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Population Dynamics, Social Resilience Strategies, and Adaptive Cycles in Early Farming Societies of SW Central Europe

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Abstract

Inferred European Holocene population size exhibits large fluctuations, particularly around the onset of farming. We attempt to find explanations for these fluctuations by employing the concept of cycling, especially that of the Adaptive Cycle. We base our analysis on chronologically and chorologically highly resolved ceramic and site data from the Linear Pottery culture (Germ. *Linearbandkeramik*) of the early Neolithic of southwestern Central Europe. Typological seriation with dendrochronological anchor dates provides the age model for these data. Ceramic motifs are analysed with respect to the temporally changing diversity in decoration. The temporal sequence of major decoration motifs is interpreted as an indicator of social diversity: when stylistic diversity is low, social diversity is low and vice versa. The sequence of secondary decoration motifs is interpreted in terms of individual lineage emphasis: when this diversity is low, there is strong emphasis on individual lineage and vice versa. The diversity time series are complemented by a relative population size indicator derived from the count of occupational features. Diversity and population size share a shape that is typical for (part of) an Adaptive Cycle, and they differ in their positioning on the time axis — they are time-lagged. By relating the different curves to the (metaphorical) stages of the Adaptive Cycle, we find that these cycles progress at non-identical speed in different aspects of a social system. By relating the social dynamics to well-dated and highly resolved climate fluctuation records, we find evidence that severe climate excursions shaped the location of tipping points in the social system and that these social tipping points precede inferred population decline by several generations.

Keywords

Early Neolithic; Central Europe; social resilience; cycling; climate

1 Introduction

For a number of years, it has become evident that neither global nor regional Holocene population trajectories followed a steady upward and linear trend, but instead – when investigated at higher temporal resolutions – underwent non-linear increases and decreases (Zimmermann, 2012a; Shennan, 2013). Particularly around the onset of agriculture, population trends show often considerable ups and downs (Bocquet-Appel, 2011; Shennan et al., 2013). These population dynamics also seem to be reflected in the genetic record with certain haplogroup lineages decreasing during periods of population decline (Brandt et al., 2015). While these Early Neolithic fluctuations have been thoroughly described, hypotheses for their existence and their exact curve progression on the time-line are only beginning to be formulated. The current debate ranges around external forcing such as climate fluctuations (Weninger et al., 2009; Clarke et al., 2016; Sánchez Goñi et al., 2016), or internal forcing such as social factors (Peters, 2012; Zimmermann, 2012a; Shennan, 2013; Downey et al., 2016) or combinations of both (Gronenborn et al., 2014; Gronenborn, 2016). Palaeogenetic research on diseases (Rasmussen et al., 2015) has yet focused on the earlier Neolithic data set – such approaches may eventually add a whole new aspect to the debate on population dynamics.

In the meantime, we here continue arguing along traditional lines and investigate how a combination of both internal (social/political) dynamics and external (climate/environment) triggering or even forcing might have shaped the population curves of early farming societies in Temperate Europe. Building upon previous work (Gronenborn, 2012; Gronenborn et al., 2014; Gronenborn, 2016), we try to specify the application of Resilience Theory (RT) and the concept of Adaptive Cycles (AC) (Holling and Gunderson, 2002), but also the demographic-structural theory (DST) formulated by Turchin and Nefedov (2009), and to classify and define attributes for certain parameters of RT in the archaeological record. As before, we use data from the early farming societies of Temperate Europe, the Linear Pottery culture (Germ. *Linearbandkeramik* – LBK).

2 Resilience and Adaptive Cycles in Historiography and Archaeology

While the application of RT and AC dates back about a decade within archaeology (Redman, 2005; Kintigh et al., 2014, pp. 11–12) the concept of resilience itself and historical thinking in cyclical dynamics is considerably older, in fact both go back to Classical Antiquity.

2.1 Resilience

The academic application of the term and the concept of resilience dates back several decades in psychology (Werner et al., 1971), sociology (Pettit, 2007), and the environmental sciences (Holling, 1973) from where the idea eventually became introduced to archaeology. However, most archaeological studies have omitted or avoided precise definitions of RT parameters, such as resilience and connectedness, and taken the theory rather as a background template channelling the general line of thought. Indeed, has the defintory vagueness inherent in RT been criticised before (Olsson et al., 2015). It is therefore important to examine how certain factors may be extracted from an archaeological data-set, in order to apply the theory more precisely.

Resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks (Walker et al., 2004); resilience is an emergent property, which is neither observable in or deducible from any single aspect of a society or ecosystem, and which is a consequence of feedbacks and interactions within the system and across its different scales; resilience may develop unconsciously and is maximised in ecosystems and social systems (Cropp and Gabric, 2002; Kirmayer et al., 2009). Resilience is a continuous process, an active response to constant threats (Holling, 1973; Adger, 2000; Berkes et al., 2008; Keck and Sakdapolrak, 2013; Lorenz, 2013). Furthermore, as individuals, groups, or systems move through time, threats and stressors change as do specific historic situations, therefore resilience strategies change and flexibly adapt to the particular situation or emerge newly; in fact, inflexibility in hazard response strategies may be utterly counterproductive (Janssen et al., 2003, p. 727; Lorenz, 2013, p. 12).

2.1.1. Social Resilience

In the social sciences, the wider resilience concept has been criticized for its neglect of the individual, of agency (Olsson et al., 2015, p. 9). However, when environmental resilience is decoupled from social resilience, the latter concept becomes more applicable as research on social resilience focuses on inherently in-group forms or strategies of coping with either external or internal stressors (Keck and Sakdapolrak, 2013).

Social resilience strategies develop as responses to specific historic situations: Under certain historic circumstances a high level of social diversity may be an appropriate and successful strategy. This would entail a high number of social sub-groups, such as lineages, political fractions, religious sub-groups, or very generally social identities. Other historic circumstances may require more rigid forms of organisation and group cooperation (Turchin, 2003, pp. 29–38; Hegmon et al., 2008; Carballo, 2013). This then would be a reverse of previous diversity strategies.

Social diversity encompasses what Turchin (2003, pp. 36–38) calls „collective solidarity“. Collective solidarity is for instance related to Ibn- α aldūn's concept of α abīyah best translated as “the sense of social solidarity” (Ritter, 1948, p. 3) (see also below), Durkheim's (1883) “mechanical solidarity” (Fr. *solidarité mécanique*), Weber's (1980) “social acting” (Germ. *soziales Handeln*), or Olson's (2003) “collective action”. According to Turchin and Nefedov's (2009, p. 33) predictions for their DST low diversity should correspond to low collective solidarity and high diversity to high collective solidarity. Albeit problematic, as even in present-day data-sets it is difficult to be discerned in material or textual records, “collective solidarity” may nevertheless be an enormous forcing agent in historical trajectories. The question raised then is, how do these resilience strategies of differing social diversity become visible in the archaeological record?

Social diversity strategies may become expressed in festivities and their archaeological remains (Dietler and Hayden, 2001), or may become visible in the active sharing of styles and style diversification (Sackett, 1977; Conkey and Hastorf, 1990). Particularly styles have been studied extensively both ethnographically and ethnoarchaeologically for their manifold social and political signaling content: Styles may be an essential expression of social identities like ethnicity (Barth, 1969). These are self-ascribed and believed by the respective individuals and their groups, are social constructs to set this group apart from others (Barth, 1969; Lentz, 1995; Kent, 2002). This self-identification operates on various levels, from individuals, to families, to lineages, and to broader socio-political entities like tribes or states (Blanton, 2015).

Intensified cooperation, whether forced or voluntary, may equally leave archaeological traces such as increased erection of communal buildings, discussed e. g. for enclosures of the Upper or Young Neolithic (Edmonds, 1993; Andersen, 1997; Whittle et al., 2011), or warfare (Ember and Ember, 1994; Cacioppo et al., 2011). Warfare – understood here in a very general sense as organized group violence – may not only be indicative of periods of unrest, but may also be a factor leading to stabilization (Bowles, 2009). In times of expansion warfare may

become a social and political ideal and successful warriors are seen as heroes whose idealisation serves to build resilience (Divale and Harris, 1976). However, as all too well known, warfare and a warring ideology may have an initially beneficial effect on societies in enhancing group cooperation and solidarity, yet its long-term consequences may lead to widespread material and social destabilization amongst all participating parties, sometimes to prolonged periods of complete social and political destabilization (Ember and Ember, 1992; Ember and Ember, 2007).

The above, albeit very brief, introduction into resilience and the component of social solidarity shows that these are essentially very volatile concepts. Nevertheless, are there possible archaeological markers, as will be discussed below. Strategies change, depending on the feedback with other parameters operating on trajectories. But are those changes unstructured, or do they follow patterns? This question is related to the concept of cycles.

2.2 Cycles

Cycling of socio-political and economic systems is a concept already documented for ancient Greek historiography (Ryffel, 1949; Liddel, 2010). A first elaborate and dynamic system of a cyclical succession of increasingly complex political organizations was developed by Polybius during the second century BC (Labuske, 1977). The forcing behind the changes from one consecutive system to another is the eternal conflict between common welfare on one side, and vanity and envy on the other (Polybius Hist. VI, II 7-9).

After Polybius and other theoreticians of Classical Antiquity thinking had progressed more along unilineal trajectories, often with an emphasis on the decline of societies, a line of thought termed degenerationism. Medieval theoreticians were for example the already mentioned Ibn-~~al~~aldū (Ibn-~~al~~aldū and Giese, 2011) and Macchiavelli who incorporated elements of degenerationism in his *Discorsi* (Pinzani, 2012). Early Modern and Modern approaches emphasizing crises and decline include Gibbon (1906), and economists like Malthus (1820), de Sismondi (Stewart, 1984; Redmond and Spencer, 2012), or the historian-philosopher Spengler (Spengler et al., 1991).

A related, yet opposing field of theories is evolutionism, including Marxism, and neoevolutionism (Spencer, 1897; White, 1959; Engels, 1989). However, both evolutionism and neoevolutionism do not so much emphasize alternating cycles, although the transitions from one stage to another may have aspects of collapse and reformation.

Cyclical thinking in terms of combinations of evolutionism and degenerationism appear again in Dunoyer's hypothesis of economic cycles with alternating upward and downward movements (Benkemoune, 2009). Twentieth century theorists were Kondratieff (Makasheva et al., 1998), and scholars of the French *Annales* school like Braudel (Braudel and Reynolds, 1986),

Archaeological approaches encompassing elements of cycling are embedded in the “dual processual theory” proposed by Blanton et al. (1996). Societies shift between the stages of network and corporate strategies, with the former being elite-dominated while the latter emphasise group solidarity and cooperation. Cycling is also a component of political anthropology-related approaches as for instance in Anderson (1996). Based on data from the later prehistoric North American South-East he suggested a model of increasing and decreasing political complexity of chiefdoms. Lastly, within the last 15 or so years the concept of Adaptive Cycles was taken from socioeconomics and ecology, with hitherto numerous applications, also decidedly in opposition to all-too degenerationist concepts emphasizing collapse (McAnany and Yoffee, 2010a). AC are part of the panarchy framework which outlines the nested set of AC over various scales (Gunderson and Holling, 2002). AC have been described on so many occasions that we abstain here from any further explanation and refer to the respective literature (Holling and Gunderson, 2002). It needs however to be underlined, that the concept, in the words of Scheffer (2009, p. 79), is a “heuristic model, obtained in an inductive way” using “intuitive metaphors”. In archaeology the cycle model was readily picked up and altered: Zimmermann (2012a) suggested the term “cultural cycles” as more appropriate for archaeology, Gronenborn et al. (2014, p. 75) have suggested to apply a two-dimensional visualization instead of the three-dimensional infinity symbol.

Somewhat parallel to the application of AC and the panarchy framework in archaeology Turchin (2003) and Turchin and Nefedov (2009) have begun to work with secular cycles in historiography or rather in mathematical modeling of historic trajectories. However, this work was confined to later periods of prehistory and history, to complex political systems like states and empires (Turchin, 2009). Turchin and Nefedov (2009, pp. 19–21) divide the secular cycle into two opposing tendencies which they term “integrative” and “disintegrative”, hence combining evolutionist with degenerationist views. Integrating demographic components, social structure and dynamic factors like surplus extraction, state breakdown, and instability they formulated the demographic-structural theory (DST) (Turchin and Nefedov, 2009, 33 Tab. 1.1). DST is in many ways related to AC, but emphasises economic and political factors more than environmental ones, like e.g. the role of elites (Turchin and Nefedov, 2009, 17-18; 20-21). However particularly this variable may be difficult to investigate for societies less hierarchically organized. “Collective solidarity”, already referred to above, is one fundamental variable in their theory (Turchin and Nefedov, 2009, 33 Tab. 1.1).

The concept of “collective solidarity” does not exist in RT, but it might be related to the variable “connectedness”. Holling (2001, p. 394) define “connectedness” as “a measure that reflects the degree of flexibility or rigidity” of “the internal controllability of a system”. We find this definition problematic for our purpose – particularly as the variable in AC culminates towards the tipping point – and have suggested the more neutral term “complexity” as a measure of social, political, and economic diversity (Chapman, 2008; Page, 2010; Gronenborn et al., 2014, p. 75).

In our model (Fig. 1), derived from AC and DST and refining our own previous work (Gronenborn et al., 2014), early phases of a cycle would be characterized by low diversity, low collective solidarity, low complexity. These variables rise until they reach a tipping point after which the process is reversed, a mechanism which has also been termed “complexity

cascade” (Coombes and Barber, 2005). With the loss of social diversity, more rigid forms of political organization and group cooperation may develop, warfare may be one component of this phase. Hence, somewhat in opposition to Holling (2001) or Hegmon et al. (2008), “connectedness” or “rigidity” is not a marker of societies at their peak of accumulation, but rather a marker of the decline or disintegrative period when societies attempt to return to comfort.

After this condensed and thus inevitably incomplete introduction to the research history we want to shift to the case study with the aim to enhance our present understanding of how social resilience strategies operate within cycling systems. Relating to our own previous work we are particularly interested in investigating early farming societies, as these may have undergone the first pronounced cycles in human history, ultimately leading to complex societies and states (Zimmermann, 2012a). As markers of information on social resilience strategies, we have chosen to investigate styles, best preserved in the archaeological record of early European farming societies as decoration motifs on ceramics.

Ceramics is probably the most comprehensive archive of styles in the global archaeological record, and numerous studies have investigated how pottery style analyses may help to unveil past social and political structures (Hally et al., 1990; Dietler and Herbich, 1994; Graves, 1994; Gosselain, 2000; Sommer, 2003; Gokee, 2015). Mostly, these studies were concerned with questions of stylistic boundaries and their social and political embedding – classic questions of traditional archaeology –, but some studies did look for underlying dynamics. For instance, did Shennan and Wilkinson (2001) demonstrate that neutral evolution would not fully explain the Rhineland early farming society data set and that Firdich’s (1994) original idea of a social component in the observed changes had to be considered.

In a related study Kohler et al. (2004), following Henrich and Boyd (1998), suggested that unexpectedly low design diversity in pre-hispanic Puebloan Southwest ceramics would reflect a tendency towards stylistic conformity, which is further interpreted as an effect of increased within-group cooperation. In another case-study from late prehistoric-early historic southern Ontario, Canada, Hart et al. (2016) were able to show how a process of socio-political coalescence was also reflected in changes in pottery style: In the course of the consolidation of the Iroquois nations and historic confederacies a certain pottery style became dominant, reflecting a trend to uniform signalling practices as a strategy of integration in the course of the drastic changes around the early European contact period (Hart et al., 2016, pp. 20–21). A study by Blanton (2015) had previously suggested that signalling may be particularly effective in the course of ethnic group building.

Drawing on the above studies, we postulate that low stylistic diversity may be interpreted as an indicator of low social diversity or high group cooperation sensu Kohler et al. (2004), whereas increased stylistic diversification would indicate an increased socio-political diversification or complexity. A return to less diversification would then mark a reverse of the socio-political process (Fig. 1).

3 The Central European LBK

Studying cyclical trajectories, particularly in regard to social resilience, requires robust time-series of indicators. The major methodological but also theoretical task is to extract, classify, and quantify appropriate proxies for social resilience from the archaeological record. This proves all the more difficult, as resilience strategies are inherently volatile (see above). Finding short-term response strategies in any non-textual, material record may be less problematic if the specific historic scenario is well documented materially and a certain strategy may be linked with a certain stressor, but it will be very difficult to extract a homogenous and robust indicator for a long-term resilience trajectory from any data set.

We apply our research questions to a data-set produced from the general record of a well-documented archaeological entity, namely from the western Linear Pottery culture (LBK) of Central Europe. Having emerged in Western Hungary (Strien, 2014; Bánffy, 2015; Jakucs et al., 2016) these early farmers migrated to about the Rhine during their first expansion stage, and then moved further westward to the Rhineland, Alsace, southern Belgium and ultimately the Paris Basin during their final stage (Fig. 2) (Burnez-Lanotte et al., 2008). The archaeological remains are characterized by long houses, forming single farmsteads, clusters, hamlets and sometimes extensive villages (Lüning, 1982; Zimmermann et al., 2005; Hamon et al., 2013; Coudart, 2015). Since the 1930ies LBK settlement history has been examined with a thorough and continuously refined methodology, a combination of typochronological studies of ceramics and absolute dating methods like ¹⁴C-dating and dendrochronology (Stehli, 1994; Strien, 2000; Kerig, 2005). LBK is particularly well-suited for fine-grained archaeological investigations as the characteristic pottery is highly decorated with numerous motifs – the typical incised bands and filling motifs (Fig. 3). A thorough description of the method and definitions of band types are available online (Kerig et al., 2010). Band types may be chronologically and chorologically arranged and reveal fine-graded chronological information but also information on social structures such as group and sub-group affiliation. One of the most detailed information was produced from the data of the site of Vaihingen (Strien, 2005; Bogaard et al., 2011). From this and other data it may be inferred that western LBK was organized as segmentary societies along what could be called lineages, or more general descent lines (Bentley et al., 2008; Strien et al., 2014).

3.1 The regional case study: Resilience indicators for the Linear Pottery culture (LBK) of Southwest Germany

The following analyses are based on data being compiled in dASIS (distributed Archaeological Site Information System), a corpus of currently more than 4000 entries for the Early and Upper Neolithic in SW and W Germany and adjacent regions consisting of numerous regional sub-sets (Bruhn et al., 2015). Two of the sub-sets – LBK in Württemberg and the Rhineland – have a typochronological resolution of 25 years (Figs. 4 and 5). For this study we focus on the Württemberg data as the information on ceramics follows the most

current band type classification standard. Out of the Württemberg data base (Neckar valley and region around Ulm) we extracted a population proxy and two indicators for changes in ceramic styles. While the Württemberg data-set provides up-to-date chronologically fine-grained and regional high-density ceramic information, the information on population dynamics is unfortunately inferior to the data from the Rhineland where extensive excavations and surveys have resulted in numerous complete site plans. These do allow calculations of absolute population numbers (e.g. Zimmermann et al., 2009), however the Württemberg settlement data does not. Thus, we took the abundance (counts) of features (pits) per chronological entity as a population proxy (Fig. 4 d), or more precisely as a human activity indicator, interpreted as a population proxy.

Our applied archaeological age model (Fig. 5) is largely based on the dendrochronological anchor dates from the wooden wells of Kückhoven and Mohelnice (Schmidt and Gruhle, 2003), thus we apply the abbreviation BC instead of cal BC (calibrated ^{14}C -measurement) for our age model. We prefer these typo-chronologically-based and dendrochronologically anchored pottery series because they allow including data from surveys, collections and salvage excavations from which no ^{14}C -measurements are available. Furthermore, this method allows to date features and sites within the later 6th millennium ^{14}C -plateaus (Petrasch, 1999; Cladders and Stäuble, 2003, 497 Fig. 4). The chronological entity is based on the concept of “house generation” as defined in the western LBK compound or yard model (Germ. Hofplatzmodell) (Boelicke, 1982; Kind, 1989; Zimmermann, 2012b). We here use a length of 25 years per house generation as a calculated mean of life-spans of real individual houses. Thus, the chronology is counted backwards – or forward – in 25-year increments, beginning with the Kückhoven anchor dates (fig. 5). An inherent problem is, that the age-model becomes increasingly imprecise towards the early LBK as discrepancies between mean duration and actual life-spans of individual houses add up. For the early phases the dendrochronological date from the Mohelnice well serves as another anchor date, however somewhat imprecise since the actual felling date for the beam is unclear (Schmidt and Gruhle, 2003). This age model is still under construction and obviously needs to be complemented by carefully selected ^{14}C -measurements from undisturbed contexts, and – preferentially – further dendrochronological dates from other wells (Tegel et al., 2012). While the age model still has its drawbacks, particularly towards the older period, we feel it to be agreeably robust for the yLBK and the study area dealt with here.

The Württemberg population proxy is compared to a measure of diversity (Shannon diversity index) (Shannon, 1948), calculated for the LBK decoration motifs (Germ. Bandtypen). The age model applied to this data series is methodologically based on correspondence analysis and consist of irregular spaced style phases (Figs. 3; 4). The resulting graph (Fig. 4 c; Tab. 1) shows that diversity amongst band motifs in the Württemberg data set is low at the beginning of LBK and rises to a tipping point around 5150 BC after which it declines, most rapidly after 5120 BC.

BC (midpoint)	stylistic phase	secondary motifs (number) Vaihingen only	H	band types (number) Württemberg	H
5400	1	117	1,76	703	1,93
5335	2B1	127	1,65	615	2,08
5288	2B2	239	1,73	842	2,39
5241	3	266	1,80	1096	2,60
5194	4	187	1,93	897	2,84
5153	5	67	1,64	858	2,94
5118	6	99	1,15	1626	2,87
5088	7	103	0,91	713	2,44
5065	8A	77	0,96	799	2,33
5041	8B	15	0,49	264	1,97

Tab. 1. Age model midpoints for ceramic style phases in figure 4, absolute counts for secondary ('Zwickel') motifs and band types, and Shannon diversity indices (H) for Vaihingen and Württemberg, respectively.

This major band type series is plotted against the Württemberg population proxy curve (Fig. 4 c, d) resulting in the observation that the inferred considerable population increase towards the end of the LBK runs parallel to a reduction in stylistic diversity. This data set is complemented by a series from a single site, Vaihingen (Fig. 4 b), showing the diversity of secondary motifs (Germ. *Zwickel*) of which some are indicative of LBK lineages (Strien, 2005, Abb. 5; Bogaard et al., 2011, Tab. 1). We currently use data only from Vaihingen because this specific information is not yet available for a broader region.

Combined with the population proxy curve, and following our theoretical model outlined above (Fig. 1), these two style/decoration motif time series may reflect slightly differing but probably related social resilience strategies within the Württemberg LBK cycle:

- We interpret the curve progression in major band motif diversity as a change in social diversity: Accordingly, LBK societies in Württemberg had set out with a low social diversity which gradually evolved to a higher diversity around 5150 BC, after which the process is reversed towards the final stages of LBK when, during a period of rapid population increase and ultimate decrease, low diversity reappears. These changes in social diversity are further interpreted as changes in social resilience strategies: LBK societies began as socio-politically homogenous, conform, and gradually evolved towards a more diverse, pluralistic structure, a process reversed towards the final phases. It must be noted here, that Frirdich (1994) has already described the considerable increase in novel band types during the Middle LBK in the Rhineland, which she interpreted as a signal of a loosening of social norms.

- The secondary motif (Zwickel) data series in Vaihingen indicates a strong lineage emphasis by display on ceramic vessels until the end of LBK II (Flomborn) after which this marker suddenly decreases. With the onset of the younger LBK (yLBK) this way of lineage signalling apparently either lost its meaning or had shifted to other platforms. Equally, LBK figurines largely disappear at that very same period (Hofmann, 2012).

3.1.1 Resilience strategies and palaeoclimatic proxies in Early Neolithic SW Central Europe

These inferred social resilience strategies may be compared with paleoclimate proxies. We have chosen a newly available data set from Bunker Cave in the German Central Hill region (Sauerland), and used the Mg/Ca ratio as an indicator for precipitation rates (Fohlmeister et al., 2012; Wassenburg et al., 2016). This set is then compared to the ring width index and carbon isotopes from the Kückhoven well (Helle and Schleser, 1998; Helle and Heinrich, 2012). Both proxies show an increase in dryer conditions during the 52nd century BC which are thought to have culminated in two pronounced drought signals at 5130±5 and particularly for 5106/5 BC when low moisture seems to have been paralleled by high temperatures (Helle and Schleser, 1998; Helle and Heinrich, 2012). Generally, the last 30 years prior to the construction of the well in 5089 BC is characterized by abrupt temperature fluctuations of 1.5 to 2°C (Helle and Heinrich, 2012). A trend towards decreased (winter) precipitation during the terminal sixth millennium cal BC is also visible in the proxies calculated by Sánchez Goñi et al. (2016). Thereafter precipitation rates seem to have increased again. The tendency towards less rainfall is paralleled by an increase in LBK sites in more elevated locations (Gronenborn et al., 2014, p. 80), and very obviously also in a general population increase both in northern and southern Württemberg but also in the Rhine-Meuse region (Gronenborn, 2016, 221 Fig. 10.5). During and after the driest period, marked by the drought events, population seems to have decreased for one house generation (25 years). At that period the Württemberg band motif diversity index shows a clear tipping point towards decreased diversity (Fig. 4 c). As argued above, we interpret this as a change towards decreased social diversity. Already before, around 5200 BC, had individual lineage identification become either rather unimportant, or had vanished from the archaeological record.

Parallel to the inferred population increase after 5175 BC, enclosures were erected (Fig. 3 d), indicating an increasing desire for territorial marking and protection. This is also the time of the appearance of LBK mass burials, among them Talheim in Württemberg (Wahl and König, 1987; Strien et al., 2014), which mark a period of increased and intensified interpersonal violence throughout the wider western region of LBK (Meyer et al., 2013; Meyer et al., 2014). While this terminal LBK period of warfare – in the sense of organized group violence – has been a topic of intensive debate, with an occasional tendency of revising the evidence altogether (Zeeb-Lanz, 2009; Link, 2014; Stäuble, 2014), we are of the opinion that the recent anthropological site studies, as in the case of Kilianstädten (Meyer et al., 2015), do show that late to terminal LBK societies underwent a period of considerable violent unrest. Certainly, these indications are more numerous in the west but they do appear also in more easterly

regions (Meyer et al., 2014). The precise character and dimension of warfare during the Central European Early Neolithic is yet unclear, but the mass graves indicate that surprise attacks in the course of raids were part of the strategies (Christensen, 2004, p. 131; Strien and Wahl, 2007; Meyer et al., 2015). The Talheim evidence shows that attackers could have come either from the wider region (Strien et al., 2014), whereas the Kilianstädten evidence suggests an attack from a neighbouring hamlet (Lohr, 2013). In any case, particularly the Kilianstädten case shows that enclosures had been erected as defensive measures (Kerig, 2008). However, it needs to be stressed, that warfare is not a characteristic of the ultimate decline period (Fig. 4 e). In fact, there are a number of indications that the terminal LBK period underwent a period of reconciliation with enclosures being backfilled and sites resettled (Wotzka et al., 2001; Lohr, 2013).

From the above it may be inferred that late LBK violence and unrest has no single cause but seems to have been triggered by a combination of an increase in population, a sudden environmental crisis which may have led to short-term food shortages (Strien et al., 2014), and the subsequent resurrection of social rigidity and competition, paralleled by further population increase. Eventually the western LBK system declined, however this last tipping point differs from region to region (Gronenborn, 2016, Fig. 5). In more easterly regions where settlements often continue this decline is much less pronounced, but nevertheless does appear as a stylistic break (e. g. Link, 2012).

These changes of the terminal 52nd century BC in Württemberg LBK, and likely in similar ways also in the Rhineland and Hesse, Alsace and the Haspengau in southern Belgium, are paralleled with the emergence of the early Middle Neolithic Hinkelstein group (HST) in the region around Worms (Jeunesse, 1998-99; Jeunesse and Strien, 2009). While HST is clearly rooted in later LBK pottery of the region (Meier-Arendt, 1975), it nevertheless marks a considerable break with previous traditions both in burial traditions (Spatz, 1999; Breitwieser, 2009), and architectural traditions (Friederich, 2011). HST is also characterized by an entirely new decoration system, originally composed of stylized, abstract human figures (Fig. 5). Based on these new motifs Spatz (2003) had interpreted HST as a spiritual movement, which would have emerged in a core zone around Worms under influence from the west (Jeunesse and Strien, 2009, p. 244). This new identity spread rapidly towards the Main and Neckar rivers, replacing late LBK communities in the respective regions (Lindig, 2002).

This scenario focuses on internal social processes and one external factor, namely precipitation fluctuations. For a current want of robust data it omits external stressors like contemporaneous non-LBK populations for which slight but yet inconclusive data exists (e. g. Gronenborn, 2010). Eventually, the scenario presented will have to be complemented by these and other components.

4 Conclusion

How then does the empirical LBK data presented above relate to the AC or the secular cycles of Turchin and Nefedov (2009) and others? Adaptive Cycles and LBK have been regarded in

combination before, either intuitively (Gronenborn, 2012), critically (Stäuble, 2014), or with reference to actual data (Peters, 2012; Gronenborn et al., 2014; Gronenborn, 2016). As AC have the somewhat problematic character of an “intuitive metaphor” (Scheffer 2009, p. 79), this present work seeks to substantiate the earlier endeavours by refining the concept and further explore its applicability to archaeological data.

The data presented on changes in decoration motifs reveal an early emerging trajectory towards increasing diversification (Fig. 3 b-c). Population is low but rising, particularly during the earliest LBK. This trajectory is well in accordance with cycling concepts, both AC (Fig. 4 a) as well as the secular cycle DST concept proposed by Turchin and Nefedov (2009, 33 Tab. 1.1). In AC this would be the α -phase, in DST the expansion or growth phase. After 5300 BC population is slightly rising further. In the AC panarchy concept this would be the r phase, in Turchin and Nefedov’s (2009, p. 33) concept a transition between the expansion and the stagflation phase. Contrary to our empirical data both are characterized in DST by population increase and high population rates. However, the early farming LBK case study shows an increase in population rates only towards the end of the stagflation (DST) or K-phase (AC). The most notable dynamics during the r-phase are essentially social, namely the high rate of inferred social diversity and lineage emphasis until the end of LBK II (Flomborn). Population only increases with a decrease of lineage emphasis; the population positive feedback point lies at 5160 BC (Fig. 3 a-c).

Thereafter, and apparently contemporaneous with the dry period of the latter 52nd century BC, a reverse shift to decreasing social diversity sets in. This social tipping point around 5125 BC marks the beginning of the Ω - (AC) or crisis phase (DST). However, contrary to Turchin and Nefedov’s (2009, p. 33) predictions, empirical data from the early farming case study shows a considerable increase in population, which means that the population peak is actually a component of what is usually conceived of as the decline. The population increase trend was briefly slowed by the subsequent possible crisis period of the latter 52nd century but then continued despite the social rearrangements towards decreasing diversity. The final population tipping point is around 5060 BC when calculated for the entire area of Württemberg, however if North and South Württemberg are calculated separately the tipping points differ by about two generations (5120 and 5070 BC) due to the offset in the shift towards HST (Gronenborn, 2016, Fig. 5).

The Württemberg LBK case study makes it necessary to revise and complement some of the concept predictions – both for AC and DST:

- Social and population tipping points are not necessarily contemporaneous. In fact, in the presented case study there is an offset of four or five generations depending on the marker (Fig. 3 b-d). This then leads to the conclusion that population dynamics may not be taken as an immediate and sole indicator for cycle dynamics. In fact, population dynamics may have been initiated by antecedent social dynamics.
- The concept of social resilience can only be taken as a loosely defined and very flexible adaptation process, as suggested by Adger (2000) and Desjardins et al. (2015,

pp. 157–162). As stated by Olsson et al. (2015, 2 Tab. 1) resilience is ethically neutral: A certain socio-political strategy may be advantageous in one situation but may become problematic in another as the inferred trajectory from low to high and back to low social diversity within the Württemberg LBK suggests. High social diversity may have proven ineffective under external stress, thus groups rapidly reverted back to less diversity. In this, even the LBK warfare may have been an appropriate strategy, as it may have led to increased in-group cooperation and stricter organization. It may well have been this process that eventually culminated in a “rigidity trap”, as proposed by Hegmon et al. (2008). Interestingly this trend towards lower social diversity is at first paralleled by an increase in population.

- Cyclic processes are not successive to each other but are intercalated, with each stage being a consequence of previous mechanisms and processes (Gronenborn et al., 2014; Stäuble, 2014): In our case, does HST emerge and expand during the terminal LBK and then brings about the changes leading to the Middle Neolithic. Thus, the depression or intercycle phase of the DST does not exist as a cycle-separating entity. Rather, reorganization towards the following cycle runs parallel to the decline of the previous one (Fig. 1). The decline or “disintegrative” (Turchin and Nefedov, 2009, p. 20) section of a cycle may thus be understood as a fluid transition from one historic period to the next (McAnany and Yoffee, 2010b).

A last observation concerns the role of climate in shaping cycles. Turchin and Nefedov (2009, p. 29) state that climate may become a significant factor when population is high, but many other studies claim that climate is a non-issue when it comes to explain cycle dynamics (e.g. Shennan, 2013; Shennan et al., 2013). Indeed, mathematical modelling on coarser time scales has indicated that its role should not have been dominant (Lemmen and Wirtz, 2014). However, as the high-resolution early Neolithic data-set suggests, climate may well have been a factor in shaping this particular social trajectory: The most obvious correlation between climate fluctuations and cultural dynamics is the contemporaneity of the dry period of the latter 52nd century BC with the onset of the decline or Ω -phase (Fig. 3). Moreover, the previous observation of a slight interrelation between humid phases and population increase and dry phases and adverse effects on population persists. Nevertheless, it needs to be emphasized that the latter appears to be true only during the most extreme period whereas the general tendency towards dryer conditions apparently has had a positive effect on the settlement system as more elevated locations became available (Gronenborn et al., 2014, p. 80). Thus, while climate may have had no major implication on the general shaping of cycles, it nevertheless may have paced the position of tipping points, as in the early Neolithic LBK in Württemberg and other regions. Supporting this hypothesis based on data from the first farming societies in Central Europe, Schleussner et al. (2016, p. 9216) have recently provided “evidence in global datasets that risk of armed-conflict outbreak is enhanced by climate-related disaster occurrence in ethnically fractionalized countries”.

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Figures

Fig. 1. Concept of cyclical social resilience strategies (social diversity) and archaeological markers (stylistic diversity).

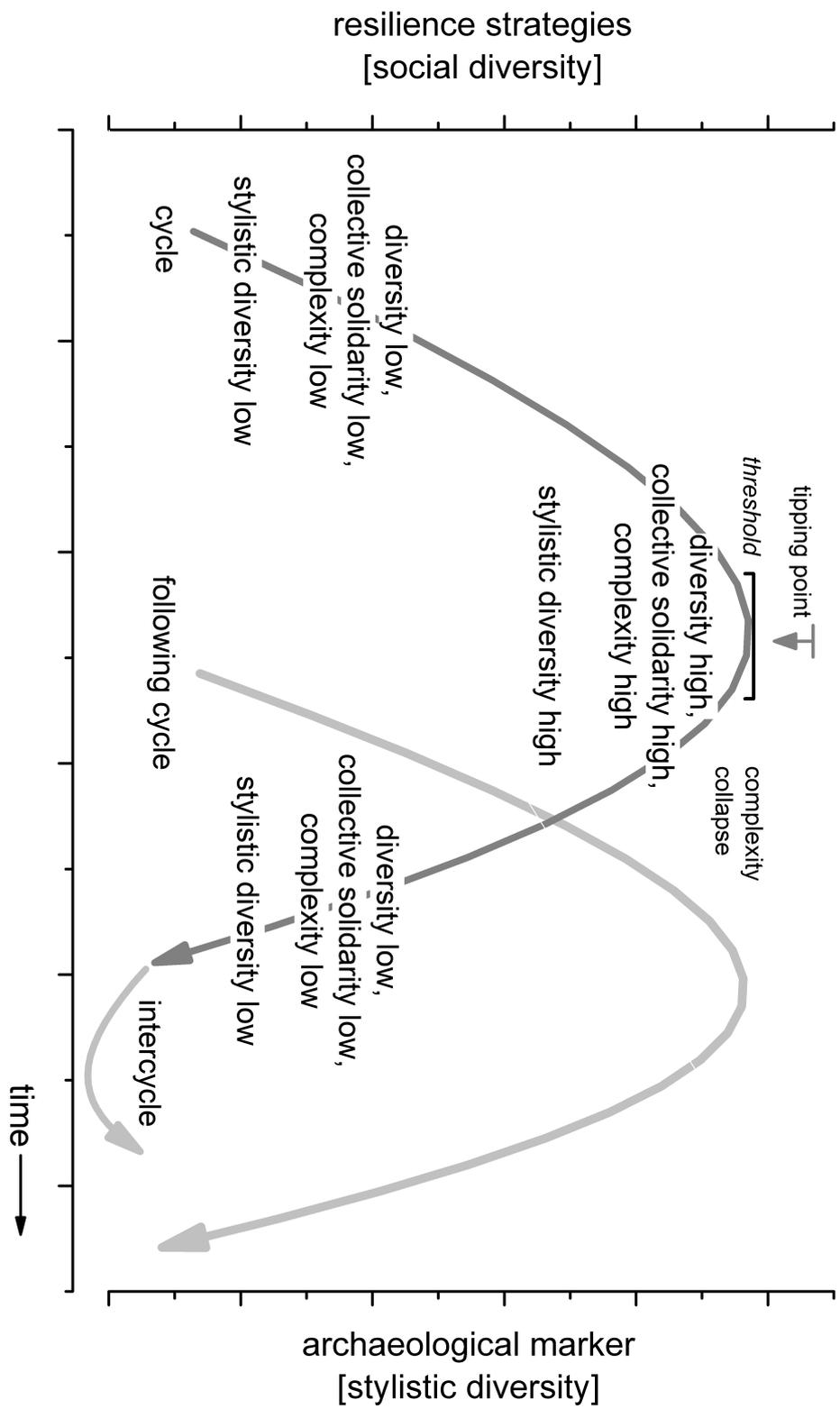
Fig. 2. LBK vessel (Germ. Kumpf) from the site Stuttgart-Möhringen with main decoration motif (Bandtyp – BT) and rim (Rand – R) and secondary decoration motif (Zwickel), dating to early yLBK (from Strien, 1984).

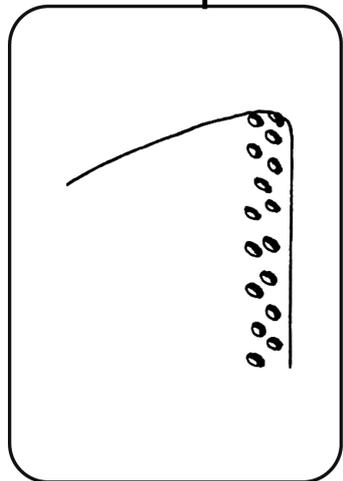
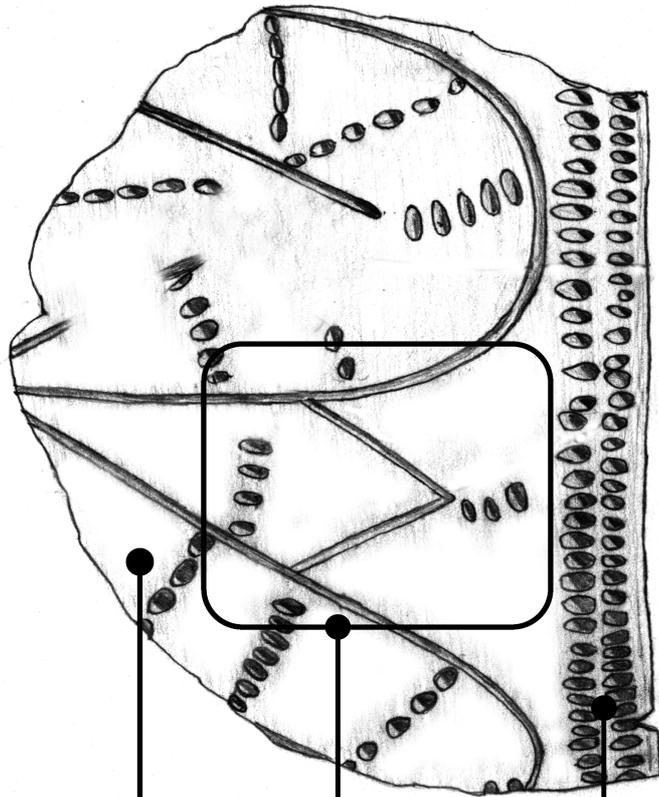
Fig. 3. Map of the western Linearbandkeramik (LBK) and Hinkelstein (HST) with sites mentioned in the text. Black box indicates Württemberg study area. Sites are marked by triangles, modern towns by circles. eLBK=earliest LBK, yLBK= younger LBK, HST=Hinkelsstein.

Fig. 4. Württemberg Linearbandkeramik dynamics and palaeoclimatic proxies. Grey bars mark inferred dry periods. Archaeology: a) adaptive cycle with stages (time uncertainty), b) secondary motifs, Vaihingen; c) band motifs Württemberg; d) population proxy Württemberg; e) enclosures Württemberg and Talheim mass grave (from left to right: Vaihingen, Bietigheim-Bissingen, Neckargartach, Schweigern, Viesenhäuser Hof, Talheim). Palaeoclimate, rainfall/humidity variability: f)-g) Kückhoven well isotope and ring-width data (Helle and Schleser, 1998), h) Bunker Cave Mg/Ca records (Wassenburg et al. 2016). eLBK=earliest LBK, yLBK= younger LBK, HST=Hinkelsstein.

Fig. 5. Age model for Rhine-Meuse and Württemberg LBK (modified after Bogaard et al. 2011; Gronenborn et al. 2014)

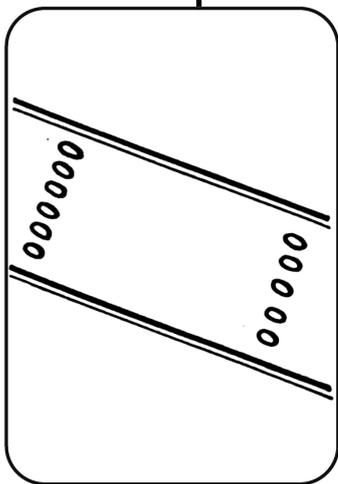
Fig. 6. Anthropomorphic decoration of early Middle Neolithic Hinkelstein (HST) and Stichbandkeramik (STK) vessels. 1 Worms-Rheingewann, burial 50; 2 Praha-Bubeneč (after Spatz, 2003, p. 577 with further references).



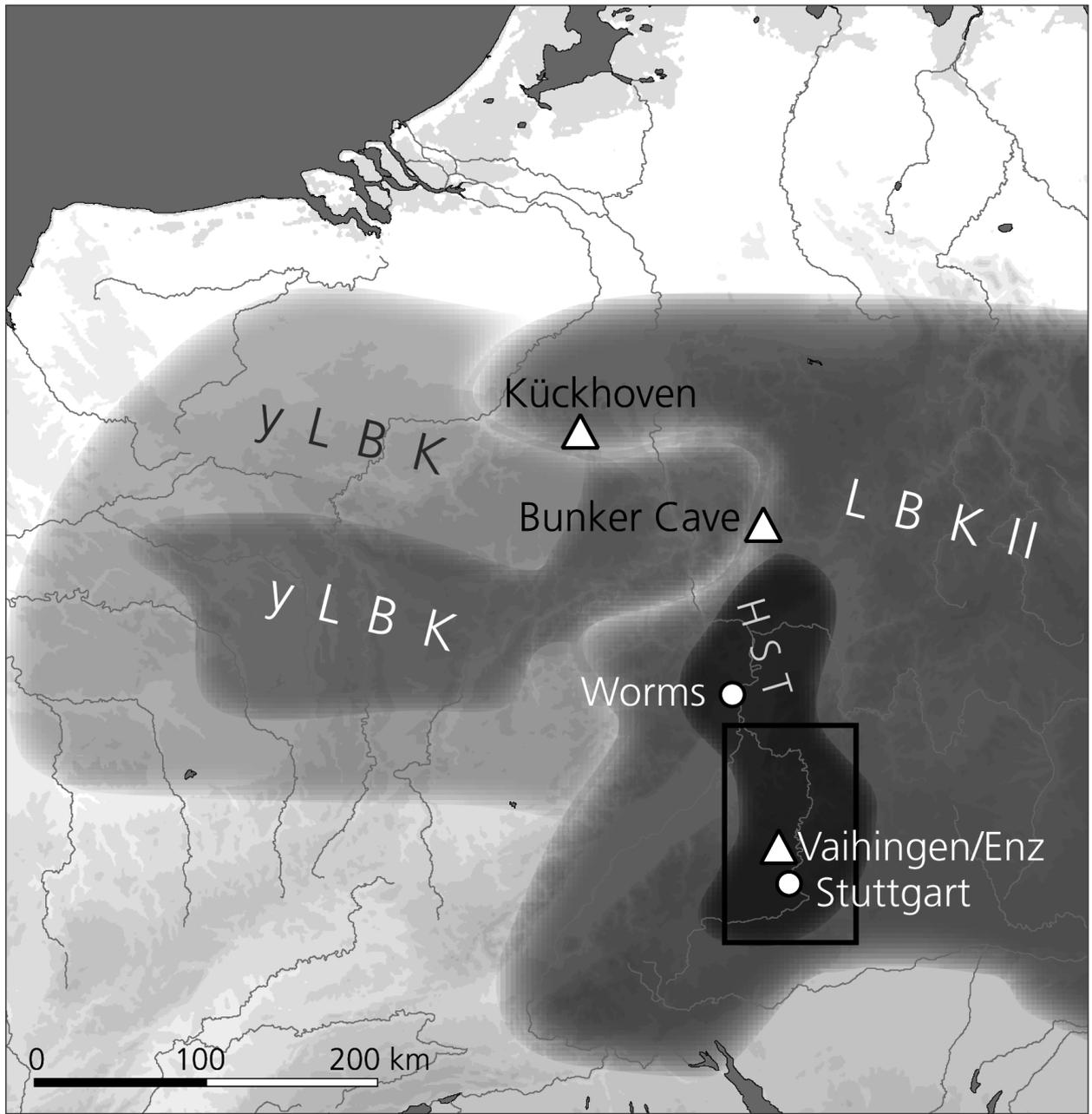


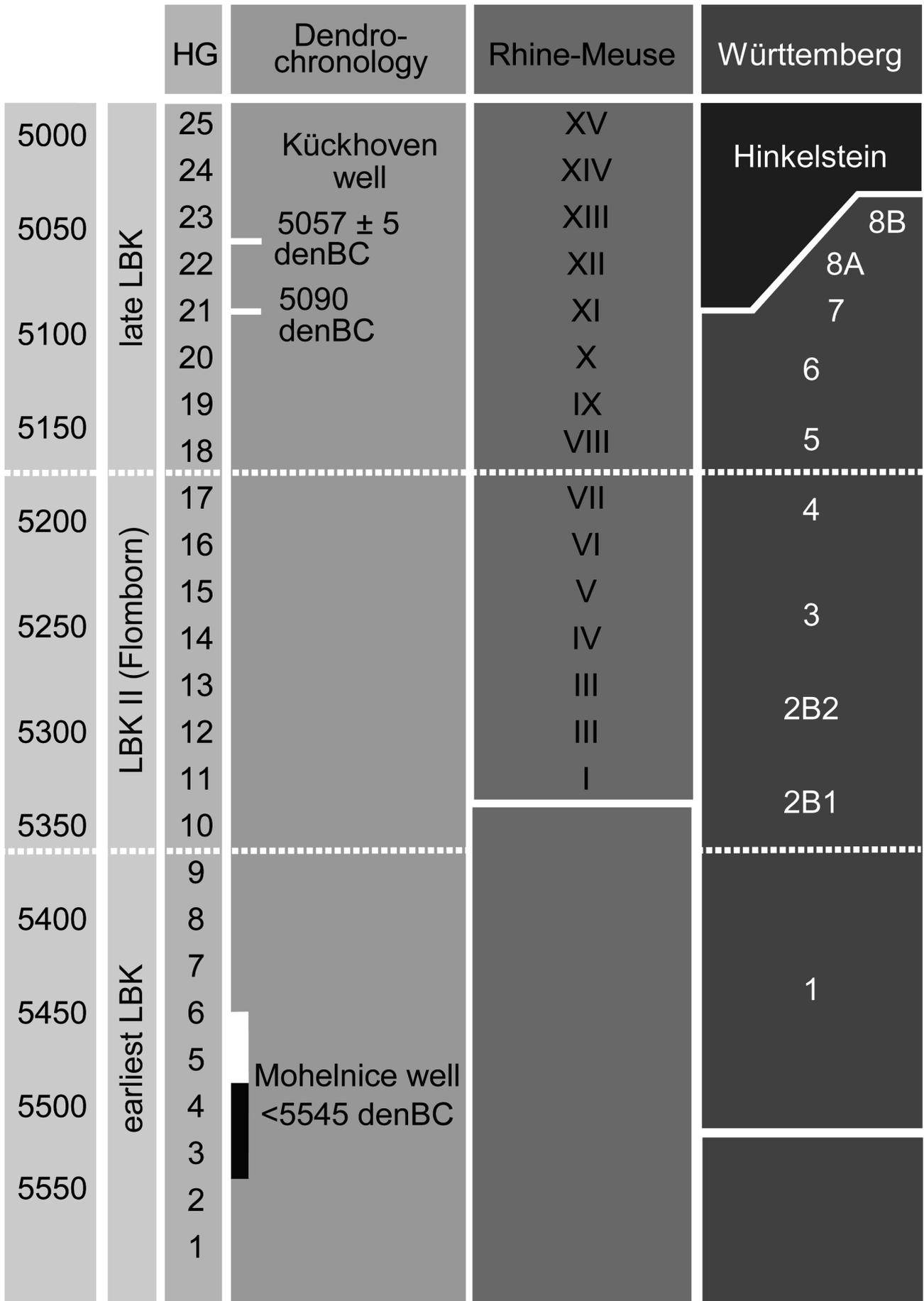
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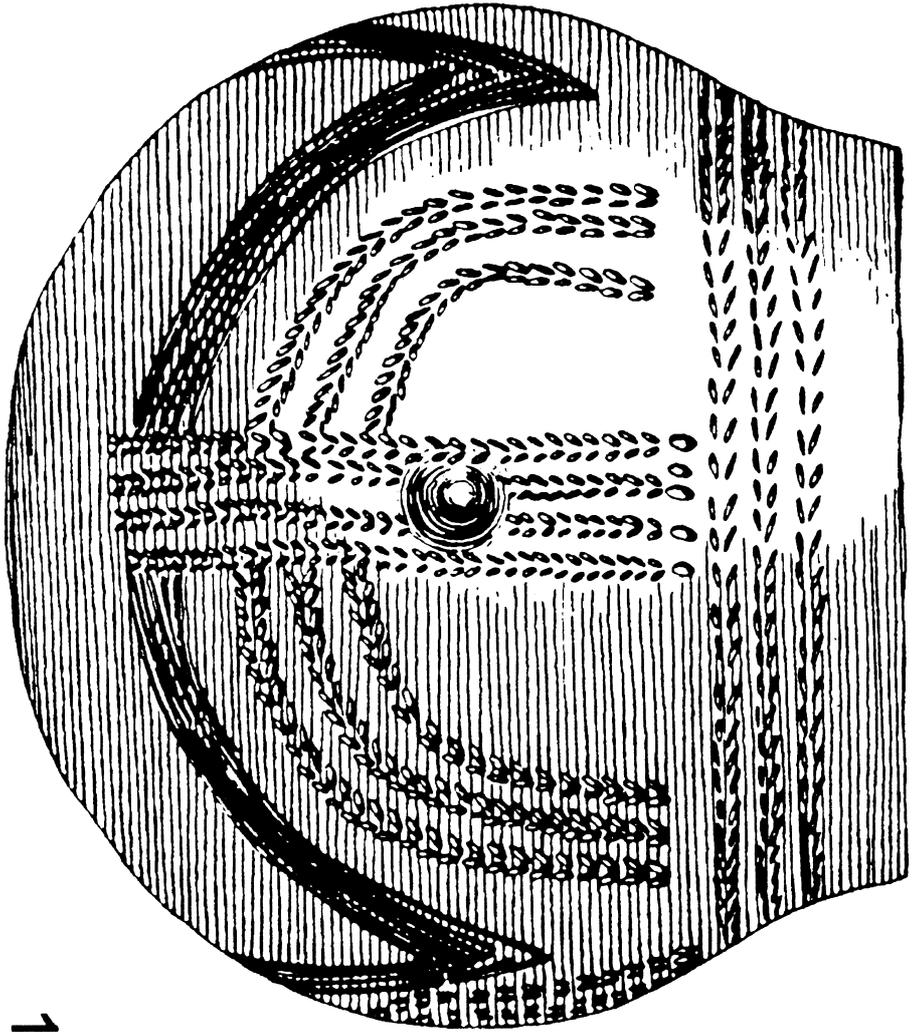
secondary motif



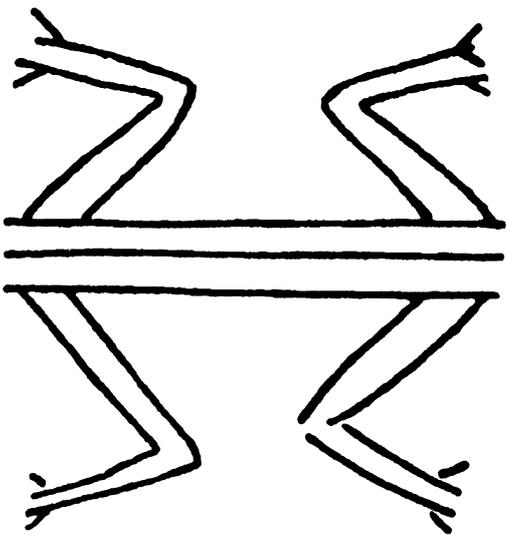
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