached. However, at this point any given culture will have come into equilibrium with their new environmental and cultural landscape. This can result in incredibly rapid material culture change, including, but not limited to, the adoption of agriculture.

ARGUMENT 5

A Viable Unified Model for Archaeological Frontier Zones

This model is important because it involves interactions between hunter-gatherers and agriculturalists who exhibit the same general level of social complexity. Both groups throughout the history of agriculturalisation in the Baltic Basin can be classified as anarchies, which exhibit poorly complex social organisation. This may be the only area of the world in which such a study can be conducted, as greater social complexity among agriculturalists can be disregarded as a primary driving force in what would essentially be a quasi-colonialist or globalising model of the adoption of agriculture by hunter/gatherer/fisher groups (Rowley-Conwy 2014, pp. 185–191). Of particular note are the long hiatus periods in the adoption of agriculture, as they represent periods during which hunter/gatherer/fisher groups had access to agriculture but chose not to adopt it. This implies that Baltic Basin hunter/gatherer/fisher groups potentially perceived no functional or ideological advantage in agricultural products or the technology required to produce them.

Therefore, this new model was developed to better understand the nature of the region's

agriculturalisation and to determine the inter- and intra-cultural forces driving archaeological events in the Baltic Basin during agriculturalisation. Ideally this model would be normalisable with already recognised patterns for the spread of agriculture and in fact, given proper frames of reference, it is actually a unified model that behaviourally explains all of the agricultural frontier more parsimoniously than all of the previous models. The introduction of the self-organised criticality of human social structure (Brunk 2002b), coupled with some modifications to Structuration, has allowed the construction of a model which could study the highly contentious, and ultimately poorly understood, anthropological process of agriculturalisation. Under such a model the outliers, e.g. cases in the Baltic Basin (Zvelebil 2005; Piličiauskas *et al.* 2017b) or Atlantic Europe (Sheridan 2016; Bogucki 2017), ultimately prove rather than disprove several new underlying governing dynamics which unify previous models within the proposed model.

The model ultimately conforms to the original theory of Structuration (Giddens 1984) and is composed of simplified definitions of the cultural parameters first enunciated by Marek Zvelebil (2005). The model views cultural change as an emergent property (non-predictable and non-determinant) of the complex interaction between systems of systems in a high fidelity (mutually intelligible) information exchange linkage. This means that results are completely path dependent but that paths do not lead directly and logically, but may lead indirectly and illogically to specific outcomes. This also means that similar cases following different path dependencies should not necessarily show normalised patterns of results. As they do show normalisation of results, it indicates that there are unrecognised governing dynamics at work within the particular systems of systems under study. See Figure 3 for model diagrams showing the simplest possible configurations of two single cultural units in communication.

The Model definitions are as follows:

General Definitions for Structuration within the Unified Model:

1. Structural Conditions: the dynamic ecology and quaternary geology of an area, structure of human resource relationships, structure of relationships between people and categories of people, and culturally specific systems of symbolic order. These structural conditions may in and of themselves not exert agency but may cause cultural stress and psychological affect within cultures (Barrett 2000; Zvelebil 2005).

2. Structural Principles: recursively dialectic and historically contingent traditions of knowledgeability including beliefs, norms, and codes of practice created and curated through active intra-cultural agency by agents who understand they are recursively manipulating the structure (although they may not understand that it is also manipulating them) (Barrett 2000; Zvelebil 2005).

3. Routine Practice or Habitus: daily activity which, without conscious thought, teaches through experienced societal norms, rules, and traditions of knowledgeability. Habitus is reproduced through embodied social practice and in so doing reproduces culture. In this way, habitus governs social reproduction and the maintenance and construction of traditions of knowledgeability. Changes in Structural Conditions enacted directly by the habitus of enough actors with the same shared experiences self-validates in the sense that changes to Structural Conditions made via agency must be validated through structural principles (Bourdieu 1977; Giddens 1984; Hodder, Cessford 2004; Zvelebil 2005; Jordan 2012).

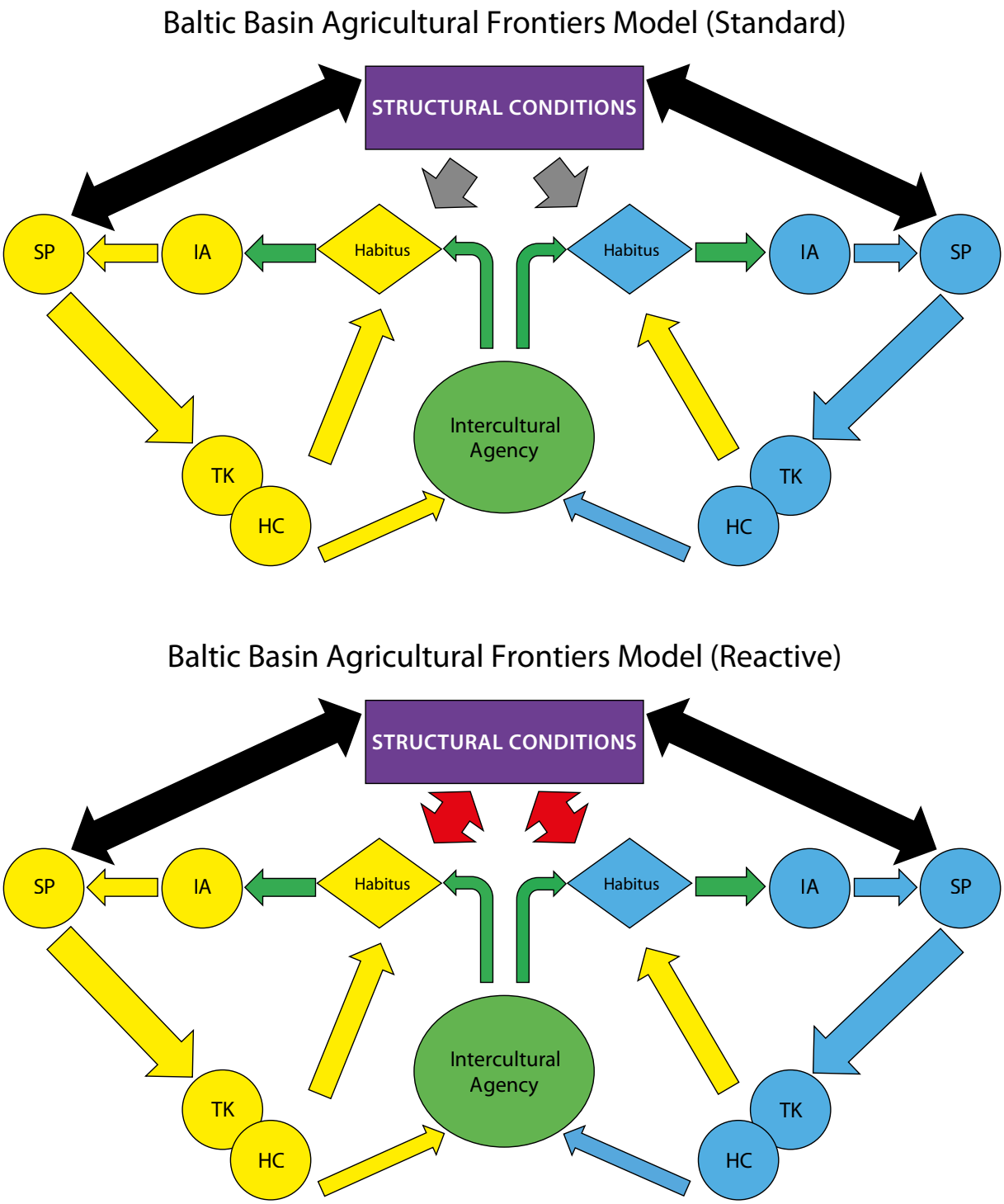

Figure 3: The Structuration model in Normal operation (above) and the Structuration Model in Reactive (Stress Effect overload) (below). Each Colour (Blue and Yellow) respectively represents an independent Cultural System of Systems. *Model Diagrams Conceived and Drafted by C.B. Troskosky 2016.*
Abbreviations: IA = Intracultural Agency, SP =Structural Principles, TK= Traditions of Knowledgeability, HC = Historical Constraint.

4. Intracultural Agency: the embodied, knowledgeable, recursive, historically and spatially contingent act of activating structural principles by an individual or any number of individuals. This attempt will be made to modify traditions of knowledgeability and historical constraint in order to do something: to modify structural conditions or to attempt to thwart the doing of anything by any number of individuals or groups of other individuals.
    a) This results in an array of event cascades, representing successful agency, which will be seen in the archaeological record, unsuccessful agency for which the agency will not be seen in the archaeological record, and a number of unforeseen consequences generated by both which will be visible in the record. The total number of unintended consequences will be greater in number than the original attempts at agency; this is strictly a consequence of the nature of systemic entropy over time. (Barrett 2001; Zvelebil 2005; Jordan 2012).

5. Historical Constraint: society as it is, rather than as it appears to be, to knowledgeable agents within the system, including all structural constraints which allow or disallow successful agency via validation and the affordances offered by the natural and social landscape in which that society persists. This is the medium of temporal and cultural reality in which agency and habitus must operate (Zvelebil 1995, p. 89).

6. Tradition and Social Memory: examples of structural conditions, which can be deliberately employed through agency to manipulate cultural practices in order to do things or validate the reproduction of culture. There are many other types of structural conditions, which are beyond the scope of this paper (Zvelebil 1995, p. 89).

7. Cultural Inheritance and Intergenerational Transmission of Knowledge: the transmission and reproduction of culture is only understandable in the context of Traditions of knowledgeability, which includes in part the practical use of cultural knowledge. Traditions of knowledgeability include both knowledge and material culture. The process of reproduction of traditions of knowledgeability is socially embedded, structured, and modified by habitus, agency, and Historical Constraint.
    a) The reproduction of culture results in the change over time of material culture signatures and patterns. The archaeological record is therefore a reflection of changes in traditions of knowledgeability within a culture over time. This information is decodable in the modern era through theoretically appropriate archaeological interpretation (Barrett 2001; Zvelebil 2005, p. 89).

8. Intercultural Agency: agency originating in one culture which, as an output, acts directly upon the habitus of another through intercultural interaction. This involves the transmission of portions of a culture's Tradition of Knowledgeability through literally any form of intercultural interaction or unintended consequence of attempted agency.
    a) This functions as a simple information flow or the lack thereof between the two cultures in contact.

The model assumptions are as follows:

Specific Assumptions Regarding the Unified Model:

1. Assumption of the Non-Conservative Nature of Culture.
    a) The people and societies represented by archaeological cultures should not be expected

to be intrinsically culturally, technologically, or genetically conservative.

b) The extreme conservatism of model starting conditions regarding these variables is a product of the real historically contingent cultural conditions present in the archaeological record of the study areas rather than an arbitrary constraint imposed by the model.

2. Assumption of the Relationship between Psychological Affect and Cultural Stress.
   a) Individual and group Psychological Affect is suffered by the people of an archaeological culture that is actively being stressed.
   b) Stress in this case is the result of dissonance between environmental, intra-cultural, or inter-cultural Structural Conditions and existing Structural Principles within a culture.

3. Assumption of the Normal Operation of the Reproduction of Culture under Structuration.
   a) The Reproduction of Traditions of Knowledgeability, as outlined by Giddens (1984, p. 170), will occur below the Stress Affect limit.

4. Assumption that under normal conditions Intra-cultural agency and habitus will co-govern the active maintenance and modification of structural principles utilising extant traditions of knowledgeability and Historical Constraint.
   a) Agency exerted to modify structural conditions by nature requires structural validation (Sewell 1992, pp. 13–19).

5. Assumption of the Operation of the Reproduction of Traditions of Knowledgeability beyond the Stress Affect Threshold (in cultures under stress affect).
   a) Traditions of Knowledgeability will be reproduced above the Stress Affect Threshold; however they will reflect whatever state Cultural Principles are in as it occurs.

6. Assumption that when rates of stress affect are high enough, habitus will override intra-cultural agency as the dominant factor in the active modification of Structural Principles. Lived changes in society do not require structural validation and will, through the reproduction of culture, change structural conditions intrinsically through repeated action reproduced as traditions of knowledgeability.
   a) Major changes during these periods do not require structural validation.
   b) Reproduction of radically different and hybrid culture assemblages may occur, representing heavily modified traditions of knowledgeability which in turn represent a radical new normal.
   c) Archaeological Assemblages following these periods may or may not be reconcilable with those of the original culture once these periods of stress affect beyond cultural thresholds are ameliorated by habitus-generated structural change.

7. Assumption of the Resumption of Normal Operation of Structuration when Affective Stressors are removed or when cultural change has ameliorated them below threshold levels.
   a) Once the dissonance between structural conditions and structural principles are reconciled, habitus will stop being reactive to stress affect and the model will return to its base state.

8. Assumption that models conform to the Thermodynamic Arrow of Time.
   a) This has the following effects:
      i) Models can only move forward in time.
      ii) All models will continuously gain entropy with repeated iterations. In this case,

this will be expressed by the creation of additional Historically Contingent Affordances through the unintended consequences of Agency and attempts at agency.

iii) If allowed to run continuously, higher entropy iterations may allow for unanticipated or novel and emergent model behaviour.

The Archaeological Frontier Heuristic Device

The General Structuration Model provides a driver for the model of the 'Agricultural Frontier' which does not conform to Zvelebil's conception of the same phenomenon (Zvelebil 2005, pp. 89–95). The agricultural frontier in this conception is a culturally constructed semi-permeable membrane existing both on the physical landscape and within the minds of knowledgeable actors on either side. It is actively manipulated in everyday dealings with others to either allow or disallow the exchange of specific types of cultural information, technology, and/or knowledgeable persons in either direction. This new construction allows for the passage of cultural material (information, objects which represent information) or people who have information from one group to another.

This 'Frontier' essentially defines the diffusion gradient of total information over time in both directions in a given area. How much of this information is culturally accepted and how quickly it is transferred into a culture's traditions of knowledgeability is governed by the General Unified Model. The Frontier can also be moved in space through active intra- and intercultural agency. This may or may not change its specific active permeability in that new location.

This Frontier model must be reactive to the General Unified Model even though this may seem like an idiosyncrasy. It is, however, the defining heuristic device for visualising intercultural exchange across the Agricultural Frontier Zone over time. It also allows for a very important second level splitting of the information received and incorporated, allowing for dichotomies, such as public/private sphere or any other sort of divide, to develop in what information is allowed to diffuse across it successfully. It is the phenomenological analogue through which the model may be seen to operate in the archaeological record. It is through the Frontier Model which we can see the material correlates of the event cascades generated by stress affect within the self-organised Criticality informed Structuration model.

Historical Path Dependency

Contingent singularities in the path of events can be identified, which leads to the creation of either a momentum-driven event cascade or a self-positively reinforcing process event cascade loop. Both forms lead to a path-dependent determination that a particular event irrevocably changed the path of events within a study area from that point moving forward. This will be true for all events, but contingent singularities represent events for which the pathways have changed irrevocably, and do not represent natural oscillations in materialities within the area under study (i.e., there is always some exchange across a frontier zone but not all of that exchange leads to irreversible macro-level changes). Likewise, these natural oscillations can be broadly recognised as coherent with the signal representing a period of time in the archaeological record while contingent singularities represent (ultimately) the results of large event cascades and a corresponding distinct change in the signal in the archaeological record, which represents real changes in lived reality and, therefore, behaviour (of any type) within the study area.

Agriculturalisation is viewed to be this sort of emergent irrevocable change in social structure and behaviour (Bogucki 2017, pp. 18–22). All contingent

singularity events are by nature examples of emergent behaviour (Bak 1996, p. 51; Kohler 2012, pp. 100–102). This does not mean that they are not acts of agency, merely that those agency options could, by definition, not be enacted before the singularity point of a contingent event cascade or path-dependent sequence because historically contingent affordances were not present. However, the materiality of the archaeological record consists primarily of the residues of behaviours associated with habituated action embodied in the sea of event cascades generated constantly by acts of agency and the unintended consequences of these actions, rather than by intentional agency-driven actions. Agency represents only the coherent portion of the record, which can, in the present and using available methodologies, be discriminated as intentional from the 'noise' of unintended consequences which comprises the vast majority of the archaeological record (Justeson 1973).

The event cascades generated by unintended consequences furthermore interact in positive and negative feedback relationships with each other within the systems of systems that comprise society, allowing for novelty in social conditions, which allow for emergent behaviour during cascade events at all scales. The size of the event cascade, however, allows for the scale independence of the emergent behaviour in both the social non-normativity or geographic extent of change within a networked system up to the total size of that system (Bak *et al.* 1988). It is in this manner that the archaeological record serves as an appropriate medium for path dependency analysis of event cascades in a multiscalar manner.

Study of the materiality of the archaeological record following Agriculturalisation or some other large-scale emergent and irrevocable cascade should be significantly different following those events (Bogucki 2017, pp. 22–24). The character of the signal represented by these material remains (Justeson 1973) may be used to analyse the nature of change which happened during a large rapid cascade, and to a less limited extent, how an event most likely happened, and will fingerprint the material culture contributions of the cultures involved in these interactions.

These periods represent times where signal to noise ratios are significantly higher because extraneous unexpected consequences are being actively utilised and consumed, resulting in highly coherent and dramatic changes in archaeological material culture (Justeson 1973).

ARGUMENT 6

New Governing Dynamics for Structuration in the Unified Model

At least in Western Lithuania, within a span of approximately 300 years after the initial small groups of CWC migrants entered the region, the material culture is almost universally typed CWC. This transition occurred without the production of a significant number of hybrid forms throughout the basin but with hybrid forms in the Lithuanian coastal zone (Piličiauskas *et al.* 2017b). This is indicative of the agency of a very small percentage of the population exerting not only a unidirectional flow in traditions of knowledgeability but also the ability to infiltrate and co-opt the existing cultural structure from within. It is also highly likely, especially considering the distinct hybrid freshwater fishing and pastoral resource base at Šventoji during this time, that Corded Ware individuals became integrated into hunter/gatherer/fisher societies very rapidly.

However, it is not clear in which direction stress affect forced the CWC and Sub-Neolithic groups at this juncture, merely that significant hybridisation occurred on a generational scale. This hybridisation led to a new subsistence pattern involving domesticated ungulates with some form of continued riverine and lacustrine exploitation and a decreased reliance on wild game. This time scale is incredibly important as it implies wide-ranging changes over very short

periods of time followed by another long period of stasis. This would indicate a punctuated equilibrium. If a punctuated equilibrium exists in the movement of the archaeological frontier, it requires that Giddens's Structuration (Giddens 1984) be amended as it is incomplete with respect to two governing dynamics of cultural change which allow for information flow-driven emergent behaviour between cultural systems in contact, behaviour which is brought about by self-organised Criticality (sensu Brummitt *et al.* 2012).

The Unified Model is constituted to encompass the demonstration of the governing dynamics of information flow between two closed knowledge domains (articulated as archaeological cultures) in contact over time. The necessary interplay between the operation of habitus and agency within the model, as it relates to knowledge domains, requires certain conditions for the emergent behaviour within the system of systems composing each unit predicted by the model. Emergent system behaviour can be generalised as being represented in the archaeological record by the rapid appearance of hybridised or radically different cultural assemblages representing heavily modified traditions of knowledgeability.

In the case study under investigation, the marker for this emergent technology is the adoption of agriculture. The emergence of agriculture in this case is accompanied by a dramatic change in the materiality of the archaeological assemblages which represents an abrupt disconformity with the appropriate loss of both vertical and lateral continuity with an accompanying apparent lack of the necessary hiatus in archaeological deposition according to recorded radiometric or other temporal markers across this span of time.

These governing dynamics can be constructed as follows:

1. Cultures which are experiencing stress affect will become increasingly less conservative with regard to the adoption of an alien material culture and ways of life as the intensity of stress affect is increased.
   a) In a system with two cultures under the same stressors, the culture, which is experiencing greater stress affect will become more susceptible to intercultural agency.
   i) This can broadly be used to reconstruct most situations in which an intercultural exchange takes place. It allows for changes in the archaeological record, which appear either diffusionistic or migratory, to be characterised as 'processes' which are in fact event cascades characterised by individual times between events falling below the threshold of archaeological temporal sensitivity. Individual events occur below the threshold of identification via radiocarbon or other dating techniques.
2. At a critical threshold of stress affect, cultures may become reactive to the stressors in their physical and social landscapes, which leads to the complete abandonment of societal mechanisms for cultural conservatism, resulting in new material cultural assemblages which may not be reconcilable with the original cultural assemblages. These cultures can be considered to be under stress affect forcing conditions.
   a) This can broadly be used to reconstruct specific situations of cultural change for situations in which neither diffusion nor migration-style process event cascades can be invoked. These event cascades contain punctuated equilibrium events.
      i) All 'process' style events can be normalised to this model through the recognition of 'process' as an event cascade in which the threshold of archaeological sensitivity has been breached at the individual event level. They merely appear to be 'process' driven and are actually composed of micro-punctuated equilibrium events.

(1) This allows the normalisation of the movement of archaeological frontiers to occur within a single unifying model.

3. These statements allow for better explanations of apparent disconformities in the archaeological record on the macro scale. They also allow for the discriminatory power to parse 'good' knowledge claims from 'bad' ones for the construction of historical modes of explanation for the periods of time during which the agricultural frontier was spreading.

DISCUSSION

For the vast majority of human existence, human beings have lived as hunter/gatherer/fishers. Agriculture is a relatively recent addition to the human adaptive package; yet we treat it as something special rather than just a suite of novel technologies. This could be viewed as incredibly hubristic and ethnocentric. It probably is, and this bias has resulted in the perception throughout the discipline that the Neolithic Revolution was somehow a special suite of technological adaptation, without which the world would never have come to be. Going back and saying 'what if' is a form of nihilism which we cannot allow ourselves given the completely contingent nature of history. Therefore, we cannot claim that the Neolithic Technological Package defines people 'more like us' than those who lived in the Mesolithic. We can merely state that they are different from those who came before them. In this same manner, our contingent history has made us alien to them, and to future archaeologists, who will view our cultural practices as different from those currently practiced at some indeterminate time in the future. This is just a function of societal change over time. One of the Laws of Archaeology, if the discipline ever drafted them, would be that societal change is inevitable given enough time. That may seem like a glib statement and it is, but it is also never been proven to be untrue. Change is inevitable.

Instead we must look for the unifying governing dynamics of human systems which allow for agriculturalisation to be possible and a theoretical lens through which they can be normalisable at all scales. This does not imply the need for the formulation of a general law of agriculturalisation as every specific instance will be culturally relativistic. Merely that we look past that cultural relativism to the structures of human systems of systems themselves in order to create a theoretical lens which can study all those different relativistic universes holistically.

Discussion II

Several attempts have been made to define the agricultural frontier (Social Superiority, Social Prestige, Environmental Adaptive, Demographic, Biological Aspects of the Crop, Inertial Based Push and Pull Models, Gravity Models, Emergent Behaviour, and Disruptive Technology). These are each different parallax views of the agricultural frontier with specific drivers behind the agriculturalisation process. Each is flawed because they cannot normalise all such events in the models which they are attempting to replace or augment. All have roots both in earlier attempts and the current influence on archaeology by fads in other disciplines. This model is different in that it can normalise, and therefore unify, all previous approaches.

The unified model allows for a full range of information exchange behaviour between cultures in contact and the effects of both intercultural agency and landscape level forcing (Environmental and Cultural Stress), which can be simplified to a concept of a generalised stress affect between two societies on an active 'Agricultural Frontier'. Stress affect takes the places gravity (or load) in the sandpile model (Bak 1996, p. 52; Brummitt *et al.* 2012).

Stress affect is defined simply as the dissonance on existing cultural structures caused by landscape-level environmental and cultural forcing. It is a rough index of how much perceived reality within a society conforms to structural expectations. It is also a direct information-based correlate for the sandpile behaviour that Brummitt *et al.* (2012) showed can cause instability within two systems in contact, including selective directionality in system behaviour while in response to stress.

Implications for the Future

The result of increased stress affect results in a direct modification of habitus if stress affect exceeds the conceived cultural expectation of normalcy for an individual or a group. When this happens, if the new governing dynamics proposed in this paper are applied to cultural systems, we can explain the archaeological phenomenon of agriculturalisation over the total orders of magnitude under which such events have happened historically, on a temporal generational scale in terms of the area which has become agriculturalised, from the micro level representing the adoption of agriculture by a single village (Zvelebil 2005, p. 97), to the medium level of agricultural adoption by an archaeological or modern hunter/gatherer/fisher cultures on the micro scale (Robb 2013, pp. 665–673), to larger scale events like those experienced in the Baltic Basin and Atlantic Facade (Bogucki 2017; Piličiauskas *et al.* 2017a; Piličiauskas *et al.* 2017b), to nearly the largest possible (global) scale realised by the Green Revolution of the 1950–1970s (Eveson, Gollin 2003) during which most forms of agriculture currently in existence on the planet were replaced.

The result of this should be a log/log plot of the magnitude of agricultural events of a certain intensity (expressed as area affected) against their frequency together with significantly large outliers and a fat tail of small level events which will terminate at the threshold of archaeological invisibility (radiocarbon threshold). The results of this computational analysis are currently in progress, although since all weakly self-organised critical systems follow this behaviour (Bak *et al.* 1988) and all human systems are weakly self-organised critically (Brunk 2002b), we expect to see results similar to Brunk's analysis of societal collapse (Brunk 2002a, p. 213, Figure 1), albeit with a different fractal dimension.

If this dataset can be shown to have interesting 1/f noise, then the model shows both emergent behaviour and punctuated equilibrium. It will also allow for the parsing of event cascades at different frequencies or intensities to allow for a path dependency analysis (Haydu 2010) and for statistical and empirical testing for the parsimony represented by different explanations of phenomena leading up to and occurring during agriculturalisation events as well as the resultant material culture assemblages, all of which go beyond the suite of analyses currently available in parallaxes of a strictly material culture study.

CONCLUSION

It has not escaped the authors' attention that this paper provides a Unified Model of Cultural Evolution. Because it is both unified and fully scalable in both time and space, one may apply the same explanatory model to events at all scales from the individual to the family, the village, the city, and the nation-state. Being temporally scalable, it is applicable from the Palaeolithic, Neolithic, Bronze Age, and the suite of Iron Ages from their inception through the Industrial Revolution, all the way to the present-day Information Age. It also means that we can meaningfully compare the points of punctuated equilibrium in social and technological development across and between these ranges.

Initial use of this model on the Lithuanian agricultural frontier shows that it was not worthwhile

for hunter/gatherer/fisher groups who lived contiguously and contemporaneously with early agriculturalists to take up agriculture until their cultural systems were sufficiently disrupted by stress affect. Once this occurred, change was very fast, on the order of generations (below the radiocarbon threshold), which offered no evolutionarily discrete transitional cultural assemblages until a new normal was established, one with radically different materialities that reflected the new cultural structures, which were once again in equilibrium with the combined social and environmental landscape stressors (stress affect).

REFERENCES

Adamczak, K., Kukawka, S., Małecka-Kukawka, J., 2017. North-eastern periphery of the Eastern group of the Funnel Beaker culture–80 years later. *Papers and Materials of the Archaeological and Ethnographic Museum in Łótź Archaeological Series,* 47, 71–90.

Bak, P., 1996. *How nature works: the science of self-organized criticality*. New York: Copernicus Press.

Bak, P., Tang, C., Wiesenfeld, K., 1988. Self-organized criticality. *Physical review A*, 38(1), 364–368.

Barrett, J.C., 2000. A thesis on agency. *In:* Dobres, M.A., Robb, J. E., eds. *Agency in Archaeology*. London, New York: Psychology Press, 61–68.

Barrett, J.C., 2001. Agency, the duality of structure and the problem of the archaeological record. *In:* Hodder, I., ed. *Archaeological Theory Today*. Cambridge University Press, 141–164.

Bitinas, A., Karmazien, D., Jusien A., 2004. Glaciolacustrine kame terraces as an indicator of conditions of deglaciation in Lithuania during the Last Glaciation. *Sedimentary Geology* 165(3), 28–294.

Bitinas, A., 2012. New insights into the last deglaciation of the south-eastern flank of the Scandinavian Ice Sheet. *Quaternary Science Reviews* 44, 69–80.

Bogucki, P., 2017. 'Disruptive Technologies' and the Transition to Agriculture in Scandinavia and the British Isles. *In:* Crabtree, P.J., Bogucki, P., eds. *European Archaeology as Anthropology: Essays. Memory of Bernard Wailes.* University of Pennsylvania Press, 9–38.

Bourdieu, P., 1977. *Outline of a Theory of Practice.* Cambridge university press.

Brazaitis, D., 2002. Narviškos keramikos stiliai rytų Lietuvoje. *Lietuvos archeologija*, 23, 51–72.

Brummitt, C.D., D'Souza, R.M., Leicht, E.A., 2012. Suppressing cascades of load in interdependent networks. *Proceedings of the National Academy of Sciences*, 109(12), E680–E689.

Brunk, G.G., 2002a. Why do societies collapse? A theory based on self-organized criticality. *Journal of Theoretical Politics*, 14(2), 195–230.

Brunk, G.G., 2002b. Why are so many important events unpredictable? Self-organized criticality as the 'Engine of History'. *Japanese Journal of Political Science*, 3(1), 25–44.

Evenson, R.E., Gollin, D., 2003. Assessing the impact of the Green Revolution, 1960 to 2000. *Science*, 300(5620), 758–762.

Galison, P., 1997. *Image and logic: A material culture of microphysics.* Chicago, Illinois: University of Chicago Press.

Gibbs, K., Jordan, P., 2013. Bridging the Boreal Forest: Siberian archaeology and the emergence of pottery among prehistoric hunter-gatherers of northern Eurasia. *Sibirica: the Journal of Siberian Studies*, 12(1), 1–38.

Giddens, A., 1984. *The constitution of society: Outline of the theory of structuration.* University of California Press.

Girininkas, A., 2013. *Lietuvos archeologija: Ankstyvasis metalų laikotarpis.* Klaipėdos universiteto leidykla.

Haydu, J., 2010. Reversals of fortune: path dependency, problem solving, and temporal cases. *Theory and Society*, 39(1), 25–48.

Hodder, I., Cessford, C., 2004. Daily practice and social memory at Çatalhöyük. *American antiquity*, 69(1), 17–40.

Jordan, P., 2012. Examining the role of agency in hunter-gatherer cultural transmission. *In:* Gardner, A., ed. *Agency Uncovered: Archaeological Perspectives on Social Agency Power and Being Human*. London: UCL Press, 110–137.

Justeson, J.S., 1973. Limitations of archaeological inference: an information-theoretic approach with applications in methodology. *American Antiquity*, 38(2), 131–149.

Kohler, T.A., 2012. Complex systems and archaeology. *In:* Hodder, I., ed. *Archaeological theory today*. Cambridge: Polity Press, 93–123.

Kriiska, A., Oras, E., Lõugas, L., Meadows, J., Lucquin, A., Craig, O.E., 2017. Late Mesolithic Narva stage in Estonia: pottery, settlement types and chronology. *Estonian Journal of Archaeology*, 21(1), 52.

Kuhn, T., 1962. *The Structure of Scientific Revolutions*. Chicago, Illinois: The University of Chicago Press.

Meltzer, D.J., 1979. Paradigms and the nature of change in American archaeology. *American Antiquity*, 44(4), 644–657.

Milisauskas, S., ed., 2011. *European prehistory: A survey*. New York: Springer Science & Business Media.

Piličiauskas, G., 2016. Lietuvos pajūris subneolite ir neolite. Žemės ūkio pradžia. *Lietuvos archeologija*, (42), 25–103.

Piličiauskas, G., 2018. *Virvelinės keramikos kultūra Lietuvoje 2800–2400 cal BC*. Vilnius: Lietuvos istorijos instituto leidykla.

Piličiauskas, G., Asheichyk, V., Osipowicz, G., Skipitytė, R., Varul, L., Kozakaitė, J., Kryvaltsevich, M., Vaitovich, A., Lakiza, V., Šapolaitė, J., Ežerinskis, Ž., 2018. The Corded Ware culture in the eastern Baltic: new evidence on chronology, diet, beaker, bone and flint tool function. *Journal of Archaeological Science: Reports*, 21, 538–552.

Piličiauskas, G., Jankauskas, R., Piličiauskienė, G., Craig, O.E., Charlton, S., Dupras, T., 2017a. The transition from foraging to farming (7000–500 cal BC) in the SE Baltic: A re-evaluation of chronological and palaeodietary evidence from human remains. *Journal of Archaeological Science: Reports*, 14, 530–542.

Piličiauskas, G., Jankauskas, R., Piličiauskienė, G., Dupras, T., 2017b. Reconstructing Subneolithic and Neolithic diets of the inhabitants of the SE Baltic coast (3100–2500 cal BC) using stable isotope analysis. *Archaeological and Anthropological Sciences*, 9(7), 1421–1437.

Piličiauskas, G., Kisielienė, D., Piličiauskienė, G., 2017c. Deconstructing the concept of Subneolithic farming in the southeastern Baltic. *Vegetation History and Archaeobotany*, 26(2), 183–193.

Piličiauskas, G., Mažeika, J., Gaidamavičius, A., Vaikutienė, G., Bitinas, A., Skuratovič, Ž., Stančikaitė, M., 2012. New Archaeological, Paleoenvironmental, and ^{14}C Data from the Šventoji Neolithic Sites, NW Lithuania. *Radiocarbon*, 54(3–4), 1017–1031.

Rinterknecht, V.R., Bitinas, A., Clark, P.U., Raisbeck, G.M., Yiou, F., Brook, E.J., 2008. Timing of the last deglaciation in Lithuania. *Boreas* 37(3), 426–433.

Robb, J., 2013. Material Culture, Landscapes of Action, and Emergency Causation: A New Model for the Origins of the European Neolithic. *Current Anthropology*, 54(6), 657–683.

Robson, H.K., Skipitytė, R., Piličiauskienė, G., Lucquin, A., Heron, C., Craig, O.E., Piličiauskas, G., 2019. Diet, cuisine and consumption practices of the first farmers in the southeastern Baltic. *Archaeological and anthropological sciences*, 11(8), 4011–4024.

Rowly-Conwy, P., 2014. Foragers and farmers in Mesolithic/Neolithic Europe, 5500–3900 cal BC: beyond the anthropological comfort zone. *In:* Foulds, F.W.F., Drinkall, H.C., Perri, A.R., Clinnick, D.T.G., Walker, J.W.P., eds. *Wild things: recent advances in Paleolithic and Mesolithic research*. Oxford: Oxbow Books, 185–201.

Sewell Jr, W.H., 1992. A theory of structure: Duality, agency, and transformation. *American journal of sociology*, 98(1), 1–29.

Sheridan, J.A., 2016. The Neolithisation of Britain and Ireland: Arrival of Immigrant Farmers from Continental Europe and its Impact on Pre-existing Lifeways. *In:* Sanz, N., ed. *The Origins of Food Production*. UNESCO, Mexico Office, 226–245.

Tadić, B., Dankulov, M.M., Melnik, R., 2017. Mechanisms of self-organized criticality in social processes of knowledge creation. *Physical Review E*, 96(3), prieiga per: DOI: 10.1103/PhysRevE.96.032307.

Zvelebil, M., 2005. Homo habitus: agency, structure and the transformation of tradition in the constitution of the TRB foraging-farming communities in the North European plain (ca 4500–2000 BC). *Documenta Praehistorica*, 32, 87–101.

Лозе, И.А., 1979. *Поздний неолит и ранняя бронза Лубанской равнины*. Рига: Зинатне.

ABBREVIATIONS

CWC – Corded Ware culture
EFN – Eastern Forest Neolithic
GAC – Globular Amphora culture
RC – Rzucewo culture
TRB – Funnel Beaker culture
WFN – Western Forest Neolithic

BENDRASIS VAROMŲJŲ JĖGŲ MODELIS AGROKULTŪRINIAMS PASIENIAMS

Christopher Barber Troskosky, Jonathan Mark White, Lukas Gaižauskas

Santrauka

Straipsnyje pateikiamas bendras modelis, paaiškinantis žemdirbystės perėmimui būtinų žinių perdavimą erdvėje.

Straipsnis yra iš šešių dalių sudarytas modelio pagrindimas: keturiose dalyse pristatomi įrodymai, įvedantys į modelį, penktame jis apibūdinamas, paskutinėje aptariamas neatpažintų valdančių dinamikų – varomųjų jėgų – taikymas. Baigiama diskusija apie modelį ir minėtus įrodymus.

Sukurtas ne vienas teorinis modelis agrokultūriniam pasienių judėjimui (socialinės viršenybės, socialinio prestižo, prisitaikymo prie aplinkos, demografinis, biologinių javų savybių, inercija paremtos traukos ir stūmos modeliai, gravitacijos modeliai, emerdžentinės elgsenos ir ardančios technologijos modeliai) paaiškinti. Tie modeliai tėra įvairūs (paralakso) požiūriai į agrokultūrizaciją, pagrindinius ją lemiančius veiksnius ir turi trūkumą, nes negali normalizuoti visų įtaką darančių veiksnių iš tų modelių, kuriuos siekia pakeisti ar paremti, papildyti. Paprastai nauji modeliai atsiranda iš ankstesnių bandymų ar kitų disciplinų madų įtakos archeologijai. Straipsnyje pateikiamas modelis skiriasi tuo, kad gali normalizuoti ir apimti visus modelius.

Bendrasis modelis įtraukia elgseną, susijusią su bendraujančių kultūrų keitimusi informacija, taip pat tiek tarpkultūrinį veiksnį, tiek kraštovaizdžio spaudimą (kultūrinis ir aplinkos stresas). Juos galima supaprastinti kaip apibendrintą streso afektą aktyviame „agrokultūriniame pasienyje“ tarp dviejų bendruomenių. Streso afekto sąvoka pakeičia kritinį smėlio krūvos modelio krūvį (Bak 1996, p. 52, Brummitt *et al.* 2012).

Streso afektas paprastai apibrėžiamas kaip egzistuojančiose kultūrinėse struktūrose atsirandantis

disonansas, sukeltas kraštovaizdžio lygmens klimato ir kultūrinio aplinkos spaudimo. Tai yra apibendrintas rodiklis, kaip suvokiama tikrovė bendruomenėje atitinka struktūrinius lūkesčius. Streso afektas taip pat yra tiesioginis, informacija paremtas koreliantas smėlio krūvos elgsenai, aprašytai Brummitt *et al*. 2012. Ši elgsena lemia dviejų kontaktuojančių sistemų stabilumo praradimą; sistemų elgesiui reaguojant į stresą būdingas selektyvus kryptingumas.

Preliminarus modelio taikymas agrokultūriniam Lietuvos pasieniui rodo, kad šalia ankstyvųjų žemdirbių gyvenusioms medžiotojų-rankiotojų-žvejų grupėms nebuvo priežasties perimti žemdirbystės, kol pastarųjų kultūrinės sistemos nebuvo išardytos streso afekto. Kai tai atsitiko, atkeliavus Virvelinės keramikos kultūros gyvulių augintojams, pokytis buvo labai staigus, įvykęs per kelias kartas (dažnai staigesnis, nei galima nustatyti radioanglies datavimo metodu) bei nepalikęs jokių evoliuciškai išsiskiriančių pereinamojo laikotarpio kultūros pėdsakų. Pokyčiui įvykus, įsigalėjo nauja, visiškai kitokia materialiosios kultūros požymių visuma, rodanti naujas kultūrines struktūras, kurios vėl pasiekė pusiausvyrą su jungtiniu socialinio ir fizinio kraštovaizdžio spaudimu (streso afektu).

Autoriai nepamiršta, kad straipsnyje pateikiamas būtent bendras kultūrinės evoliucijos modelis. Kadangi modelis kartu yra bendras ir taikomas kintamu mastu laike bei erdvėje, jis gali būti taikomas įvairių mastelių objektams nuo individo iki šeimos, kaimelio, miesto ar tautinės valstybės. Pritaikymas kintamu mastu laike reiškia, jog jis gali būti taikomas nuo paleolito, neolito, bronzos amžiaus ir daugelio geležies amžiaus laikotarpių iki pat informacijos amžiaus dabartyje. Galiausiai, modelis padeda prasmingai palyginti socialinio ir technologinio vystymosi punktualizuotos pusiausvyros taškus šių sričių viduje bei tarp jų.

ILIUSTRACIJŲ SĄRAŠAS

1 pav. Tiriamojo laikotarpio keramikos seka Lietuvoje. Atkreipkite dėmesį į pailgus dubenėlius – lemputes, siejamas su miškų neolito kultūrų įtaka. *Pagal* Robson *et al.* (2019).

2 pav. Archeologinės radimvietės ir kultūros, paminėtos tekste. Strėlėmis pažymėtos galimos Virvelinės keramikos kultūros plitimo per miškų neolito pasienį kryptys apie 2800 BC. Taip pat pažymėtos Piltuvėlinių taurių ir Rutulinių amforų kultūrų teritorijos. Sąveika tarp Rutulinių amforų ir Pietų Lietuvos miškų neolito grupių prasidėjo iki 2800 BC. *Sudarė L. Gaižauskas, 2019.*

3 pav. Struktūracijos modelis normaliame (viršuje) ir reaguojančiame (streso veiksnio perkrovos) (apačioje) veikimo režimuose. Atskiros spalvos (mėlyna ir geltona) rodo nepriklausomą kultūrinę sistemų sistemą. Santrumpos: IA – veiksniai kultūros viduje, SP – struktūriniai principai, TK – išmanymo tradicijos, HC – istoriniai suvaržymai. *Modelių diagramas sukūrė ir nupiešė C. B. Troskosky*, 2016.

Gauta 2019 06 15
Priimta 2019 08 02