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Connectivity Between Northern Iberia and Western France (2900–1100 cal BC): The Flux of Metalwork in the Bay of Biscay Modelled by Multivariate Clustering

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Connections between northern Iberia and western France around the Bay of Biscay during the Chalcolithic, Early Bronze Age, and Middle Bronze Age are addressed in this article through a multivariate cluster analysis of a dataset of 1273 metal finds, comprising 4554 metal artefacts grouped into five multiregional clusters with distinctive distributions, chronologies, content, and contexts. Changes in distribution and chronology show that metalwork from faraway regions was deposited in similar ways, reflecting changing patterns of interregional connectivity. Changes in context and content suggest social transformations. The clustering method known as Latent Class Analysis is presented here in the hope that it will be applicable to other datasets elsewhere in the world.

Keywords: Bronze Age, Chalcolithic, Bay of Biscay, Atlantic Europe, metalwork, cluster analysis

INTRODUCTION

This article has two objectives. First, to present a study about connectivity in the Bay of Biscay area between the Chalcolithic and the Middle Bronze Age (2900–1100 cal BC). The Bay of Biscay is defined as the coastline that runs from the Douro estuary in northern Portugal to the entrance of the English Channel in Brittany. The study of connectivity in Atlantic Europe has focused on different parts of the Bay of Biscay (Coffyn, 1985; Gomez de Soto, 1990; Bradley, 2014; Kerouanton et al., 2017); but it has rarely been the subject of study in its entirety (Callaghan & Scarre, 2017; Latorre-Ruiz, 2021). Here, I analyse connectivity in the entire Bay of Biscay zone by compiling a dataset of 1273 metal finds consisting of 4554 metal artefacts and comparing the metalwork from its different regions (Supplementary Material 4 lists these finds and another approximately 100 that were not included because they had items which cannot be identified for reasons enumerated below). The intention is to understand how the Bay of Biscay's regions interacted and show the importance of this body of water in apprehending connectivity in Atlantic Europe.

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My second objective is to show the potential of the clustering technique known as Latent Class Analysis (LCA), used here to reveal clusters of 'metal finds'. Metal finds are defined as one or several metal items deposited simultaneously or, in few cases, during the same period, in the Chalcolithic, Early Bronze Age, or Middle Bronze Age. Other clustering techniques have been used to create typologies or divide sites of the same type (e.g. burials) into groups (Everitt, 2011: 12). By contrast, network analyses have recently been used to analyse more complex archaeological datasets containing different categories of sites and artefacts (Arthur et al., 2018). This article aims to show the potential of LCA for studying datasets from various categories of sites dated to different periods containing a common range of items in multiple combinations.

I shall start with a brief summary of my analysis, before presenting the dataset and the clustering method, and discussing the outcome of the study. Figure 1 summarizes the patterns identified. The vertical axis corresponds to the five clusters identified by the LCA clustering analysis, named after randomly chosen Greek letters, whose chronological order cannot be presupposed. The Chi, Kappa, Gamma, Iota, and Tau clusters represent groups of metal finds with distinctive distributions, chronologies, content, and contexts; the most iconic content and context from each cluster are illustrated alongside each cluster. The horizontal axis indicates the appearance and disappearance of each cluster. The five inset schematic maps show the main distribution of each cluster (the name of each region appears on the inset map in Figure 2). Patterns can be

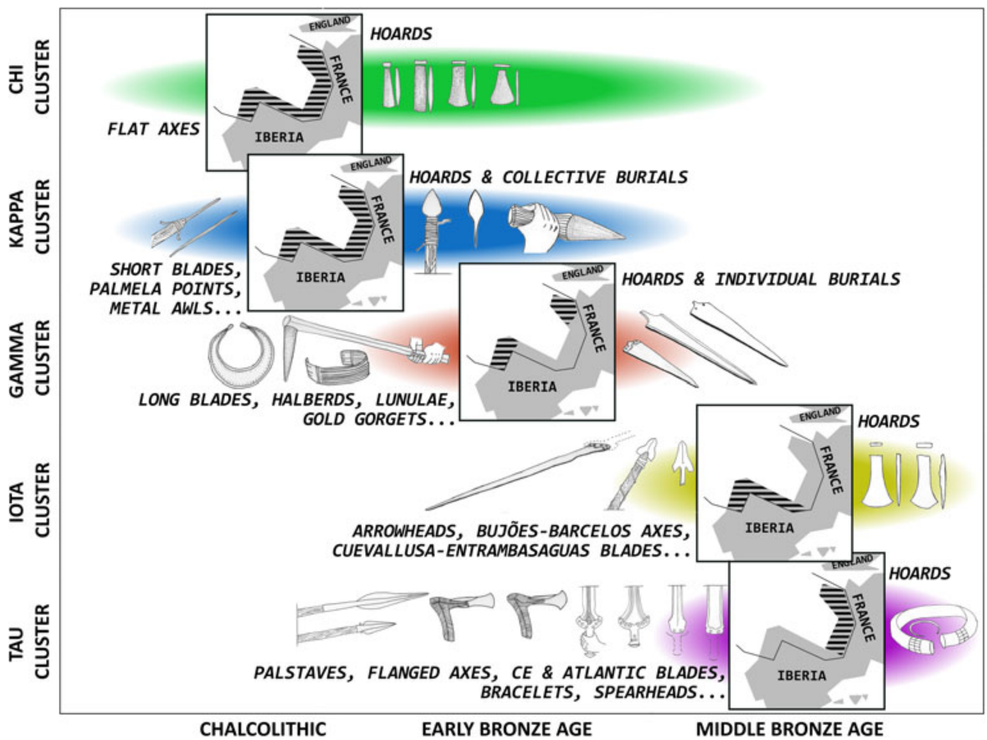

Figure 1. *Summary of results, with the main features of the five clusters of metal finds identified.*

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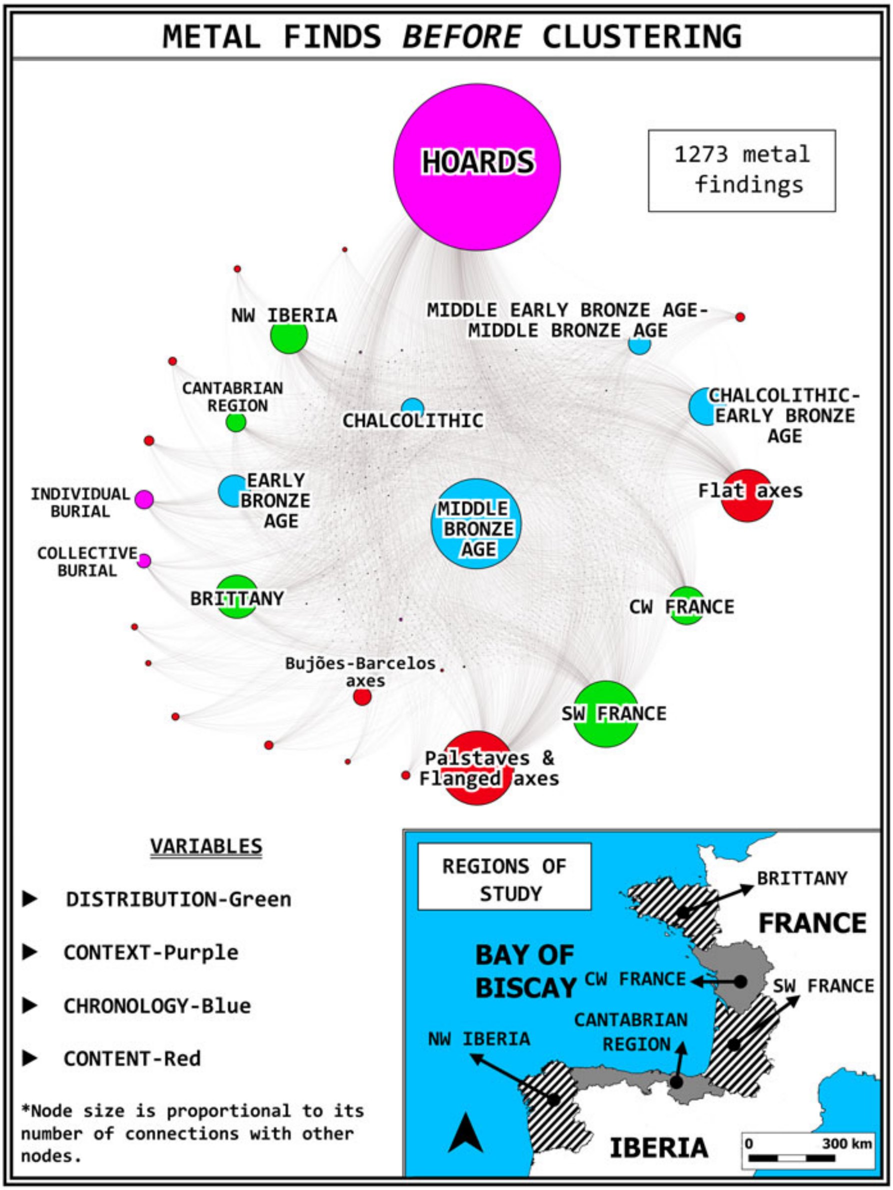

Figure 2. *The 'chaos' of the metalwork dataset represented as a network, before clustering.*

summarized in three phases, each corresponding to one of the periods studied, i.e. the Chalcolithic, Early Bronze Age, and Middle Bronze Age:

- Phase 1 covers the Chalcolithic. It includes flat axes classified in the Chi cluster and other simple items such as daggers and metal awls classified in the Kappa cluster. Both clusters are distributed throughout the Bay of Biscay area.
- Phase 2 corresponds to the Early Bronze Age. The previous items are joined by new artefact types, mostly recovered at the two edges of the Bay of Biscay, Brittany and north-western

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Iberia. These new items come from finds grouped in the Gamma cluster and consist of different types of longer blades, halberds, and precious decorative artefacts.

- Phase 3 spans the Middle Bronze Age and starts with the disappearance of the previous three clusters at different rates, which are replaced by two new sets of metalwork finds grouped in the Tau and Iota clusters. Tau is concentrated in Brittany, central-western, and south-western France and Iota in northern Iberia. This suggests that the French and Iberian sides of the Bay of Biscay were not connected, although this situation would be reversed in the Late Bronze Age (Burgess & O'Connor, 2008). Another alternative is that both sides were connected but used the same raw materials to manufacture different metal artefacts.

The Dataset

The dataset compiled is the most thorough inventory of metalwork in the Bay of Biscay's regions. It relies on a bibliographical search and an inspection of a selection of the material. The aim of assembling the dataset was not to catalogue all the metalwork but to include a sample of each metal type from each region studied so that the inclusion of additional items should not affect the patterns identified. This approach allowed me to study an area that, in relation to other metalwork studies, is comparatively large and focuses on all metal artefact categories and types of sites. A further aim was to show that the application of LCA can rejuvenate the sub-discipline of typo-chronological metalwork studies.

Figure 2 represents the metalwork dataset as a network showing its 'chaos' before clustering. Discussing it serves to explain the internal organization of the dataset. The cloud of small nodes at the centre of the network represents metal finds. The bigger and coloured nodes, most of which are on the network's periphery, represent values of the four variables defining each metal find: distribution, chronology, context, and content. In Figure 2, finds are connected to the values defining them in the dataset. For example, a node representing a Chalcolithic hoard would be connected to these two values. The size of the values depends on the number of connections representing their popularity in the dataset. Only the most popular values are labelled. Each variable and its values are discussed one by one. Finds are described with one value of each variable except for the variable 'content'.

'Content' refers to the metalwork in each find. Metalwork types were grouped into eighteen artefact categories shown in Figure 3 (See Supplementary Materials 2 for discussion). These categories are the values of the variable content. In the dataset, each find was described with one or more of them corresponding to the metalwork it contained. In Figure 2, finds are connected to one or more of the values representing the artefact categories found in them. Grouping types into eighteen categories was necessary to reduce the number of variables in the cluster analysis and create a general picture by combining the secondary information provided by each type. Figure 4 shows the share of each of the artefact categories in the dataset. As expected from other European areas (Gabillot, 2003: 20–21), axes represent the bulk of the objects in the dataset, that is, they were deposited more frequently and are likely to have been manufactured in higher quantities. For approximately 100 finds, it was impossible to identify items because they were severely fragmented, or lost, or so poorly described that they could not be assigned to any category. These finds were not

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Figure 3. *The eighteen artefact categories used in the cluster analysis.*

included in the study (but are included in Supplementary Material 4).

The next three variables—context, chronology, distribution—have several values. Only one value for each variable is used to describe finds. In Figure 2, this is represented by connecting each find to one value. The variable 'context' has five values: 1) collective burials, 2) individual burials, 3) settlements, 4) rock art depictions, and 5)

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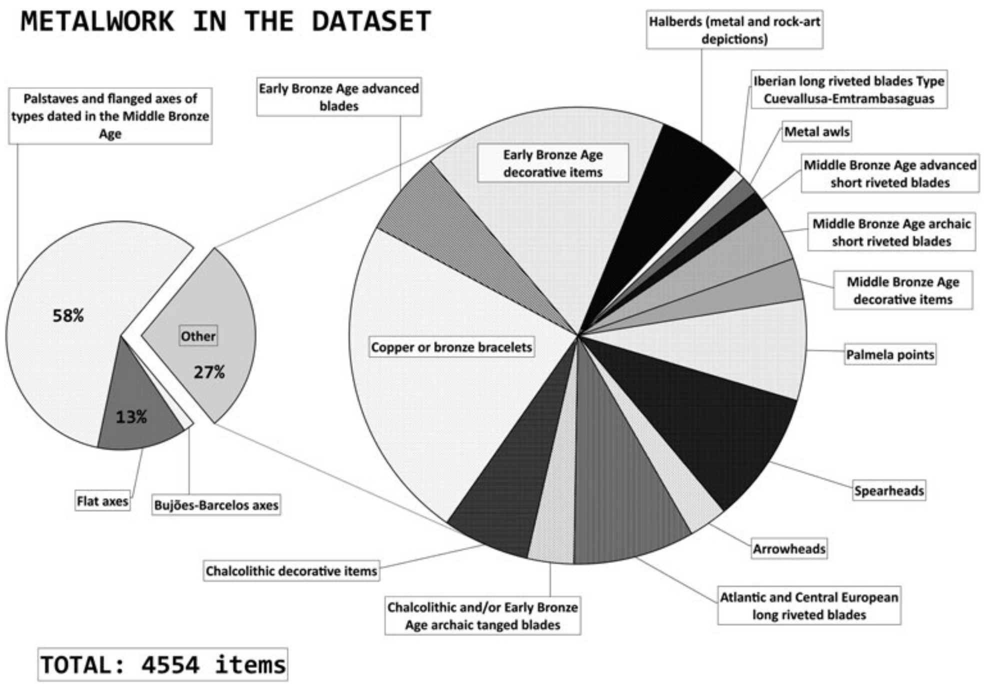

Figure 4. *Composition of the dataset divided into the eighteen artefact categories used in the cluster analysis.*

hoards. 'Hoards' are a Bronze Age phenomenon defined as one or more 'objects that were apparently deposited together on the same occasion' (Bradley, 2013: 122). 'Rock art' refers to several halberds depicted in rock art and widely accepted as representations of metal halberds. The context of forty-six per cent of the finds (n=584) had to be inferred due to their poorly known contexts (see Supplementary Material 4). Of these, eighty-nine per cent (n=520) are old and stray finds classified as hoards. This default classification is a common but problematic aspect in Bronze Age studies (see, for example, Fontijn, 2002: 89) that must be considered when assessing the results. In the case of the finds in the dataset, local and regional studies suggest that in many cases they could be hoards.

The variable 'chronology' has five values: 1) Chalcolithic, 2) Chalcolithic-Early Bronze Age, 3) Early Bronze Age, 4) middle Early Bronze Age-Middle Bronze Age, and 5) Middle Bronze Age. The chronological framework is outlined at the beginning of the results, and it is discussed in depth in Supplementary Materials 1.

The variable 'distribution' has five values which are this study's five regions. The inset map in Figure 2 shows the five regions adjacent to the Bay of Biscay's coastline that have been used as units of analysis in other studies (e.g. Nonat & Prieto-Martínez, 2022) and here. Each region overlaps several modern political entities ('região' in Portugal, 'provincia' in Spain, and 'département' in France). Brittany regroups the départements of Côtes-d'Armor, Morbihan, Finistère, Ille-et-Vilaine, and Loire-Atlantique; for central-western France, Charente, Vendée, Vienne, Charente-Maritime, Deux-Sèvres, Maine-et-Loire, and Indre-et-Loire; for south-western France, Gironde, Lot-et-Garonne, Dordogne, Landes, Pyrénées-Atlantiques, Hautes-Pyrénées, and Gers;

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the Cantabrian region encompasses Asturias, Cantabria, northern Navarra, Guipúzcoa, Vizcaya, and Álava; north-western Iberia is represented by Pontevedra, A Coruña, Ourense, Lugo, and Região do Norte.

Cluster Analysis

The LCA clustering was computed in the 'R environment for statistical computing' version 4.1.2 (R Core Team, 2021) using the package 'poLCA' (Linzer & Lewis, 2011) (see Supplementary Materials 5 for a complete transcript). LCA has been used at least once in archaeology (Moustaki & Papageorgiou, 2005) and is considered to be superior to 'dendrogram' clustering because it copes better with large datasets and can be customized (Schreiber & Pekarik, 2014). Customization means that, although LCA has some basic characteristics (Katherine, 2013: 554–56), it can be implemented in different ways. The family of LCA techniques has received different names, such as mixture model clustering (Vermunt & Magidson, 2002: 90). The generic label 'LCA' refers to one of the oldest and most popular techniques (Hancock et al., 2019: vii).

LCA is explained in Figure 5, which illustrates the standard way of representing LCA analyses, the so-called 'latent model' or LCA model. It includes a code of letters (C, Y, X). The letter C indicates the population of individuals ('metal finds') that the model wants to divide into homogenous subpopulations ('latent classes'). To do so, it defines each metal find with several 'categorical manifest variables' (twenty here) indicated with the letter Y. Variables context (Y1) and chronology (Y2) have numbered values such as 1) Chalcolithic or 5) Settlement. Content is represented by variables Y3 to Y20, each representing the study's eighteen artefact categories (shown in Figure 3). They have two values—1) No, and 2) Yes—which indicate whether finds contain artefacts of that category. Variables are used by LCA to transform each metal find into a sequence of twenty numbers, with each number corresponding to a variable and to a value of that variable. For example, a Chalcolithic settlement with a palstave would be 1, 5, 2, followed by seventeen number ones. LCA groups these sequences into clusters based on their similarities.

Two remarks must accompany this LCA model. First, to avoid distribution biases, regions are not included. Finds should not be clustered together because they were found in the same region. Second, the model does not consider the number of items in each find. Two contemporary finds of the same type of context containing palstaves, one with eight and another with two, would be identical. Only the combination of artefact categories alongside context and chronology defines finds. The reason is pragmatic. In some finds, artefacts can be assigned to a category, but they are so fragmented that it is difficult to determine their exact number. In others, we know which artefact categories were originally found, but the exact number of artefacts of each category is unknown.

Two aspects of Figure 5 require further explanation: how many clusters LCA finds and the meaning of the letter X. The latter is employed in latent models to indicate the 'latent variables' labelled here 'historical processes'. Latent variables are the phenomena behind each subpopulation or cluster found by LCA (Linzer & Lewis, 2011: 22). Thus, latent variables are the hypothetical things or circumstances that created the clusters identified by LCA (Katherine, 2013: 556). This study's assumption is that prehistoric phenomena caused people to deposit metalwork in similar ways. These 'similar ways' and the phenomena or 'historical processes' which

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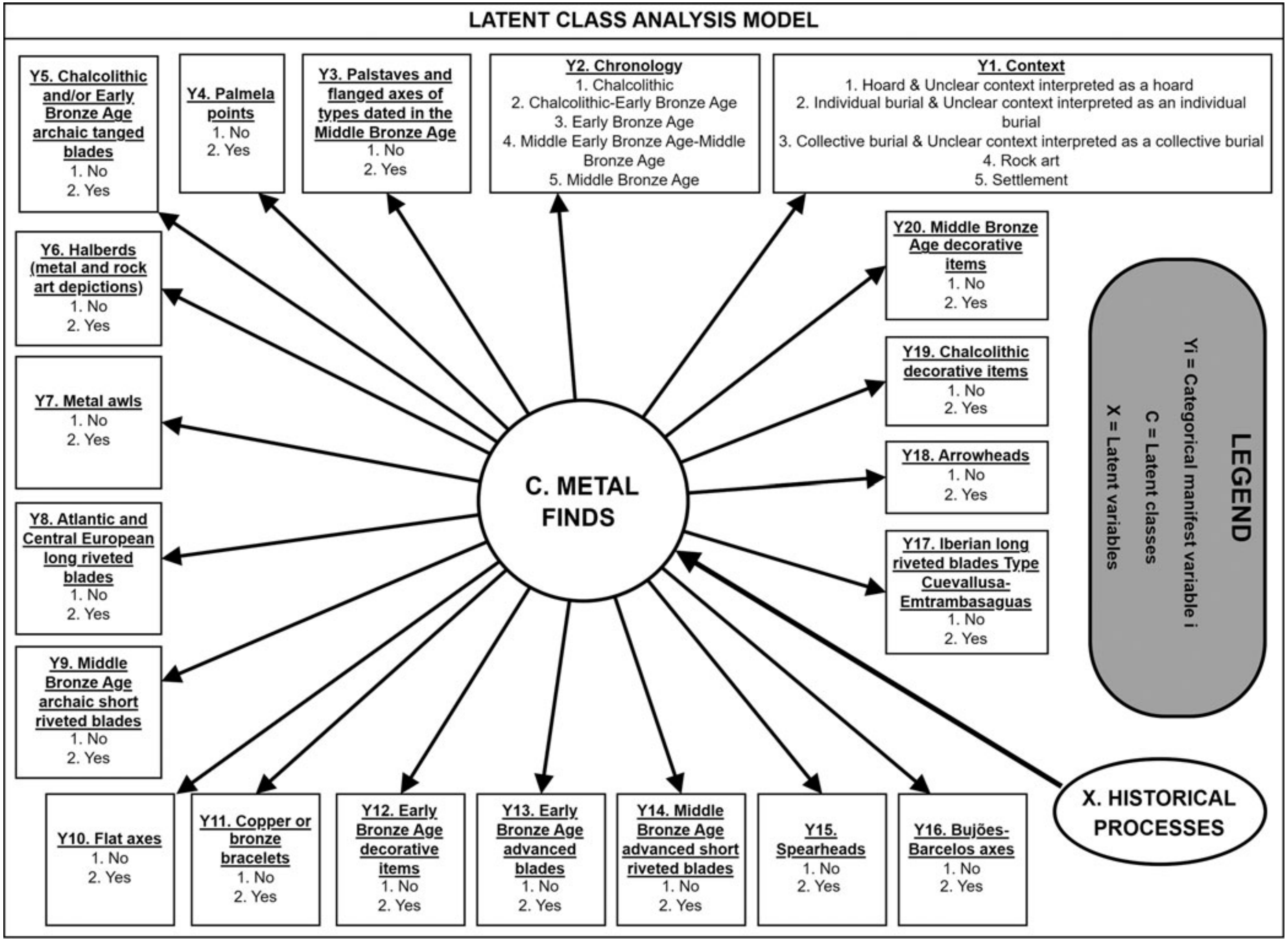

Figure 5. *The LCA model used for clustering. Regions are not included to avoid distribution biases.*

potentially caused people to behave in such a way are discussed below.

LCA forces researchers to specify the number of clusters found, and there are two schools of thought concerning how to find the 'correct' number (Weller et al., 2020: 292). One claims that it must be chosen after comparing several possibilities, while the other advocates different 'parsimony measures', such as the 'Bayesian Information Criterion', which indicate the number of clusters that make the most sense mathematically. The former choice was followed and, after computing the model for two to ten clusters, the five-cluster scenario was chosen as the one that makes the most sense archaeologically (see discussion in Supplementary Material 3).

Results

LCA reveals five clusters, which represent groups of metal finds with homogenous contents, chronologies, and contexts whose distribution links the Bay of Biscay's regions. The clusters Kappa and Chi correspond to the Chalcolithic (2900–2600/2300–2000 cal BC) and the Early Bronze Age (2300–2000/1800–1600 cal BC). Cluster Gamma equates with the Early Bronze Age and clusters Tau and Iota belong to the Middle Bronze Age (1800–1600/1300–1100 cal BC).

Figure 6 presents these clusters (Figure 1 should also be used for reference). It works like a table with five columns corresponding to a cluster and four major rows corresponding to the dataset's four variables (chronology, content, distribution, and context). The cluster's distribution is included, although regions were not used in the cluster analysis to avoid distribution biases. The data presented in the rows is self-evident except for the 'content' row. This shows several labels and percentages. The labels are the names given to the eighteen artefact categories in the study (see Figure 3), indicating the most common categories in each cluster. The percentage next to each label does *not* indicate, as it might seem, the percentage of artefacts of that category in the cluster. Instead, it indicates the percentage of the total number of artefacts of that category *in the dataset*. Thus, the Chi cluster does not only contain flat axes, but it has eighty-nine per cent of *all* the flat axes in the dataset.

Chalcolithic and Early Bronze Age

The best way to start discussing the five clusters in the Bay of Biscay area is to begin with the Chi cluster. To put it simply, the Chi cluster indicates that, regardless of the region, between the Chalcolithic and a little after the end of the Early Bronze Age, almost all 'flat axes' (the label 'flat axe' applying to several different types of axes that were mostly used between the Chalcolithic and the Early Bronze Age) were deposited in hoards that only contained them.

The values representing the Chi cluster are shown in the first column of Figure 6. Most of its finds (84 per cent) are dated to the Chalcolithic and the Early Bronze Age, while sixteen per cent date to the transition to the Middle Bronze Age. Chi only contains flat axes, which accounts for eighty-nine per cent of all the flat axes in the dataset. Regarding distribution, the Chi cluster, in comparison with other clusters in Figure 6 ('distribution', left histogram), is evenly distributed over all the regions. Nevertheless, two regions contain fewer metal finds belonging to this cluster: the Cantabrian region (13 per cent) and Brittany (8 per cent). The reason is that Cantabria has few flat axes while, in Brittany, flat axes were also deposited in

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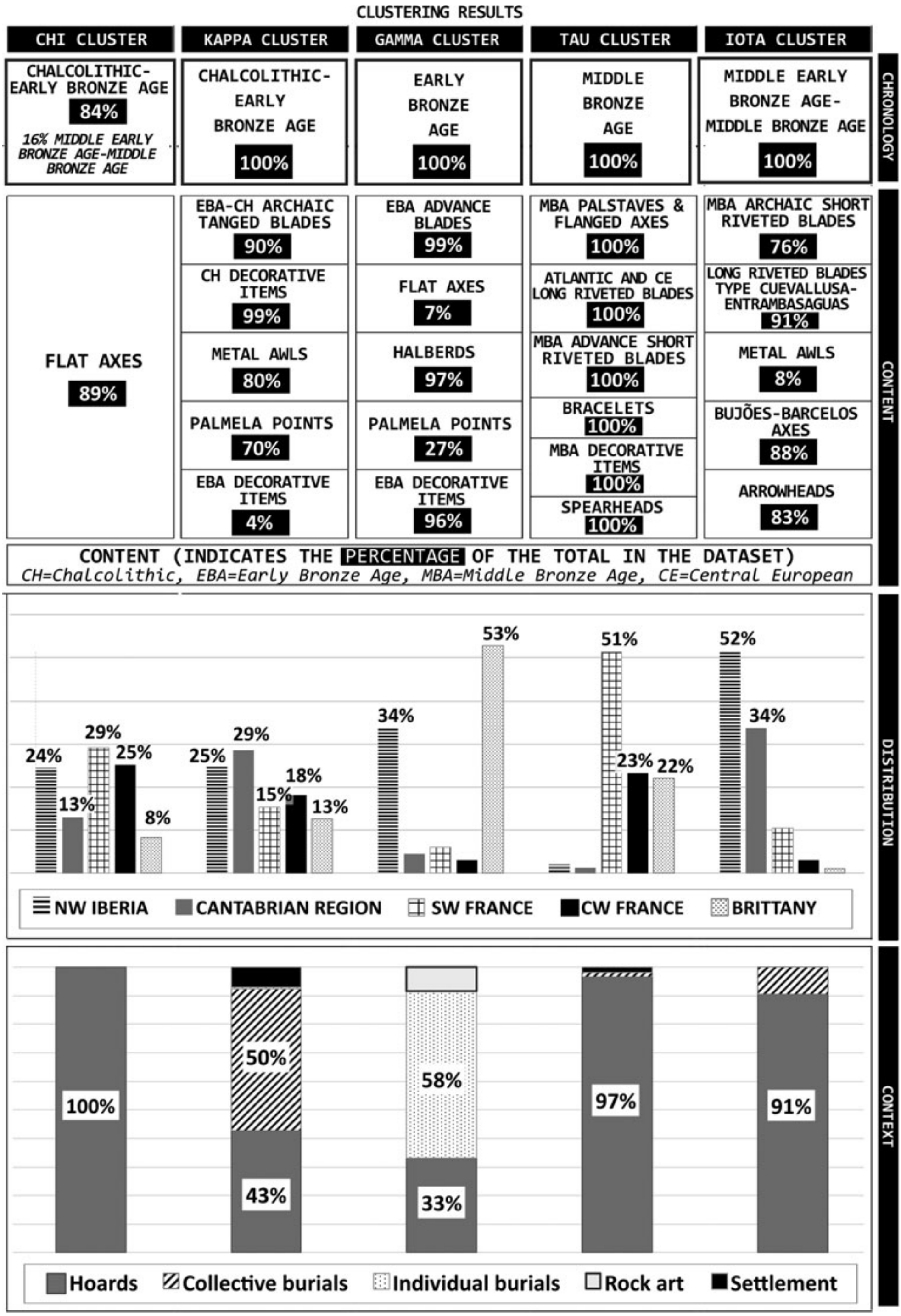

Figure 6. *Results of the cluster analysis. Columns correspond to the five clusters identified and named-after Greek letters. Blocks of rows correspond to the variables in the study (chronology, content, distribution, and context).*

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burials. This is exceptional; indeed, seven per cent of all the flat axes in the study were found in single graves clustered in the Gamma cluster (Figure 6, third column, 'content'). Nevertheless, this is a secondary pattern that will not be explored further. Finally, in terms of context (Figure 6 bottom, 'context', left), all the flat axes in the Chi cluster were found in hoards. This shows that flat axes were mostly deposited in hoards containing nothing else, for reasons discussed below.

The Kappa cluster is mostly contemporary with the Chi cluster. Its metal finds contain metalwork that started to be used in the Chalcolithic but ceased to be produced around the end of the Early Bronze Age. They mainly comprise four artefact categories: short blades (100–150 mm), labelled here 'Chalcolithic and/or Early Bronze Age archaic tanged blades' but also known as 'copper-alloy daggers'; metal awls, some small and resemble sewing needles while others are larger and resemble knitting needles; Palmela points, a common category of arrowhead in Iberia and southern France; and simple decorative items, labelled here 'Chalcolithic decorative items' because they started to be used at that time. The latter category includes beads and thin spiral bracelets among other artefacts.

Regarding distribution, the finds of the Kappa cluster are equally distributed throughout the regions studied, like the Chi cluster. This is particularly clear if we compare its distribution (Figure 6, 'distribution', second histogram) with that of the three clusters to the right of it. With regard to context (Figure 6 bottom, 'context', second from left), Kappa's metalwork was deposited in collective burials belonging to different funerary traditions (50 per cent) and hoards (43 per cent); the latter differ from the hoards in the Chi cluster, which only contained flat axes.

After the Chalcolithic, only represented by the Chi and Kappa clusters, a new cluster appears, joining the previous two. The Gamma cluster (Figure 6, middle column) coexisted with Chi and Kappa during the Early Bronze Age, its disappearance marking the end of that period. This cluster consists of 'elite' items, such as blades with lengths not previously seen (more than 200 mm long), halberds, and gold collars. These items concentrate in Brittany and north-western Iberia, where they are found in single graves and hoards, implying that the rest of the regions studied did not use them. Suggestions of contact between Brittany and north-western Iberia at this time are not new (Briard, 1998) and the Gamma cluster seems to confirm this. All over Europe, 'elite' finds like these have been interpreted as indicative of chiefdoms (Kristiansen 2015: 1104). This issue is discussed below.

Despite the similarities of the Gamma cluster's finds, their distribution (Figure 6, 'distribution', third histogram) shows that their presence in Brittany (53 per cent) was stronger than in north-western Iberia (34 per cent). Although the Gamma cluster sets these two regions apart from the rest of the Bay of Biscay area, its presence in each of them differs.

Regarding context (Figure 6 bottom, 'context', third from left), most finds in this cluster consist of single graves (58 per cent) and hoards (33 per cent). Hoards in both regions follow similar patterns. On the other hand, the single graves in Brittany belong to the Armorican Tumulus tradition and the burials in north-western Iberia to the Vilavella-Atios group (Brandherm, 2007). The former group includes more burials, which are also more homogenous and can be divided into distinct series (Nicolas et al., 2015), while the latter includes fewer burials, with each burial containing slightly different combinations of artefacts which might reflect a less well-established tradition of burying people in single graves (see Brandherm, 2007: 74, 76).

In terms of content, another difference in the Gamma cluster distinguishes the finds from Brittany from those of north-western Iberia. The two regions share three artefact categories: Early Bronze Age advanced blades, halberds, and Early Bronze Age decorative items. The decorative items are similar in both regions, whereas the other two categories can be subdivided into regional types that differentiate Brittany from north-western Iberia. These regional types nevertheless share attributes not seen in the other regions of the Bay of Biscay, which suggests that some connections may have existed. The length of the blades (which are grouped in the category 'Early Bronze Age advanced blades') in these two regions is striking compared to the short blades of the contemporary Kappa cluster (labelled 'Chalcolithic and/or Early Bronze Age archaic tanged blades') (see Figure 3 for differences). The halberds, despite typological differences between regional types, are an artefact category that is virtually absent in the rest of the Bay of Biscay regions. In short, while Brittany and north-western Iberia represent two 'personalities' of the Gamma cluster, they share features that set them apart from the rest of the Bay of Biscay area.

Middle Bronze Age

The end of the Early Bronze Age is marked by the disappearance of the Chi, Kappa, and Gamma clusters. They are replaced by a new generation of metal items classified as Tau and Iota (Figure 6, fourth and fifth columns).

Tau and Iota are similar with regard to chronology and context but are complete opposites in terms of distribution and content. Simply put, while the Iota cluster is concentrated in northern Iberia and contains metalwork only employed in the Iberian Peninsula, the Tau cluster is represented in France and contains a more 'international' range of metalwork, known in Atlantic and Central Europe. This seems to confirm the view that Atlantic Iberia was isolated during the Middle Bronze Age (Gibson, 2000: 73), although an alternative is that this region used raw materials of the same provenance to manufacture a different range of artefacts.

Regarding chronology, the Tau and Iota clusters' metalwork mark the beginning of the Middle Bronze Age. The only small difference is that the appearance of the Iota cluster may be slightly earlier for two reasons. One is that its metalwork is more 'archaic', meaning that it has attributes that place it closer to the metalwork of the Early Bronze Age. A second reason is that the Iota cluster contains a few artefacts that are overwhelmingly found in the Kappa and Gamma clusters and vice versa. These two features seem to indicate that the transition from the metalwork used in the Early Bronze Age to that used in the Middle Bronze Age in north-western Iberia and the Cantabrian region was progressive. Nevertheless, this does not mean that the items in the Kappa and Gamma clusters were employed in a generalized way in the Middle Bronze Age. In contrast, the Tau cluster seems to appear suddenly and rapidly, replacing the previous metalwork.

Regarding content, two features are apparent: the 'archaicity' of the Iota cluster and the more 'international' character of Tau. This also serves to illustrate the different categories of artefacts found. Iota contains Bujões-Barcelos axes, which are common in Atlantic Iberia and share traits with the flat axes from earlier periods, and hence are more 'archaic'. Tau contains a wide range of different types of palstaves and flanged axes. The latter two are virtually non-existent in Iberia during the Middle Bronze Age but are common throughout western Europe and are more distinct, morphologically speaking, from the flat axes of the previous periods than the Bujões-Barcelos axes. Arrowheads are present in the Iota cluster in sizeable numbers but are scarcer in the French regions. In contrast, the Tau cluster contains three Middle Bronze Age artefact categories not found in the Iota cluster: spearheads, bracelets, and Middle Bronze Age decorative items, the latter mainly metal pins. Importantly, spears, bracelets, and metal pins are common items in Atlantic and Central Europe but are not found in the Iota cluster. Finally, the two clusters contain different categories of blades. The blades in the Iota cluster are common in the Iberian Peninsula. Here, they are grouped into two categories: the 'Iberian long riveted blades of Cuevallusa-Entrambasaguas type' and the 'Middle Bronze Age archaic short riveted blades'. In contrast, the Tau cluster contains various types of blades found in different parts of Europe, grouped here in the 'Atlantic and Central European long riveted blades' category, and shorter blades with characteristic trapezoid tangs, grouped here in the 'Middle Bronze Age advanced short riveted blades' category. Differences between blades on the two sides of the Bay of Biscay reinforce the idea that Iberia was isolated.

The context and distribution of the Tau and Iota clusters is more straightforward. Regarding context (Figure 6 bottom, 'context', right), most of the finds are hoards in both Tau (97 per cent) and Iota (91 per cent). Burials, whether collective or single, were seemingly no longer considered an appropriate place for depositing metalwork. The metal finds of the Iota cluster (Figure 6, 'distribution', right histogram) are concentrated in north-western Iberia (52 per cent) and the Cantabrian region (34 per cent), while the metal finds in the Tau cluster are concentrated in the French regions studied. This distribution is not even, as many finds are concentrated in south-western France (52 per cent), compared with central-western France (23 per cent) and Brittany (22 per cent). This is due to the great number of hoards found in the department of Gironde traditionally grouped into the 'Bronze Médocain' (Couderc, 2017). This curious concentration of hoards has not been paid much attention outside France, but it deserves more attention. Another reason for the uneven distribution of finds in the three regions in the Tau cluster is owed to the way distributions are represented in Figure 6. The issue is that distributions in Figure 6 represent the percentage of metal finds in each region regardless of the amount of metalwork contained in each find. In Brittany during the Middle Bronze Age, a few finds equate to a large number of items. This is particularly true for palstaves and flanged axes. In other words, although only twenty-two per cent of the metal finds of the Tau cluster are concentrated in Brittany, the number of items per find is higher than in central-western and south-western France. This, however, does not negate the importance of south-western France. Equally, it does not distort the main message of Figure 6: in relation to metalwork typologies, during the Middle Bronze Age in the Bay of Biscay area, Iberia and France seem to have been more separated than not.

Discussion

The Chi cluster shows that, before the Middle Bronze Age, almost nine out of ten metal axes were deposited in hoards containing nothing else throughout the Bay Biscay area. This is not new in the Bay area, as many polished stone axes from Brittany have also been recovered unaccompanied by other items in contexts

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classified here as hoards (Cassen et al., 2013: 929). Similarly, in Ireland and southern Scandinavia copper axes were also deposited like their stone predecessors (Roberts & Frieman, 2015: 720). This suggests that hoarding metal axes before the Middle Bronze Age is a behaviour that cannot be automatically linked to a new economic rationale involving the accumulation and trade of metal, unless the deposition of stone axes was similarly doing this with other materials. This cannot be fully sustained without cross-regional studies of the deposition of Neolithic axes in the Bay of Biscay area. Comparing the biographies of Neolithic axes to those of the Chalcolithic–Early Bronze Age may help us understand why the first metal axes were deposited. Studies focusing on the latter have been conducted in Ireland (Cooney & Mandal, 1998) and Scandinavia (Vandkilde, 1996), suggesting that the role axes played in the earlier Metal Ages was probably similar to that of the Late Neolithic stone axes.

The contemporary Kappa cluster raises a comparable question. Its decorative items, Palmela arrow points, and copper daggers are mostly found in collective burials (50 per cent) throughout the Bay of Biscay area. Despite the lack of in-depth studies, they may potentially have had Neolithic predecessors in stone: lithic blades (whose equivalence to copper daggers in the regions studied has not been proposed before and must therefore be treated with caution), stone arrowheads, and decorative items such as variscite beads have been repeatedly recovered in collective burial in north-western Iberia (Rodríguez Rellan & Fabregas Valcarce, 2011), easternmost Cantabria (Beguiristain Gúrpide, 2011), and Brittany (L'Helgouac'h, 1976: 371). This may indicate that the people depositing the metalwork grouped in the Kappa cluster were following old practices with items made of metal, a tendency trend that has already been identified in south-eastern France (Mille & Carozza 2009: 160–61). Be that as it may, another forty-three per cent of the items in the Kappa cluster comes from hoards. This is a way of depositing arrowheads, blades, and decorative items that, in the quantities identified here, does not seem to have existed at the end of the Neolithic; following old traditions cannot alone account for the deposition of new metal items. Another possibility is that the hoarding of Neolithic items has not been recorded because the casual recovery of stone artefacts, unlike metal objects, is not considered important enough to be reported. In any case, the small metal hoards of the Kappa cluster (containing mostly one to three items) do not seem to indicate a radical transformation by themselves. All in all, the Kappa cluster suggests that things did not change much after metalwork was introduced in the Bay of Biscay area, and this is further supported by the archaeological record of its regions showing no evidence of radical change in the transition to the Chalcolithic (see Supplementary Material 1).

This plausible but hypothetical picture of communities using and depositing metalwork in a way similar to that of the Neolithic changes radically in Brittany and substantially in north-western Iberia during the Early Bronze Age. New weapons, in the form longer blades and halberds, appear alongside new 'precious' decorative items such as the Irish lunulae; the number of single graves also increases greatly. The latter have been interpreted in Brittany (Nicolas et al., 2015: 144) and north-western Iberia (Brandherm, 2007: 77) as indicative of a new class of people more important than the rest. This is clearly linked to models of the Bronze Age European political economy that see it as dominated by chiefs who controlled the flow of copper and other commodities (Earle and Spriggs, 2015: 517–18; Kristiansen

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2015: 1095–96). This has been criticized from the perspective of the single graves from Brittany; its 'lavish' items could have been offerings of other community members (Brück & Fontijn, 2013: 207). In north-western Iberia, people sumptuously buried in single graves may have acted as an embodiment of the community and its values (Bettencourt, 2011: 130). The common issue that underlies these alternative interpretations of single graves is the idea that European Bronze Age societies were not unequal, which represents a main point of disagreement (Fontijn, 2019: 11). 'Unequal' is taken to refer to societies in which individuals are only differentiated by age, gender, and kinship (Ames & Maschner, 2008: 489). The Gamma cluster by itself cannot resolve this issue, but it illustrates that solid multiregional datasets may lead to better informed arguments.

The Gamma cluster shows that what was happening in Brittany and north-west Iberia was not reflected in other regions of the Bay. This indicates that some European Bronze Age societies were more susceptible to changes than others, which has implications for the supporters and detractors of inequality. If chiefs were common in the European Bronze Age, ensuring that they did not come to prominence was equally likely and a major feature of this period. Discussing why chiefs do not appear in some regions (e.g. Araque, 2020) should be as important as addressing the evidence for their existence in others. If inequality was very low, the Gamma cluster points to the importance of explaining why some regions, such as north-western Iberia and Brittany, were changing in similar ways. Interpretations in favour of equality operate almost by default in regional frameworks. Yet, 'luxurious' metalwork and single graves have an extra-regional component that must be addressed. The Gamma cluster, alongside the Chi and Kappa clusters, shows that the European Bronze Age was neither a monolithic entity nor a set of disconnected regions.

The metalwork deposited in the Bay of Biscay area after the Early Bronze Age suggests that two different societies dominated it: one on the French side, represented by the Tau cluster, that was hoarding axes, using spears and bracelets in combination with blades, and engaging in relations with other areas of north-western Europe (Nordez, 2019: 278–79); another in northern Iberia, represented by the Iota cluster, that was indifferent to or disconnected from this way of doing things (Ontañon Peredo, 2013: 225; Parcero Oubiña & Criado, 2013: 262). Thus, while in the Early Bronze Age the outer regions (Brittany and north-western Iberia) and inner regions (central-western France, south-western France, and Cantabria) were connected to each other and established two separate spheres of interaction (outer *vs* inner regions), during the Middle Bronze Age, the French and Iberian regions were linked to each other, thereby establishing two new spheres of interaction (French *vs* Iberian regions).

A potential explanation for the French–Iberian Middle Bronze Age disconnection in the Bay of Biscay area lies in the opening and closing of very important copper mines. Between the Early and Middle Bronze Ages, the mines of El Aramo and El Milagro in Asturias in northern Iberia closed, while an intense mining activity began in Wales around the Great Orme (Blas Cortina, 2011: 109; Williams & Veslud, 2019). Although difficult to quantify, it is possible that during their different periods of exploitation, these mines were among the most important mines in western Europe (O'Brien, 2015: 96, 149). El Aramo and El Milagro's exploitation and closing could explain the disconnection between north-western Iberia and Brittany. Equally, the exploitation of the Great Orme during the

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Middle Bronze Age could partially explain the appearance of the Tau cluster. Unlike northern Iberia, the French regions of the Bay of Biscay would have been part of the network of exchange that also included the Great Orme. This network could have included not only copper, but also types of artefacts and ideas about how to deposit metalwork that would explain the apparent isolation and typological 'archaicity' of the Iota cluster in particular, and of Middle Bronze Age Atlantic Iberia in general. This does not necessarily mean that the latter was in crisis or isolated, it indicates that intentionally or by accident it was not part of the mentality and metalworking traditions that dominated north-western Europe during the Middle Bronze Age.

Conclusion

Apart from a recent article by Callaghan and Scarre (2017; see also Latorre-Ruiz, 2021), the Bay of Biscay area has been largely neglected as an area of study for later prehistoric Europe. This article adds this area to the group of bodies of water articulating interaction in Atlantic Europe at the end of prehistory, alongside the English Channel (Marcigny & Ghesquière, 2003), the North Sea (Van de Noort, 2006), and the Irish Sea (Waddell, 1992). It is offered against the background of major opportunities in the study of prehistoric Europe created by the so-called third science revolution in archaeology, including palaeogenetic research (Kristiansen, 2022). Holistic metalwork studies focusing on multiple regions, all categories of artefacts, and all types of sites have the potential to help contextualize these new enquiries. Together with analyses of the materials, examinations of use-wear, and clustering techniques, they can rejuvenate the old sub-discipline of metalwork studies.

This article has also shown how multivariate clustering techniques such as LCA can be used to find patterns in archaeological datasets. It helps to synthesize large datasets into approachable or 'digestible' clusters of information, although it is important to remember that statistics is just a discipline for 'producing convenient summaries of data' (Hand, 2008: 3). This article has highlighted major variations between regions, and only after these are understood can minor patterns become apparent.

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Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/eaa.2023.41.

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Biographical Note

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Relations entre le nord de l'Ibérie et l'ouest de la France (2900-1100 av. J.-C.) : le flux des objets en métal dans le Golfe de Gascogne groupés par l'analyse multivariée

Dans cet article, l'auteur examine les relations entre le nord de l'Ibérie et l'ouest de la France autour du Golfe de Gascogne pendant le Chalcolithique, le Bronze ancien et le Bronze moyen par l'analyse multivariée de 1273 ensembles contenant 4554 objets en métal. Il identifie cinq groupes multirégionaux caractérisés par leur distribution, leur chronologie, leur contenu et leur contexte. Les variations dans l'espace et le temps indiquent que les objets en métal provenant de régions lointaines avaient été déposés de façon semblable reflétant les transformations au sein des relations interrégionales. Les changements de contenu et de contexte laissent penser à des transformations sociales. L'auteur présente la méthode d'analyse multivariée dite Latent Class Analysis (LCA) *dans l'espoir qu'elle soit utilisée dans l'étude d'autres ensembles de données à travers le monde.* Translation by Madeleine Hummler

Mots-clés: âge du Bronze, Chalcolithique, Golfe de Gascogne, Europe atlantique, objets en métal, analyse multivariée

Zusammenhänge zwischen Nordiberien und Westfrankreich (2900–1100 v. Chr.): Der Fluss der Metallobjekte im Golf von Biskaya durch multivariate Analyse modelliert

Die Zusammenhänge in der Biskaya zwischen Nordiberien und Westfrankreich während der Kupferzeit und Früh- und Mittelbronzezeit werden hier mittels einer Analyse von 1273 Funden, welche 4554 Metallgegenstände enthielten, untersucht. Diese wurden in fünf multiregionalen Gruppen mit unterschiedlichen Verbreitungen, Chronologien, Inhalte und Kontexten gegliedert. Veränderungen in ihrer Chronologie und Verbreitung zeigen, dass Metallobjekte aus weit entfernten Gebieten auf *ähnlicher Weise deponiert wurden, welche auf verschiedene interregionale Verbindungen deuten. Veränderungen in Kontext und Inhalt weisen auf sozialer Wandel. Die sogenannte* Latent Class Analysis (LCA) *clusteranalytische Methode wird hier beschrieben, in der Hoffnung, dass sie Anwendung in der Untersuchung von Befunden aus anderen Gegenden der Welt findet.* Translation by Madeleine Hummler

Stichworte: Bronzezeit, Kupferzeit, Golf von Biskaya, atlantisches Europa, Metallgegenstände, Clusteranalyse