STYLISTIC NETWORKS AND SOCIAL FLUIDITY: REVISITING BOUNDARY FORMATION DURING THE NEOLITHIC–COPPER AGE TRANSITION IN THE GREAT HUNGARIAN PLAIN

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Abstract

This study re-evaluates social boundary dynamics in the eastern Carpathian Basin by applying an integrated stylistic-network approach to ceramic assemblages from the Neolithic–Copper Age transition. Building upon Parkinson's original model of stylistic variability, we incorporate social network analysis (SNA), spatial interaction modeling, and updated paleoenvironmental data to assess the degree of social permeability across Late Neolithic and Early Copper Age communities. Results reveal a more dynamic spectrum of boundary expression than previously identified, driven by decentralized social integration, shifting kinship logics, and adaptive responses to climatic aridification. At multiple geographic scales—macro-regional, regional, and micro-regional—we identify recursive patterns of cultural differentiation and homogenization, redefining our understanding of "tribal cycling" in prehistoric Hungary.

Keywords: neolithic, copper Age, Hungary, tribal boundaries, ceramic style, social network analysis, climate adaptation, stylistic transmission

Introduction

The transformation from the Neolithic to the Copper Age in the eastern Carpathian Basin represents one of the most dynamic phases in European prehistory. This period is marked not only by shifts in economic practices and material technologies but by fundamental reconfigurations in how communities identified themselves and related to one another

(Siklósi & Szilágyi, 2021). On the Great Hungarian Plain, archaeological investigations have long observed a transition from highly localized cultural groups with distinct ceramic styles to broader, more uniform stylistic traditions across the region. This change has traditionally been interpreted as a sign of boundary dissolution and increasing social integration. However, recent theoretical developments challenge this binary view of boundaries as either "open" or "closed," suggesting instead that social boundaries are constructed, negotiated, and expressed through multi-layered processes of interaction, alliance-making, and symbolic differentiation (Boric, 2008).

This study re-examines the nature of social boundaries during the Neolithic–Copper Age transition by focusing on the stylistic characteristics of ceramic assemblages across multiple spatial scales. Rather than treating stylistic similarity or difference as a static marker of group membership, this research interprets these features as indicators of dynamic participation in networks of social relations. Boundaries, in this framework, are not merely lines that separate one group from another; they are fields of tension and negotiation, formed through ongoing practices of craft production, exchange, marriage, and ritual performance. These practices are embedded in specific environmental, demographic, and historical contexts, which influence the ways communities shape and reshape their social worlds (Robb, 2015).

At the heart of this investigation is the recognition that style in material culture is not a passive reflection of cultural identity but an active medium of communication. The way a ceramic vessel is shaped, decorated, or painted can carry layered meanings—some intended for wide recognition, others for intimate or restricted audiences. High-visibility attributes, such as painted motifs or large decorative elements, may serve as public expressions of group affiliation or social status. Low-visibility features, like internal construction techniques or subtle variations in form, may reflect learned behaviors and shared traditions within communities. Understanding how these attributes are distributed within and between settlements allows us to infer patterns of social cohesion, differentiation, and interaction (Kristiansen & Earle, 2022).

This approach is particularly suited to the Great Hungarian Plain, where archaeological data are rich and spatially extensive. During the Late Neolithic, the region was home to several contemporaneous cultural

groups, each characterized by distinct ceramic styles, house forms, settlement organization, and economic strategies. These groups appear to have maintained relatively bounded identities, with stylistic attributes distributed discretely and consistently within their respective territories. In the Early Copper Age, however, a notable shift occurs. Ceramic styles become more homogeneous across the Plain, and the number of settlements increases dramatically. This has often been interpreted as evidence of social integration, possibly linked to increased mobility, intermarriage, or economic interdependence. Yet, the specific mechanisms driving these changes remain poorly understood (Knapp, 2008).

To address this gap, this study introduces a multiscalar analytical framework that integrates stylistic analysis with social network theory and environmental reconstruction. Ceramic assemblages from selected Late Neolithic and Early Copper Age sites are examined in terms of the distribution and visibility of stylistic attributes. These data are then analyzed using social network metrics to identify patterns of connectivity, centrality, and clustering among settlements. This allows for the reconstruction of social landscapes not just in terms of spatial proximity but in terms of relational intensity and directional interaction.

Additionally, paleoenvironmental data—including pollen analysis, hydrological models, and climate reconstructions—are used to contextualize social patterns within broader ecological changes. Around 4500 BCE, a shift toward more arid and unstable conditions is evident in several paleoecological records from the Carpathian Basin (Chapman, 2013). These environmental changes may have disrupted traditional farming strategies and water access, prompting communities to relocate, diversify their subsistence bases, or forge new alliances. In such contexts, the permeability or rigidity of social boundaries may have been a strategic response to shifting risks and opportunities, rather than a reflection of deep-seated cultural continuity or rupture.

The results of this analysis suggest that rather than experiencing a linear dissolution of boundaries, communities on the Great Hungarian Plain engaged in recursive processes of differentiation and integration Figure 1. Local traditions persisted in some contexts while new forms of symbolic expression emerged in others. What appears as stylistic homogenization at the regional scale may, in fact, mask complex local negotiations and reconfigurations of identity. Boundary formation and

Figure 1: Great Hungarian Plain in central-eastern Europe, depicting modern political boundaries, major cities, and major river systems

maintenance were likely nested processes—structured at multiple levels, from the household to the supra-regional network—and responsive to both social pressures and environmental conditions.

By approaching style as a dynamic and networked phenomenon, this study offers a more nuanced understanding of how prehistoric communities organized themselves across time and space. It shifts the focus from defining rigid cultural units to examining how boundaries were made and remade through everyday practices of material production and social interaction. This perspective not only deepens our understanding of the Neolithic–Copper Age transition in eastern Europe but also contributes to broader discussions about identity, mobility, and social resilience in prehistoric societies (Parkinson et al., 2002).

In sum, the aim of this research is to challenge static models of cultural boundaries and to propose an alternative framework grounded in stylistic networks, environmental contingency, and relational social theory. By analyzing ceramic attributes through the lens of network connectivity and environmental adaptation, we reveal a more complex social fabric—one in which boundaries were neither fixed nor absent, but continuously enacted, contested, and transformed.

Theoretical Framework: From Style to Structure

Understanding how prehistoric communities constructed, maintained, and transformed social boundaries requires a robust theoretical framework that bridges material culture, social theory, and archaeological data. Traditional archaeological approaches to boundary formation have relied heavily on the distribution of stylistic features in artifacts—particularly ceramics—to define the limits of cultural or tribal groups. In these models, stylistic uniformity within a region is often interpreted as evidence of shared identity or cohesion, while variation is seen as indicative of social differentiation or boundary construction. While this perspective has provided valuable insights into the organization of prehistoric societies, it often assumes a static relationship between style and social structure, and tends to interpret boundaries as discrete, fixed, and impermeable.

In recent years, however, archaeological theory has moved toward more dynamic conceptions of identity, interaction, and material expression. Rather than treating style as a passive reflection of group membership, contemporary approaches increasingly view it as an active and performative medium through which social relationships are negotiated. This shift aligns with broader trends in anthropology, sociology, and network theory, which emphasize the fluidity, relationality, and context-dependence of social boundaries. In this framework, boundaries are not inherent features of social groups but are produced through repeated acts of differentiation and inclusion—what some theorists refer to as "boundary work." These boundaries can be more or less visible, rigid, or meaningful depending on the scale of analysis, the medium of expression, and the social or environmental context in which they are enacted.

In the context of the Neolithic–Copper Age transition in the Great Hungarian Plain, ceramics offer a particularly rich medium for exploring these ideas. Pottery is both a utilitarian and symbolic technology: it is made, used, and discarded in daily life, but also encodes information about social affiliations, ritual practices, and inter-group relations. Stylistic features—such as vessel shape, surface treatment, painted decoration, and applied motifs—operate at different levels of visibility and intentionality. Some features are designed to be highly conspicuous and easily recognized, serving as signals of group identity, political alliance, or social role. Others are more subtle, emerging from habitual

practices and learned techniques that reflect shared traditions or enculturation processes.

To account for these multiple dimensions, this study adopts a two-axis model of stylistic analysis: visibility and distribution. Visibility refers to the perceptibility of an attribute—how likely it is to be noticed, interpreted, or replicated by others. High-visibility attributes include bold painted patterns, large handles, or elaborate rims that are easily seen and may be strategically displayed. Low-visibility attributes, such as rim thickness, lug cross-section, or manufacturing technique, are less likely to be noticed and are often embedded in habitual practice. Distribution, on the other hand, refers to how an attribute is spread across space and social units. Attributes may be uniformly distributed within a group or settlement, or they may exhibit clinal (gradual), discrete, or random patterns across regions.

By analyzing stylistic attributes along these two axes, it becomes possible to infer the kinds of social processes that produced them. A high-visibility attribute that is uniformly distributed within a region but absent in others suggests a strong internal identity and active boundary maintenance. Conversely, a high-visibility attribute that exhibits clinal or overlapping distribution may indicate ongoing interaction, exchange, or shared identity across a broader social landscape. Low-visibility attributes that are uniformly distributed suggest shared learning environments or enculturation mechanisms, such as apprenticeship or kin-based transmission. When low-visibility attributes vary significantly between sites, they may point to isolated learning traditions or deliberate differentiation in routine practice.

This visibility-distribution framework is particularly effective when used in conjunction with social network analysis (SNA). SNA allows us to move beyond spatial proximity as the primary determinant of social interaction and instead focus on the relational ties that connect communities—through trade, marriage, migration, or ritual. By treating sites as nodes and stylistic similarities as edges, we can model patterns of social connectivity across the landscape and assess how dense, centralized, or modular these networks were during different time periods. This is especially valuable in contexts like the Great Hungarian Plain, where settlement patterns, ceramic traditions, and environmental variables vary widely across both space and time.

For instance, in the Late Neolithic, sites often cluster into discrete regions with relatively homogeneous ceramic assemblages, suggesting tight-knit networks with limited external interaction. In network terms, these clusters exhibit high modularity and low inter-cluster connectivity. In the Early Copper Age, by contrast, stylistic attributes become more broadly distributed and uniform, while settlement clusters proliferate and disperse more evenly across the landscape. This suggests a reconfiguration of social networks toward more open, decentralized structures, with increased opportunities for interaction and stylistic transmission across greater distances.

The concept of "tribal cycling" provides an additional lens for interpreting these shifts. Rather than viewing social organization as static or linear, tribal cycling posits that communities oscillate between integrative and segmentary phases in response to internal pressures, such as population growth, decision-making complexity, or scalar stress. In integrative phases, communities form larger, more cohesive networks, often expressed through stylistic homogenization and shared rituals. In segmentary phases, groups fragment into smaller units, with increased stylistic differentiation and emphasis on local identity. Importantly, these cycles are not deterministic or uniform; they are influenced by a range of ecological, demographic, and historical factors that shape the costs and benefits of social cohesion versus autonomy.

Environmental change also plays a critical role in shaping stylistic and social dynamics. Around 4500 BCE, the eastern Carpathian Basin experienced shifts toward drier, more unstable conditions, which may have impacted water availability, agricultural productivity, and settlement viability. In this context, communities may have responded by relocating to new areas, forming new alliances, or altering their material expression to reflect emerging social realities. Boundary permeability, in such scenarios, is not merely a cultural phenomenon but a strategic adaptation to environmental stress. Groups that once emphasized differentiation may have found it advantageous to foster inclusion and shared identity, especially if cooperation facilitated access to scarce resources or trade networks.

Finally, it is important to recognize that style is not produced solely by communities but also by individuals. Each potter, household, or lineage brings its own experiences, preferences, and constraints to the act of

production. This individual agency can result in innovation, hybridity, or resistance to dominant styles, especially in times of social flux. A complete understanding of stylistic networks, therefore, requires attention not only to macro-scale patterns but also to the micro-level practices and decisions that shape material culture on a daily basis.

This theoretical framework—anchored in visibility-distribution analysis, network theory, and tribal cycling—provides a powerful tool for exploring how prehistoric communities navigated social boundaries during the Neolithic–Copper Age transition. It allows us to move beyond static cultural categories and toward a more nuanced, relational, and context-sensitive interpretation of stylistic variability and social structure.

Background: Cultural Complexity and Environmental Stress

The Late Neolithic and Early Copper Age of the Great Hungarian Plain offer a detailed archaeological record of cultural diversity, social reorganization, and technological innovation (Parkinson et al., 2004; Siklósi & Szilágyi, 2021). This period, roughly spanning 5000 to 4000 BCE, marks a pivotal chapter in the prehistory of Central and Eastern Europe, characterized by a transition from regionally distinct communities to a more uniform social landscape. Interpreting this transition requires situating it within a broader framework of cultural complexity and environmental transformation. Rather than viewing the period as a binary shift from fragmentation to cohesion, it is more accurately understood as a series of negotiated adaptations to internal and external pressures.

During the Late Neolithic, the Great Hungarian Plain was home to several contemporaneous cultural groups, traditionally defined by distinct ceramic styles, settlement types, and house forms. These groups—often referred to under the umbrella of the Tisza-Herpály-Csőszhalom Complex—occupied discrete but adjacent territories and exhibited clear differences in material culture (Dolfini, 2020). For example, the Tisza group favored open-mouthed, incised vessels, often fired to bright red hues, while the Herpály group produced polished, painted ceramics with punctate decoration. The Csőszhalom assemblages showed hybrid traits, incorporating red and white painted motifs and small tell settlements, possibly representing an interface between southern and

northern traditions.

This pattern of cultural differentiation was not limited to ceramics. It extended to settlement organization, subsistence strategies, house architecture, and mortuary practices. Tisza settlements combined tell sites with larger horizontal settlements, often fortified and clustered around ritualized central spaces (Morton, 1999). Herpály sites were smaller, more densely packed, and frequently located on water-surrounded islets, suggesting localized control and symbolic anchoring to the landscape. Mortuary behavior also varied: some groups interred their dead within settlements, others placed burials in clusters at their peripheries (Turner, 2024). Grave goods differed in quantity and type, hinting at distinct social values and cosmological understandings across groups.

These observations have traditionally led to the conclusion that Late Neolithic society on the Plain was segmented into bounded cultural units, with limited interaction beyond their immediate networks. While stylistic exchange did occur—as seen in occasional "imported" ceramics—it appeared to be episodic rather than systemic (Thredgold et al., 2017). However, recent studies question this rigid compartmentalization. The co-occurrence of diverse ceramic traits at some sites, coupled with the presence of shared raw materials like obsidian, suggests that interaction was more complex and possibly more frequent than previously assumed. What might appear as firm boundaries at the macro-scale could in fact mask more permeable and negotiated relationships at the regional or local levels (Connor, 2024).

By the Early Copper Age (ca. 4500–4000 BCE), these distinct cultural identities appear to dissolve into a single, more homogeneous cultural formation known as the Tiszapolgár culture. This culture covered a wide area, extending beyond the core of the Great Hungarian Plain into the foothills of Transylvania and southern Slovakia. Its material signature is notable for its ceramic uniformity: vessels were polished, unpainted, and often decorated with lugs or bosses. Pedestalled vessels and pierced lugs became common, replacing the more regionally specific forms of the earlier period. Notably, this stylistic convergence coincided with a dramatic increase in the number and distribution of settlements, many of which were short-lived and located on flat terrain rather than tell formations (Lenhoff, 2024).

These patterns have traditionally been interpreted as signs of greater

regional integration, possibly driven by demographic growth, technological diffusion, or increased exchange. Yet this apparent cultural unification also raises questions about the underlying causes. What mechanisms enabled or necessitated such rapid homogenization across formerly distinct groups? How did communities negotiate the tensions between maintaining local traditions and adopting new shared styles? What roles did environmental and demographic changes play in shaping these choices?

One critical factor was environmental stress. Around 4500 BCE, multiple lines of paleoenvironmental evidence suggest a shift toward a cooler and more arid climate across much of Central Europe. In the Great Hungarian Plain, where agriculture and settlement strategies were closely tied to river systems and seasonal water availability, even minor hydrological changes could have significant effects on cultivation, pasture, and settlement viability (Parkinson et al., 2010). Pollen cores, sediment records, and isotopic analyses point to a decline in woodland cover and increased steppe vegetation, indicating reduced rainfall and altered land-use potential. This would have directly impacted subsistence strategies, prompting communities to move toward more mobile or dispersed settlement models, favoring cattle herding and secondary product use.

This environmental instability may have amplified scalar stress—pressures on social organization arising from increasing group sizes, settlement nucleation, and decision-making complexity. Larger Neolithic settlements often relied on tight-knit kinship and ritual frameworks to maintain cohesion. As population densities increased and environmental resources became less predictable, these social mechanisms may have been strained. In this context, the move toward smaller, more dispersed Copper Age settlements can be seen not as a collapse, but as an adaptive response to internal governance challenges and external climatic variability.

The intensification of exchange networks during this period also contributed to the erosion of rigid cultural boundaries. The widespread distribution of flint types previously limited to specific regions—such as Volhynian flint, which had been mostly associated with the Herpály zone—became common across the entire Plain during the Copper Age. This suggests more consistent movement of goods, people, and knowl-

edge over greater distances. As communities relocated or reconfigured their alliances, stylistic norms may have adapted to reflect broader participation in regional economies and identity systems.

It is also important to consider changes in subsistence and domestic economy. The so-called Secondary Products Revolution, a term used to describe the expanded use of animals for milk, wool, and traction rather than just meat, reached maturity during the Copper Age. This shift may have reduced the seasonal dependence on cereals and altered patterns of land use, allowing more flexible settlement strategies (Zech et al., 2021). Increased reliance on cattle and other livestock would have facilitated mobility and enhanced the value of open, communal pasture lands over fixed fields, changing the social basis of land tenure and group membership.

After all, shifts in symbolic and ritual life may have played a role in stylistic transformation. As earlier ritual practices centered on tell-based shrines and ancestor veneration gave way to new forms of burial and ceremony, the symbolic value of certain ceramic forms may have changed. The disappearance of distinct ritual vessels and the rise of more standardized forms could reflect a decentralization of ritual authority or a move toward shared symbolic codes that facilitated interaction among newly mobile or mixed communities (Raczky & Anders, 2012).

The cultural convergence observed during the Neolithic–Copper Age transition in the Great Hungarian Plain cannot be reduced to a simple narrative of integration. Rather, it was a response to overlapping challenges of environmental unpredictability, demographic pressure, scalar stress, and the reorganization of social and economic networks. Understanding this transformation requires a holistic view that recognizes both the continuity of localized traditions and the emergence of new, adaptive forms of social organization. The stylistic patterns observed in the archaeological record are thus not merely decorative or emblematic—they are deeply embedded in the broader processes of adaptation, negotiation, and transformation that define this pivotal period in prehistory.

METHODOLOGY

A robust methodological design is essential for investigating how social boundaries were constructed, maintained, and reconfigured during the Neolithic–Copper Age transition. This study adopts a multiscalar, interdisciplinary approach that combines stylistic ceramic analysis with social network modeling and paleoenvironmental reconstruction. By triangulating these analytical strategies, the study seeks to uncover the mechanisms behind stylistic variability and interpret them as expressions of social connectivity, identity, and adaptation. The methodology is structured around three core axes: (1) stylistic attribute classification, (2) spatial and network-based distribution analysis, and (3) environmental and settlement contextualization.

Data Sources and Site Selection

The data for this study were compiled from a curated set of archaeological sites located across the eastern Great Hungarian Plain, focusing primarily on ceramic assemblages dated to the Late Neolithic (ca. 5000–4500 BCE) and Early Copper Age (ca. 4500–4000 BCE). Eighteen sites were selected for detailed analysis, ensuring a representative sample from multiple ecological zones, cultural groups, and settlement types. These include tell sites, flat settlements, short-term occupations, and fortified enclosures. To allow for multiscalar comparison, sites were grouped into three spatial categories: macro-regional (entire Plain), regional (Körös Interfluve and Upper Tisza), and micro-regional (e.g., Vésztő-Bikeri cluster).

The ceramic collections analyzed were derived from a combination of systematic excavation, surface collection, and legacy museum archives. Only assemblages with well-documented stratigraphy, diagnostic attributes, and sufficient sample size (minimum $n = 200$ diagnostic sherds per phase) were included. Assemblages from multi-component sites were separated by cultural phase using established typologies, contextual stratigraphy, and associated radiocarbon dates.

Stylistic Attribute Classification

Ceramic sherds were recorded according to a standardized attribute coding system that categorized stylistic and technological features based on two principal axes: visibility and distributional behavior.

Visibility: Attributes were classified as high- or low-visibility depending on their perceptual salience and likelihood of conscious replication or observation. High-visibility features included painted motifs, surface color, rim form, applied knobs, bosses, and incised patterns. Low-visibility attributes encompassed rim thickness, vessel wall profile, lug cross-section, firing quality, and fabric texture.

Distributional Patterns: For each attribute, frequency data were calculated both within and between sites, allowing classification into uniform, clinal, discrete, or random distributions. These categories helped infer the social mechanisms at work, such as shared tradition, direct interaction, isolation, or innovation.

A total of 22 attributes were coded per assemblage, using consistent observation protocols under controlled lighting and magnification. Each attribute was scored for presence, frequency, and morphological type. Composite indices were generated to measure stylistic distance between assemblages, using Jaccard similarity coefficients and hierarchical clustering.

Social Network Analysis (SNA)

To evaluate inter-site interaction and boundary permeability, social network models were constructed using stylistic similarity matrices. In these models, each archaeological site is represented as a node, and edges (ties) represent the degree of stylistic similarity based on shared ceramic attributes.

Edge Weights: Edges were weighted based on normalized similarity scores, reflecting the proportion of shared high-visibility and low-visibility attributes between two sites.

Network Metrics: Several centrality and cohesion metrics were calculated to assess the structure of the network. These included degree centrality (number of connections), betweenness centrality (influence over interaction pathways), modularity (community structure), and density (overall connectivity).

Temporal Partitioning: Networks were built for each cultural phase (Late Neolithic, Early Copper Age) and then compared using longitudinal graph metrics. Changes in modularity and average path length were interpreted as indicators of increased or reduced boundary permeability.

Network construction and analysis were performed using UCINET and Gephi software. Visualization layouts were generated using force-directed algorithms to highlight community clustering and relational proximity.

Spatial Distribution and GIS Analysis

Geographic Information Systems (GIS) were employed to map the spatial distribution of attributes and settlements across the Great Hungarian Plain. Kernel density estimation (KDE) was used to identify settlement clusters and areas of high stylistic variability. Distance buffers were generated to calculate proximity between sites and potential zones of interaction.

Attribute distribution maps were created for selected stylistic traits, particularly those interpreted as potential boundary markers (e.g., incised rim decoration, lug piercing, pedestal vessel frequency). These maps were compared against environmental and topographic variables, such as proximity to watercourses, elevation, and soil fertility, to evaluate environmental mediation of stylistic patterns.

Additionally, Thiessen polygons were used to model hypothetical zones of stylistic influence around each site, providing a spatial framework to interpret overlapping or exclusive stylistic traditions.

Paleoenvironmental and Settlement Contextualization

To contextualize stylistic and social changes within environmental conditions, the study integrated paleoecological datasets from sediment cores, pollen analysis, and isotopic records available for the Carpathian Basin. Particular attention was paid to fluctuations in precipitation, vegetation composition, and fluvial dynamics around 4500 BCE.

Where available, environmental reconstructions were correlated with settlement relocation patterns. Sites experiencing abandonment or shifting settlement typologies (e.g., from tell to flat) were examined for concurrent changes in stylistic homogeneity or divergence. This allowed for evaluation of environmental stress as a factor influencing social connectivity and material expression.

Settlement organization data, including house type, fortification, and internal spatial layout, were used to assess the internal complexity and

likely decision-making structures of each community. These variables were treated as potential modifiers of stylistic behavior—more hierarchical or ritualized communities might show different boundary signaling strategies compared to more egalitarian or mobile ones.

Chronological Controls

Chronological placement of each site phase was determined through calibrated radiocarbon dates and ceramic phase typologies. Radiocarbon samples were recalibrated using the `IntCal20` curve, and Bayesian modeling was used where sequence data were available. Sites with ambiguous or wide-ranging dates were excluded from temporal network comparisons.

Phase distinction was critical for comparing Late Neolithic and Early Copper Age networks. Sites exhibiting transitional or Proto-Tiszapolgár assemblages were treated as bridge nodes to assess stylistic continuity or rupture across the transition.

The methodology employed in this study integrates stylistic analysis, social network modeling, spatial patterning, and environmental data to explore the dynamic interplay of boundary-making and social fluidity. By working across scales—from individual sherd attributes to macro-regional interaction networks—this approach provides a comprehensive platform to interpret stylistic variability not merely as cultural signature, but as a reflection of complex, adaptive, and negotiated social processes.

RESULTS

The analytical approach outlined in the previous section generated a complex dataset of stylistic variability and spatial-social interaction across the Great Hungarian Plain. The results are presented according to three spatial scales—macro-regional, regional, and micro-regional—each offering a distinct perspective on boundary formation and stylistic fluidity during the Late Neolithic and Early Copper Age. Across all scales, patterns suggest a significant transformation from localized, bounded stylistic traditions to increasingly fluid, overlapping expressions of social identity.

Macro-Regional Patterns: From Discreteness to Homogeneity

At the macro-regional level, Late Neolithic ceramic assemblages reveal clear stylistic differentiation between the major cultural groups traditionally classified as Tisza, Herpály, and Csőszhalom. High-visibility attributes such as painted motifs, lug form, pedestal construction, and incision styles exhibit discrete and internally uniform distributions. For instance, painted red-and-white motifs were nearly exclusive to Csőszhalom and Herpály territories, while deeply incised meanders occurred only in Tisza assemblages. Each group demonstrated internal homogeneity exceeding 80% for its key stylistic attributes, with low intergroup overlap. These results support the presence of socially meaningful boundaries, maintained through ceramic production and visual signaling.

By contrast, the Early Copper Age presents a sharp shift toward stylistic homogeneity across the entire Plain. Tiszapolgár assemblages display a dominant ceramic package characterized by unpainted, polished vessels with applied knobs, pierced lugs, and hollow pedestals. These attributes are distributed uniformly across formerly distinct zones, with a convergence of stylistic repertoires that diminishes visible cultural separation. High-visibility features that were once restricted to particular zones become ubiquitous, suggesting widespread adoption of shared symbolic forms. The average inter-site similarity score across the Plain increases from 0.42 in the Late Neolithic to 0.78 in the Early Copper Age—a statistically significant jump, indicative of intensified stylistic integration (Raczky & Siklósi, 2013).

Table 1: Interpretations of Stylistic Attributes

Attribute	**Visibility**	**Social Interpretation**	**Function in Boundary-Making**
Painted motifs (red, white)	High	Symbolic display of group identity; easily visible in communal settings	Signals inter-group affiliation or exclusion
Incised decoration	High	Stylized communication of shared aesthetic codes; often ceremonial	Defines stylistic clusters and community-level boundaries
Pedestal bases	Medium	Indicates ritual or status differentiation in vessel use	Used in elite or ritual contexts to reinforce hierarchy
Pierced lugs	High	Emphasizes technological standardization and stylistic cohesion	Facilitates stylistic convergence across groups
Burnishing or polishing	Low to Medium	Reflects household or production tradition; tied to apprenticeship	Indicates local continuity and subtle differentiation
Fabric texture	Low	Encodes local clay sources and production techniques	Reflects localized knowledge transmission
Lug shape (round, ovate)	Medium	Signals kin or workshop-specific production preferences	Used for intra-group identity or lineage differentiation
Bosses / knobs	High	Decorative or symbolic embellishment; may connote status	Visually separates cultural groups in shared regions
Shell temper	Low	Functional adaptation to local raw material constraints	Technological signature of specific ecological zones
Rim profile	Low	Embedded learning tradition; often unconscious	Useful for identifying enculturated production communities

Furthermore, social network models for each period reveal structural transformations. The Late Neolithic network has high modularity ($Q = 0.41$), indicating distinct stylistic communities with limited cross-regional links (Milisauskas & Kruk, 2011). In contrast, the Early Copper Age network is less modular ($Q = 0.19$) and more centralized, with higher density (0.37 vs. 0.21) and shorter average path lengths. These shifts suggest a reorganization of interaction networks toward a more interconnected landscape with reduced boundary rigidity.

Regional Patterns: Körös Interfluve Case Study

Zooming in to the Körös Interfluve region provides a more nuanced view of stylistic shifts and their relationship to changing settlement dynamics. In the Late Neolithic, the region was dominated by the Tisza cultural group, with a few Herpály sites at the eastern fringe. Ceramic assemblages cluster into discrete settlement groups tethered to major tell sites such as Vésztő-Mágor and Szeghalom-Kovácshalom. Each cluster maintained a consistent stylistic identity, with only minimal evidence of cross-cluster stylistic blending. Tell sites acted as stylistic anchors, exerting strong influence over the ceramic styles of surrounding flat settlements. Clinal variation in lower-visibility attributes, such as rim thickness and fabric, was observed across the gradient between tell and satellite sites, suggesting structured enculturation systems within each settlement cluster (Borić, 2015).

During the Early Copper Age, settlement distribution in the same region becomes more diffuse. Instead of tethered clusters around tells, the landscape is populated with numerous flat settlements, most of which appear short-lived or seasonally occupied. Ceramic analysis reveals greater stylistic uniformity across these sites. While some local variability remains—especially in lug decoration and pedestal proportion—most attributes show either uniform or clinal distributions across the region. For example, the frequency of pierced lugs rises gradually from west to east, but remains above 70% across all sites. This suggests a broader regional consensus in ceramic production, possibly reflecting the integration of dispersed kin groups or the formation of seasonal aggregation zones (Siklósi & Szilágyi, 2021; Zech et al., 2021).

The regional social network for the Early Copper Age shows increased connectivity, with every site linked to at least four others based on ce-

ramic similarity. Betweenness centrality values indicate the emergence of new central nodes—smaller flat sites that replace tells as primary hubs of stylistic influence. These results support the hypothesis that settlement relocation, possibly driven by environmental pressures, disrupted older patterns of stylistic territoriality and fostered new, more horizontal modes of interaction.

Micro-Regional Patterns: Vésztő–Bikeri Cluster

At the micro-regional scale, a detailed analysis of three Early Copper Age sites—Vésztő-Mágor (reoccupied during this phase), Vésztő-Bikeri, and Körösladány-Bikeri—reveals how boundary dynamics played out within short distances (under 2 km). Despite proximity, these sites display significant intra-cluster variation in some stylistic attributes.

For instance, pedestal vessel frequency differs markedly: Vésztő-Mágor has 56%, Vésztő-Bikeri 18%, and Körösladány-Bikeri 17%. Lug shape also varies: round lugs dominate at Vésztő-Mágor (71%), while ovate forms prevail at the other two sites. However, other features such as rim profiles and fabric textures are consistent across all three. These mixed patterns suggest overlapping but non-identical traditions—perhaps reflecting different household clusters, kin networks, or phases of occupation within the same generation (Parkinson et al., 2010).

Temporal data support this interpretation. Radiocarbon dates and ceramic typology place Vésztő-Bikeri slightly earlier than Körösladány-Bikeri and later than the final Neolithic phase at Vésztő-Mágor. The tell appears to have been reoccupied briefly after abandonment, while the Bikeri sites reflect a shift to open, palisaded villages. The random distribution of some attributes—such as encrusted decoration and incised banding—between the Bikeri sites may indicate experimentation or the introduction of new ideas through mobile individuals or visiting groups.

Table 2: Macro-regional variability – Distribution of Late Neolithic and Early Copper Age attributes across the Great Hungarian Plain

Stylistic Attribute	**Late Neolithic Distribution**	**Early Copper Age Distribution**	**Interpretive Insight**
Painted motifs (red/white)	Regionally bounded (Tisza and Csőszhalom zones)	Absent across all regions	Decline of high-visibility boundary markers
Incised decoration	Clustered in southern and central regions	Uniform but simplified motifs	Ritual symbolism replaced by broader aesthetic codes
Pedestal vessels	Concentrated in Csőszhalom zone	Widespread with formal standardization	Shift from localized ritual to shared symbolic forms
Pierced lugs	Rare and localized	Ubiquitous across regions	Increased stylistic connectivity and diffusion
Highly polished surfaces	Present in Herpály zone only	Consistent throughout the Plain	Expansion of production techniques and norms
Fabric texture	Variable by region	Largely standardized	Greater inter-regional exchange or shared learning systems
Bosses / knobs	Limited to eastern groups	Infrequent or absent	Reduction in decorative elaboration
Shell temper use	Minimal and localized	Slight increase in western sites	Functional adaptation with possible external influence
Tell-based settlement influence	Dominant stylistic cores	Decentralized and diffuse influence	Collapse of tell hierarchy and rise of horizontal networks
Average inter-site similarity score	0.42 (high variability)	0.78 (high homogeneity)	Increased stylistic integration across regions

These findings challenge the notion that proximity automatically correlates with stylistic convergence. Instead, they support a model in which ceramic styles were shaped by nested social networks—households, kin groups, and exchange partners—operating at different scales and influenced by overlapping identity strategies.

Table 3: Distribution of stylistic attributes during the Late Neolithic on the Great Hungarian Plain

Stylistic Attribute	**Tisza Group**	**Herpály Group**	**Csőszhalom Group**
Red-painted motifs	Rare	Common	Common
White-painted motifs	Absent	Occasional	Frequent
Incised meander patterns	Common	Rare	Occasional
Bosses / Knobs	Frequent	Occasional	Rare
Pedestal vessels	Rare	Occasional	Frequent
Pierced lugs	Absent	Rare	Occasional
Highly polished surfaces	Occasional	Frequent	Occasional
Tell-based settlements	Dominant	Present	Localized
Use of shell temper	Rare	Rare	Occasional
Burnished red surfaces	Frequent	Rare	Rare

Across all three spatial scales, the results consistently demonstrate a shift from strongly bounded, territorially anchored ceramic traditions in the Late Neolithic to more fluid, interconnected stylistic networks in the Early Copper Age. This transformation is reflected in decreased stylistic modularity, increased inter-site similarity, more homogenous high-visibility attributes, and reduced reliance on tell-centered settlement hierarchies. However, local and regional variation persists, often in low-visibility or subtle traits, suggesting that boundary dissolution was partial, negotiated, and context-dependent.

Stylistic convergence in the Early Copper Age did not erase all distinctions but restructured how they were expressed and maintained. Communities increasingly engaged in horizontal interaction networks, adopting shared visual languages while preserving pockets of tradition and innovation. These results provide strong support for interpreting the Neolithic–Copper Age transition as a dynamic process of social fluidity and stylistic integration, rather than a simple replacement or unification event.

Discussion

The results of this study offer a compelling reassessment of how social boundaries were constructed, expressed, and transformed during the Late Neolithic to Early Copper Age transition in the Great Hungarian Plain (Lenhoff, 2024). They demonstrate that stylistic variability in ceramic assemblages does not merely signal cultural isolation or integration but reflects broader processes of social negotiation, environmental adaptation, and shifting scales of interaction. Importantly, this transition was not a unidirectional shift from segmentation to cohesion. Instead, it was marked by the reconfiguration of boundary-making strategies, involving the dissolution of some boundaries, the reinforcement of others, and the emergence of new identity expressions (Raczky & Anders, 2012).

Traditional interpretations of this period tend to frame social change as a movement from discrete "tribal" groups toward a more unified or integrated cultural horizon (Borić, 2015). While ceramic homogeneity in the Early Copper Age suggests such integration, a deeper analysis reveals a more complex picture Figure 2. The coexistence of widespread stylistic convergence with localized differences—especially in low-visibility attributes—points to the emergence of nested interaction spheres, wherein households or kin groups maintained certain traditional practices even while participating in broader stylistic systems.

This model challenges the binary opposition of "open" versus "closed" boundaries. Instead, it suggests that boundaries were contextually enacted. High-visibility traits were used to facilitate affiliation across regional networks, perhaps for trade, marriage, or ritual gatherings, while low-visibility traits continued to encode local knowledge, learning traditions, and community-specific identities. This layered expression allowed individuals and groups to navigate multiple social affiliations simultaneously—a strategy well-suited to an era of increased mobility and environmental uncertainty.

Another major implication of these findings is the apparent decentralization of stylistic authority during the Early Copper Age. In the Late Neolithic, tell sites acted as dominant stylistic centers, anchoring surrounding satellite settlements and transmitting standard design templates within tightly bounded clusters. By contrast, the Early Copper

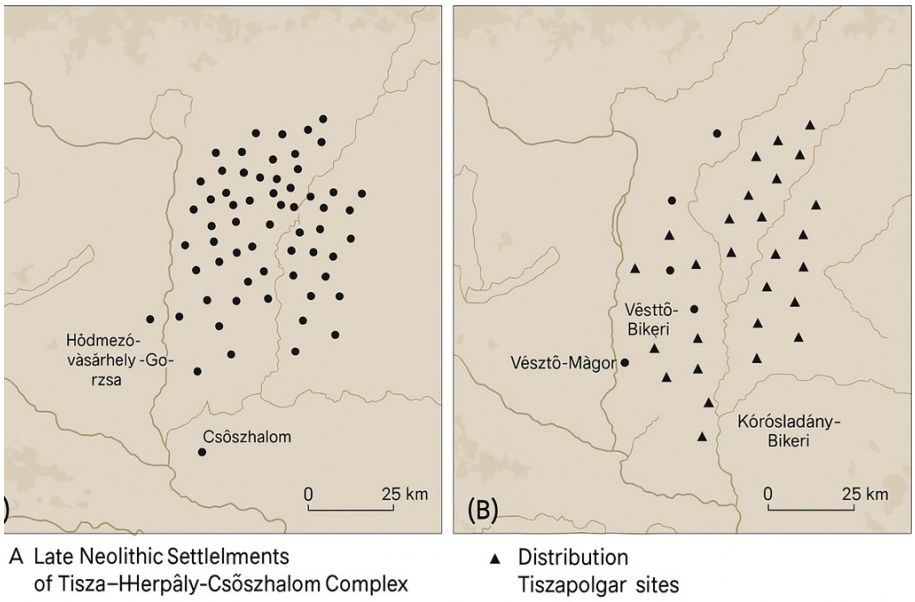

Figure 2: Archaeological distribution map of the Great Hungarian Plain showing major river systems and two key cultural phases: (A) Late Neolithic settlements associated with the Tisza–Herpály–Csőszhalom Complex, and (B) Early Copper Age settlements linked to the Tiszapolgár culture. Locations of major sites discussed in the study are marked to illustrate spatial shifts and cultural continuity across the transition

Age landscape exhibits a more horizontal structure. Flat, short-term settlements begin to replace tells as key nodes of stylistic influence. Social network analysis confirms the redistribution of centrality, with stylistic authority no longer tied to any singular monumental settlement.

This decentralization may reflect broader shifts in social organization. As communities became more mobile or relocated in response to environmental stressors, rigid hierarchies may have given way to more flexible, kin-based networks. The flattening of stylistic hierarchies corresponds with the dispersal of settlement clusters and the rise of uniform but locally modifiable ceramic forms. Such a configuration supports the idea of modular identity systems—shared stylistic grammars that could be customized according to local needs and histories.

Stylistic homogenization in the Early Copper Age has often been interpreted as a symptom of integration—either through migration, population mixing, or the emergence of more complex social formations. However, the evidence from this study suggests it was also a strategic choice. The adoption of shared ceramic motifs and forms across formerly distinct cultural regions likely served practical and symbolic purposes. It enabled the expansion of exchange networks, facilitated

peaceful interactions between previously separated groups, and allowed individuals to assert commonality in times of change.

In this context, homogenization is not necessarily a loss of cultural complexity. Rather, it is a reflection of cultural flexibility, where communities willingly modified or streamlined aspects of their material culture to meet new social realities. This perspective reorients our understanding of the Early Copper Age: not as a moment of uniformity imposed from above, but as a dynamic period of bottom-up integration, in which stylistic convergence enabled—and perhaps encouraged—new forms of social cohesion and mobility.

The environmental context of this transition cannot be overlooked. Around 4500 BCE, climate proxies suggest increased aridity and hydrological instability across the Carpathian Basin. These conditions would have affected riverine cultivation, grazing cycles, and settlement viability—prompting communities to relocate, diversify subsistence strategies, or adopt more flexible territorial arrangements.

In this setting, fluid and inclusive identity markers may have offered adaptive advantages. Ceramic styles that signaled openness, participation, and shared affiliation could help newcomers integrate into unfamiliar areas, reduce conflict over land use, and facilitate access to shared water sources or seasonal pastures. In other words, the stylistic integration of the Early Copper Age may have functioned not just as a cultural expression but as a risk-buffering mechanism—a way to expand cooperative potential under conditions of ecological uncertainty.

Moreover, the decline of large, permanent tells in favor of smaller, mobile settlements likely reduced the symbolic authority of older, place-based identities. As communities moved, identity had to become more portable. Ceramic style, widely recognized and easily transmitted, became a key medium for expressing collective belonging in the absence of fixed ritual landscapes or enduring architectural markers.

Table 4: Local Variability – Distribution of Early Copper Age Ceramic Attributes within Nearby Settlements

Ceramic Attribute	**Vésztő-Mágor**	**Vésztő-Bikeri**	**Körösladány-Bikeri**	**Interpretive Insight**
Pedestal vessel frequency	56%	18%	17%	Indicates ritual centrality or social memory at tell site
Lug shape (round vs. ovate)	71% round	63% ovate	67% ovate	Suggests kin- or workshop-level production preferences
Surface burnish quality	High gloss	Medium gloss	Medium gloss	Continuity of learned techniques with minor variation
Encrusted decoration	Absent	Occasional	Frequent	Possible experimentation or visiting influences at satellite site
Rim profile type	Uniform (thickened)	Slightly variable	Slightly variable	Suggests household-based style continuity
Fabric composition	Coarse with fine temper	Medium-coarse	Medium-coarse	Shared resource use with minor preparation differences
Pierced lugs	Common	Common	Common	Indicates regional stylistic cohesion despite local variation
Miniature vessels	Rare	Frequent	Frequent	Suggests different ritual or educational practices
Settlement type	Reoccupied tell	Flat, palisaded	Flat, palisaded	Reflects varying continuity and social structure
Radiocarbon date range	Slightly earlier	Middle phase	Slightly later	Confirms micro-sequencing within shared tradition

A further dimension of stylistic variability involves its connection to gender and generational identity. Burial data from Tiszapolgár cemeteries show that specific ceramic types and decorations were often associated with particular demographic profiles—suggesting that style may have encoded not only group affiliation but also age, gender, and social role. The presence of miniature vessels in children's graves and the association of certain lug forms with adult female burials indicate that stylistic conventions may have been used to teach and perform identity from an early age.

At the household level, ceramic production likely occurred along generational lines, with knowledge transmitted through apprenticeship. This would explain the persistence of subtle, low-visibility traits within specific settlements even after broader stylistic integration. Such continuity underscores the relational nature of style, where individual choices are embedded in familial, educational, and gendered contexts. It also suggests that boundary-making was not only a macro-social process but one enacted through everyday acts of crafting, teaching, and using material culture.

Conclusion

The Neolithic–Copper Age transition in the Great Hungarian Plain represents a period of profound transformation—not only in the material record but also in the social fabric of prehistoric communities. Through a multiscalar, network-informed, and environmentally contextualized approach to ceramic style, this study has offered a revised interpretation of how social boundaries operated across this pivotal period. Rather than conceptualizing the transition as a shift from "fragmented tribal units" to "integrated cultural formations," the findings indicate a far more nuanced process of adaptation, negotiation, and symbolic rearticulation.

At the heart of this transformation lies the changing role of style—not as a static emblem of cultural membership, but as a flexible medium of social communication. In the Late Neolithic, high-visibility ceramic attributes functioned as active boundary markers, distinguishing between discrete cultural groups and reinforcing internal cohesion through stylistic uniformity. These patterns were tethered to settlement hierarchies, especially tell sites, which acted as centers of ritual and political

authority. The internal consistency of ceramic styles within these clusters and the clear differentiation between them suggest that boundaries were intentionally maintained and socially meaningful.

The Early Copper Age, by contrast, reveals a dramatic reorganization of both stylistic and settlement patterns. The disappearance of discrete regional styles and the emergence of a more homogeneous ceramic tradition across the Plain do not reflect the erasure of identity, but rather a redefinition of how identity was performed. Ceramic homogeneity functioned not as an imposed conformity but as a shared symbolic language—enabling social interaction, mobility, and cooperation across wider networks of affiliation. Local variation persisted in low-visibility attributes and in micro-regional expressions, indicating that communities continued to maintain aspects of their traditions while adopting broader styles to participate in new forms of social integration.

These findings suggest that stylistic convergence during the Early Copper Age was not simply the result of population mixing or technological diffusion, but a conscious and strategic choice made by communities navigating a rapidly changing world. Environmental stress, particularly the shift toward more arid conditions around 4500 BCE, likely intensified the need for cooperation and flexible territorial strategies. In this context, adopting shared visual codes and standard ceramic forms became a way to lower social barriers, facilitate alliance formation, and smooth the circulation of people and resources across a volatile landscape.

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