Exploring the composition of lithic assemblages in Mesolithic south-eastern Norway

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1 Introduction

This study employs multivariate exploratory statistics to analyse lithic assemblages associated with a larger number of Mesolithic sites located in south-eastern Norway. This is done to identify latent patterns and structure in the relationship between the assemblages, with the ultimate aim of identifying behaviourally induced variation in their composition across time. However, the composition of the assemblages can be expected to be determined by a multitude of factors (e.g. Dibble et al., 2017; Rezek et al., 2020), ranging from the impact of natural formation processes, to various and intermixed behavioural aspects such as purpose, duration, frequency and group sizes at visits to the sites. The assemblages are also likely to be impacted by variation in lithic technology, artefact function, use-life and discard patterns, as well as procurement strategies and access to raw materials. Finally, analytic and methodological dimensions relating to survey, excavation and classification practices are also fundamental to how the assemblages are defined. Consequently, the analysis conducted here is done from an exploratory perspective, where all of these factors should be seen as potential contributors to any observed pattern. In an attempt to limit the influence of some potentially confounding effects, the material chosen for analysis has a constrained geographical distribution, and stems from recent investigations that have employed comparable methods for excavation and classification within larger unified projects.

Even though each individual assemblage can have been impacted by an virtual infinitude of effects that might skew an archaeological interpretation, this does not preclude the applicability of inductive analyses aimed at revealing overarching structure in the data without imposing overly complex analytical frameworks that attempt to account for these particularities (Bevan, 2015). Structure that can be revealed from considering all of the assemblages in aggregate can constitute a step in an iterative analytical chain that ultimately aims to tease apart the multitude of factors that have shaped the composition of the assemblages, and should be of value to subsequent in-depth studies of any individual site. The most immediate danger of the approach outlined here is rather to be overly naive in the causal significance and cultural importance that is ascribed to any identified pattern. As such, the main aim of this analysis is to compare the results with findings reported in previous literature concerned with the Mesolithic in southern Norway and have the generation of new hypotheses as a possible outcome. To this end, the analysis follows two analytical avenues. The first involves an analysis of the assemblages using the classification of the artefacts done for the original excavation reports. The second involves an analysis of the assemblages in light of the so-called whole assemblage behavioural index (e.g. Clark and Barton, 2017), which has been employed in other contexts to align properties of the assemblages with land-use and mobility patterns.

2 Archaeological context and material

The 54 coastal sites chosen for analysis here have a relatively limited geographical distribution in south-eastern Norway (Figure 1A). The sites were excavated as part of four larger excavation projects that all took place within the last 15 years (Jaksland and Persson, 2014; Melvold and Persson, 2014; Reitan and Persson, 2014; Solheim, 2017a; Solheim and Damlien, 2013). The sites included in the analysis consist of all Mesolithic sites excavated in conjunction with the projects that have assemblages holding more than 100 artefacts. The institution responsible for these excavations was the Museum of Cultural History in Oslo. This has led to a considerable overlap in the archaeological personnel involved, and comparable excavation practices across the excavations. Furthermore, with these projects, major efforts were made to standardise how lithic artefacts were to be classified at the museum (Koxvold and Fossum, 2017; Melvold et al., 2014). As a result, this should reduce the amount of artificial patterning in the data incurred by discrepancies in the employed systems for categorisation (e.g. Clark and Riel-Salvatore, 2006; Dibble et al., 2017). In this setting, for example, bias could potentially follow from the fact that two of the projects have sites with relatively contemporaneous dates (Jaksland, 2014; Solheim and Damlien, 2013, see also Figure 1B). Any project-dependent classification practice could as a consequence lead to an exaggeration of chronological differences between the assemblages. While this is difficult to fully account for, I do believe that the relative contemporaneity of the excavation projects, as well as the overlap in excavation and classification practices should minimise the above-mentioned effects.

A defining characteristic of the Norwegian Mesolithic is that a clear majority of the known sites are located in coastal areas (e.g. Bjerck, 2008). Furthermore, these coastal sites appear to predominantly have been located on or close to the contemporary shoreline when they were in use (e.g. Åstveit, 2018; Breivik et al., 2018; Solheim et al., 2020). In south-eastern Norway, this pattern is combined with a continuous regression of the shoreline, following from isostatic rebound (Romundset et al., 2018; e.g. Sørensen, 1979). The fairly rapid shoreline displacement means that the sites tend not to have retained their strategic or ecologically beneficial shore-bound location for long periods of time (cf. Perreault, 2019, p. 47). Consequently, the shore-bound settlement, combined with the rapid shoreline displacement has resulted in a relatively high degree of spatial separation of cumulative palimpsests, to follow the terminology of Bailey (2007), while the reconstruction of the trajectory of relative sea-level change allows for a relatively good control of when these accumulation events occurred. In other parts of the world, a higher degree of spatial distribution means that while the physical separation of material can help delineate discrete events, this typically comes at the cost of losing temporal resolution as any stratigraphic relationship between the events is lost (Bailey, 2007). However, as the rate of isostatic rebound has varied throughout the Mesolithic in the region, and local topography and bathymetry will have impacted how rapidly a site lost its shore-bound location, this effect is not evenly distributed in time and space. In the earliest part of the Mesolithic, the displacement rate within the study area would have been around as much as 8.8 cm/year, falling to around 0.5 cm/year towards the end of the Mesolithic (Sørensen et al., 2014). Thus, while relative sea-level change appears to have reduced the degree of mixing that has occurred in the assemblages, it is worth bearing in mind that this could vary depending on when and where they were in use, potentially reducing the degree to which their composition can be directly compared.

The 54 sites analysed here have been dated by reference to relative sea-level change, typology and/or radiocarbon dates (Table 1). Date ranges for sites based on shoreline displacement and typology are taken from the original reports and follow the evaluation done by the original excavators. Where radiocarbon age determinations believed to be associated with the lithic material are available, these have been calibrated using the IntCal20 calibration curve (Reimer et al., 2020) and subjected to Bayesian modelling using OxCal v4.4.4 (Bronk Ramsey, 2009) through the oxcAAR package (Hinz et al., 2021) for R (R Core Team, 2020). The only constraint imposed for the modelling of the dates was that the dates from each site are assumed to represent a related group of events through the application of the Boundary function (Bronk Ramsey, 2021). The resulting posterior density estimates were then summed for each site. Radiocarbon data is provided in the supplementary data, and has also been collated and reported by Solheim (2020).

The lithic data analysed here is based on the classification of the site assemblages done for the original excavation reports, and consists of 48 variables representing different debitage and tool types. While the

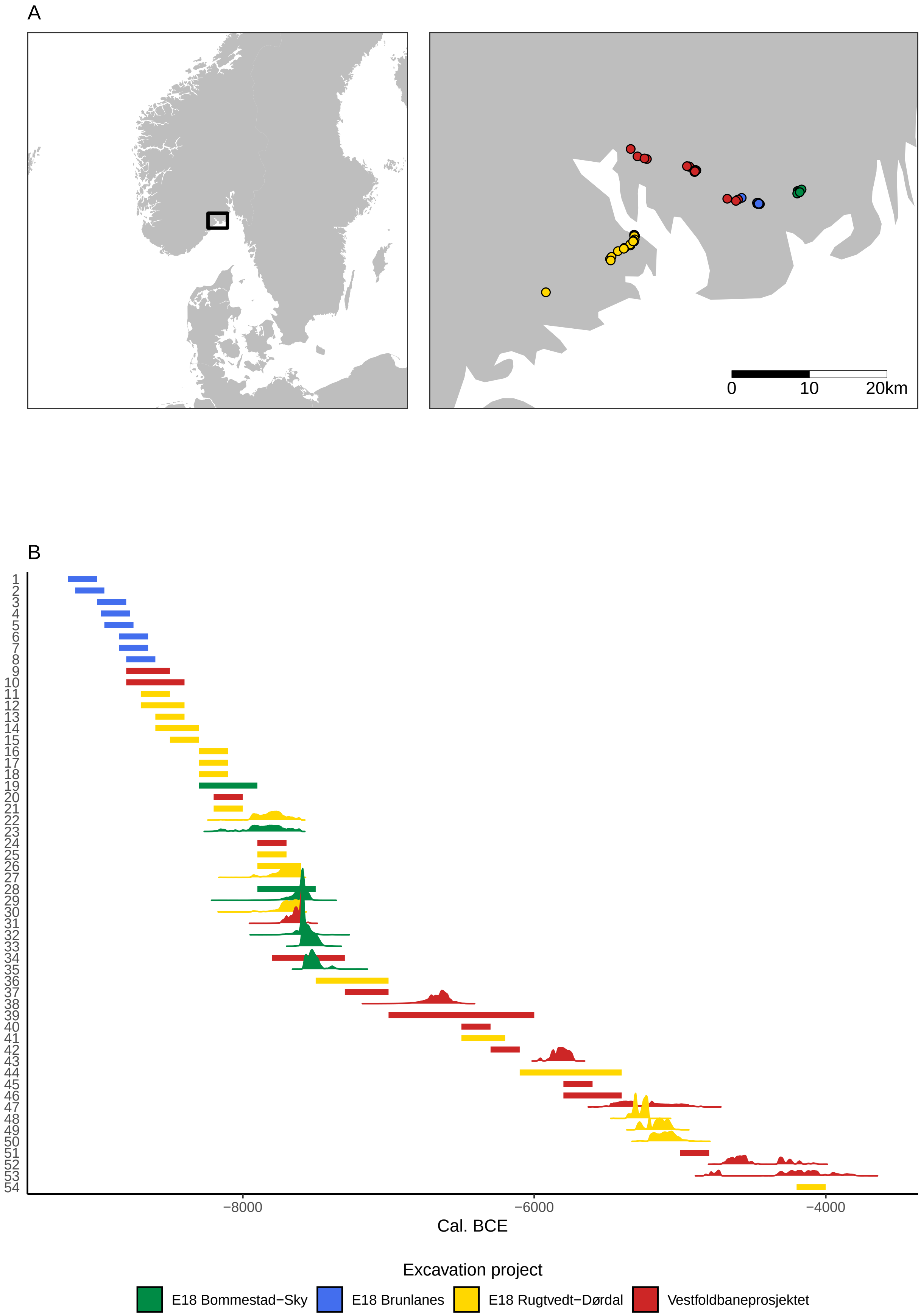

Figure 1: A) Spatial and B) temporal distribution of the sites chosen for analysis. Radiocarbon age determinations are given as the sum of the posterior density esimates. Solid lines indicate that the site has been dated with reference to relative sea-level change and typological indicators. These follow the original reports.

classification practices for the excavation projects were standardised to an extent, there are some instances where time was allocated to identify additional artefact sub-categories aimed at answering specific research questions. Some categories in the original reports have therefore been combined in the dataset. This for example pertains to the category narrow-blades, which is defined as blades of width between 8 and 12 mm. In the reports, this was only separated from (macro-)blades (width $\geq$ 12 mm) and micro-blades (width $\leq$ 8 mm) for some of the sites. Narrow-blades were combined with the blade category here. Furthermore, the artefact data have here been divided into flint and non-flint materials. Flint does not occur indigenously in Norway, and is only available locally as nodules that have been transported and deposited by retreating and drifting ice (e.g. Berg-Hansen, 1999). This means that the distribution and quality of flint has been impacted by a diverse set of factors relating to climatic and geographical factors such as, but not limited to, topographic variability, shoreline morphology and ocean currents (Eigeland, 2015, p. 46). Thus, while flint is treated as a unified category here, the variability in quality could have been substantial (Eigeland, 2015, pp. 45–53). Furthermore, the various non-flint raw materials that have been lumped together have quite disparate properties, where fine-grained cryptocrystalline materials are often used as a substitute or supplement to flint, while other, coarser materials are usually associated with the production of axes and other macro tools. Given this differentiated use, these raw-material properties are expected to be reflected in the retained debitage and tool categories. An important benefit of combining all of the non-flint materials is that this reduces the dependency on whether or not these have been correctly and consistently categorised for the reports (cf. Frivoll, 2017). While certainly a topic deserving of more attention, the general sentiment in the literature is that there would have been stable access to locally available non-flint raw-materials of good quality in south-eastern Norway (Eigeland, 2015, p. 370; e.g. Glørstad, 2011). Finally, while factors such as landscape changes through shoreline displacement can have led to variable raw-material availability at the analysed sites, the relatively constrained geographical distribution of the sites hopefully counteracts some non-behavioural sources of variation.

Studies concerned with chronological changes in the composition of lithic assemblages in southern Norway have typically had a focus on morphological variation among artefacts (e.g. Ballin, 1999; Bjerck, 1986; Reitan, 2016) or been concerned with technological processes associated with certain sub-categories of the site inventories, such as the production of blades or axes (e.g. Berg-Hansen, 2017; Damlien, 2016; Eymundsson et al., 2018; Solheim et al., 2020). Studies that have involved entire assemblages have either been concerned with general compositional traits such as relative frequency of various tool types and raw-materials (Breivik, 2020; Breivik and Callanan, 2016; Reitan, 2016; Viken, 2018), or involved extremely in-depth studies of technological organisation associated with a handful of assemblages (Eigeland, 2015; Mansrud and Eymundsson, 2016). These studies are, however, based on narratively driven methods, leaving the weighting of the different variables for the final interpretations unclear. To my knowledege, only a single study dealing with the composition of Mesolithic assemblages in southern Norway has involved the use of a multivariate quantitative framework, which was employed to structure the analysis of eight Middle Mesolithic assemblages (Solheim, 2013; see Glørstad, 2010, pp. 145–146 for a spatial application). In sum then, previous studies have typically either been limited to a small number of sites, to a subset of the inventories, to morphological characteristics, or to subjectively and narratively driven methods that are difficult to scale and consistently balance in the comparison of a larger number of artefact categories and assemblages.

Table 1. Analysed sites.

no	Site name	Dating method	Reported start (BCE)	Reported end (BCE)
1	Pauler 1	Shoreline/typology	9200	9000
2	Pauler 2	Shoreline/typology	9150	8950
3	Pauler 3	Shoreline/typology	9000	8800
4	Pauler 5	Shoreline/typology	8975	8775
5	Pauler 4	Shoreline/typology	8950	8750
6	Pauler 6	Shoreline/typology	8850	8650
7	Bakke	Shoreline/typology	8850	8650
8	Pauler 7	Shoreline/typology	8800	8600
9	Nedre Hobekk 2	Shoreline/typology	8800	8500
10	Solum 1	Shoreline/typology	8800	8400

11	Tinderholt 3	Shoreline/typology	8700	8500
12	Tinderholt 2	Shoreline/typology	8700	8400
13	Dørdal	Shoreline/typology	8600	8400
14	Tinderholt 1	Shoreline/typology	8600	8300
15	Skeid	Shoreline/typology	8500	8300
16	Hydal 3	Shoreline/typology	8300	8100
17	Hydal 4	Shoreline/typology	8300	8100
18	Hydal 7	Shoreline/typology	8300	8100
19	Hovland 2	Shoreline/typology	8300	7900
20	Nedre Hobekk 3	Shoreline/typology	8200	8000
21	Hydal 8	Shoreline/typology	8200	8000
22	Hegna vest 1	Radiocarbon	8000	7800
23	Hovland 5	Radiocarbon	8000	7700
24	Sundsaasen 1	Shoreline/typology	7900	7700
25	Hegna øst 6	Shoreline/typology	7900	7700
26	Hegna vest 4	Shoreline/typology	7900	7600
27	Hegna vest 2	Radiocarbon	7900	7550
28	Nordby 2	Shoreline/typology	7900	7500
29	Hovland 4	Radiocarbon	7900	7500
30	Hegna vest 3	Radiocarbon	7800	7600
31	Prestemoen 1	Radiocarbon	7700	7600
32	Hovland 1	Radiocarbon	7700	7400
33	Hovland 3	Radiocarbon	7650	7450
34	Gunnarsrød 7	Shoreline/typology	7800	7300
35	Torstvet	Radiocarbon	7500	7100
36	Hegna øst 5	Shoreline/typology	7500	7000
37	Gunnarsrød 8	Shoreline/typology	7300	7000
38	Langangen Vestgård 1	Radiocarbon	6800	6600
39	Gunnarsrød 2	Shoreline/typology	7000	6000
40	Gunnarsrød 6b	Shoreline/typology	6500	6300
41	Hegna øst 7	Shoreline/typology	6500	6200
42	Gunnarsrød 6a	Shoreline/typology	6300	6100
43	Gunnarsrød 4	Radiocarbon	6000	5800
44	Stokke/Polland 3	Shoreline/typology	6100	5400
45	Gunnarsrød 10	Shoreline/typology	5800	5600
46	Langangen Vestgård 2	Shoreline/typology	5800	5400
47	Vallermyrene 4	Radiocarbon	5500	5200
48	Hegna øst 2	Radiocarbon	5350	5200
49	Stokke/Polland 8	Radiocarbon	5300	5200
50	Stokke/Polland 5	Radiocarbon	5300	5000
51	Prestemoen 2	Shoreline/typology	5000	4800
52	Vallermyrene 1	Radiocarbon	4700	4100
53	Langangen Vestgård 3	Radiocarbon	4350	4000
54	Stokke/Polland 9	Shoreline/typology	4200	4000

3 Methodology

The relatively constrained geographical distribution of the analysed sites, the limited temporal range over which they where investigated, as well as the methodological equivalency across excavation projects hopefully leads to an exclusion of some biases that might otherwise skew an exploratory analysis, rendering it more likely that behaviourally meaningful patterns are identified. However, the exploratory perspective means that a wide range of combinations and transformations of variables has been explored to identify patterning in the data. While only parts of this process can sensibly be reported here, the data and employed R programming script is freely available as a research compendium following Marwick et al. (2018), allowing readers to explore and scrutinise the data and the final analytical choices made (Marwick, 2017). However, this inductive data-dredging or pattern searching approach does constitute a limited inferential framework (Clark, 2009), as it involves a post hoc accommodation of explanations to meet the observed data — data that is both selectively and subjectively reported upon. The process can still provide the identification of empirical patterns with respects to the employed units of analysis, which in turn can form the basis for social and behavioural hypotheses. This can lay the foundation for a deductive research agenda with targeted model evaluation for which clear test implications can be derived (Clark, 2009, p. 29).

The first part of the analysis involves employing the method of correspondence analysis (CA), using the lithic count data as classified for the original excavation reports. The purpose of this exercise is to evaluate the degree to which the composition of the assemblages align with patterns that have been suggested by earlier studies — studies that have employed more informally driven methods. This consequently assumes that the artefact categories employed in Norwegian Stone Age archaeology are, at least to a certain extent, behaviourally meaningful. However, the approach taken is also partially informed by the so-called Frison effect (Jelinek, 1976), which pertains to the fact that lithics studied by archaeologists can have had long and complex use-lives in which they took on a multitude of different shapes before they were ultimately discarded. Several scholars have built on this to argue that morphological variation in retouched lithics from the Paleolithic cannot be assumed to predominantly be the result of the intention of the original knapper to reach some desired end-product, but rather that what is commonly categorised as discrete types of artefacts by archaeologists can instead in large part be related to variable degrees of modification through use and rejuvenation (e.g. Barton, 1991; Barton and Clark, 2021; Dibble, 1995). Consequently, several artefact categories have here been collapsed for the CA. This for example pertains to tool types such as scrapers, burins, drills, knives and otherwise indeterminate artefacts with retouch. That these categories are internally consistent and categorically exclusive in terms of fulfilled purpose is at best a dubious proposition, in turn potentially rendering their contribution as discrete analytic units misleading. These have all been combined into the single category "small flint tools." (A full overview of the aggregated variables and their constituent parts is provided in the supplementary material). While aggregating artefact categories in this manner could potentially subsume important variation, it does also reduce the possibility that any conclusions are not simply the result of employing erroneous units of analysis. An underlying assumption is therefore effectively that the retained categories represent artefact categories that have fulfilled different purposes or are related to different technological processes. While largely intuitive in nature, it does seem reasonable to assume that for example large non-flint stone tools such as axes, adzes, chisels, clubs and hatches, here categorised as non-flint macro tools, have fulfilled different purposes than the previously mentioned small flint tools.

However, for the most part we lack even a most basic understanding of what any individual lithic object in an assemblage has been used for (Dibble et al., 2017). For example, a vast amount of artefacts defined as debitage are likely to have fulfilled the function of tools, and both debitage and formal tool types could have had various different purposes and had a multitude of shapes throughout their use-life. While use-wear analysis could potentially offer a way to identify what artefacts were used for towards the end of their use-life, these kinds of analyses are extremely time-consuming and are therefore typically only conducted on a smaller number of artefacts that have already been selected for analysis based on their shape (e.g. Solheim et al., 2018). Thus, while these analyses can potentially get at in-group variation pertaining to the end-state of a group of artefacts, they do not tell us whether or not their classification as a unified group is meaningful in the first place (Dibble et al., 2017). This has major implications that the above-outlined analysis does not take properly into account, rendering it difficult to align any identified pattern with specific behavioural dimensions. As a consequence, the second part of the analysis employs a suite of measures developed for the classification of lithic assemblages with these inferential limitations in mind (see Barton et al., 2011; Clark and Barton, 2017, and below). The logic behind these measures are founded on an understanding of technology as being organised along a continuum ranging between curated and expedient (Binford, 1979, 1973; **binford1977?**). An expedient technological organisation pertains to the situational production of tools to meet immediate needs, with little investment of time and resources in modification and rejuvination, resulting in high rates of tool replacement. Curated technological organisation, on the other hand, has been defined as related to manufacture and maintenance of tools in anticipation of future use, the transport of these artefacts between places of use, and the modification and rejuvenation of artefacts for different and changing situations.

However, following not least from the ambiguous definition first put forward by Binford (1973), the theoretical definition of curation, its archaeological correlates, and behavioural implications have been widely discussed and disputed, and no single definition has ever been reached (e.g. Bamforth, 1986; Nash, 1996; Shott, 1996; Surovell, 2009, pp. 9–13). The continuum between curated and expedient technology has for example been related to dimensions such as land-use and mobility strategies and raw-material quality and availability (e.g. Andrefsky, 1994; Clark and Barton, 2017; Kuhn, 1992; Parry and Kelly, 1987; Smith, 2015). Still, that the distinction can offer a useful analytical point of departure if clearly and explicitly operationalised seems more or less agreed upon, and some dimensions of the concept are generally accepted. For example, although precisely how it is measured may vary, the empirical correspondent to a curated technological organisation is typically defined by high degrees of retouch, as this is commonly seen as a means of realising the potential utility of a tool — or extending its use-life — by the repeated rejuvenation and modification of edges (e.g. Bamforth, 1986; Dibble, 1995; Shott and Sillitoe, 2005).

Furthermore, one concrete operationalisation of the terms have been forwarded by Barton (1998) and collegues (Barton et al., 2013, 2011, e.g. 1999; Barton and Riel-Salvatore, 2014; Clark and Barton, 2017; Riel-Salvatore and Barton, 2007; Riel-Salvatore and Barton, 2004; Villaverde et al., 1998), who through a series of studies have shown that the relationship between volumetric density of lithics and relative frequency of retouched artefacts in lithic assemblages have a consistent negative relationship across a wide range of chronological and cultural context, ranging from Pleistocene and Holocene assemblages in Europe and Asia, to assemblages associated with both Neanderthals and modern humans (Barton et al., 2011; Kuhn and Clark, 2015; Riel-Salvatore et al., 2008). This relationship is taken to reflect degree of curation, and is in turn mainly to follow from the accumulated nature of land-use and mobility patterns associated with the assemblages (Barton and Riel-Salvatore, 2014). In this model, higher degree of mobility would mean a higher dependency on the artefacts and the material people could bring with them, and dimensions such as weight, reliability, repairability, and the degree to which artefacts could be manipulated to fulfil a wide range of tasks are therefore assumed to have been factors of concern. From this it follows that the empirical expectation for short-term camps is a curated technological organisation with higher relative frequency of retouched artefacts, and a lower overall density of lithics (Clark and Barton, 2017). More time spent in a single location, on the other hand, is assumed to lead to better control of raw-material availability and to allow for its accumulation. This should in turn lead to a more expedient technological organisation with reduced necessity for the conservation of lithics and extensive use of retouch. The empirical expectation for lower degree of mobility is therefore relatively high density of lithics, a low relative frequency of retouched artefacts, as well as a higher number of cores and unretouched flakes and blades. These variables and underlying logic constitute what has been termed the whole assemblage behavioural index (WABI, Clark and Barton, 2017), and is the main framework adopted here.

However, as these measures are argued to predominantly be determined by land-use and mobility patterns, relative frequency of chips and relative frequency of non-flint material are also included in the analysis as these measures have also been linked to mobility patterns and is of central importance in Norwegian Stone Age archaeology (Bicho and Cascalheira, 2020; e.g. Breivik et al., 2016; Kitchel et al., 2021; Reitan, 2016) — the use of local non-flint material has been taken to indicate reduced mobility and increased familiarity with local surroundings (Glørstad, 2010, p. 181; Jaksland, 2001, p. 112). In sum, the variables employed in the analysis are relative frequency of secondarily worked lithics (RFSL), defined as the number of retouched or ground lithics divided by the assemblage total; volumetric density of lithics (VDL), defined as number of artefacts per excavated m^3; relative frequency of chips, defined as the proportion of artefacts with size < 0.1 cm; relative frequency of cores, simply the proportion of all artefacts classified as cores in the original reports; relative frequency blanks, here defined as the proportion of all artefacts classified as flakes, blades, micro-blades or fragments; and finally relative frequency of non-flint material. Following (Bicho and Cascalheira, 2020) the analysis is done using principal components analysis (PCA), leading to a shift in focus from the relative (cf. Baxter, 1994, p. 100).

A note should also be made on the fact that a few variables that are sometimes invoked for the classification of sites in terms of associated mobility patterns are omitted here (Bicho and Cascalheira, 2020; e.g. Breivik and Callanan, 2016). For the assemblage data itself this especially pertains to diversity in tool-types (see also Canessa, 2021), which has been omitted in light of the previously mentioned Frison effect. Some site specific aspects such as number of features has also been disregarded as taphonomic loss is likely to have led to a chronological bias in their preservation. Similarly, the number of activity areas, effectively number of artefact clusters, however defined, has also been disregarded. This follows most notably from the fact that the impact of post-depositional processes at Stone Age sites in Norway is arguably understudied (Jørgensen, 2017). This pertains for example to the impact of bio-turbation in the form of three-throws, which can have a detrimental effect on the original distribution of artefacts, and which can be expected to have been relatively frequent on several of the sites treated here (Darmark, 2018; Jørgensen, 2017).

4 Results

Figure 2 displays the CA using the lithic count data. The general impression from the plots is that a chronological dimension is associated with the patterning in the data. This is indicated by the general transition across the colour scale in the row plot (Figure 2A), combined with the fact that the two first dimensions of the CA accounts for as much as 80.53 % of the inertia or variance in the data, as well as the horseshoe curve or Guttman effect evident in the column plot (see Baxter, 1994, pp. 119–120). The earliest sites tend to be located in the upper left corner of plot A, with increasingly younger sites towards the bottom along the second dimension. Although fewer in number, the sites from the later parts of the Mesolithic are drawn out along the first dimension of the plot, and are not as impacted by the second dimension as the more numerous older sites.

The column plot (Figure 2B) reveals that the earliest sites are characterised by the flint artefact categories microburins, projectiles, as well as flint macro tools and associated debitage. It is also interesting that these sites to a larger extent are characterised by core fragments, both in flint and non-flint materials, rather than the cores themselves. The non-flint material on the earliest, or among the earliest sites, appears to be centred around the production of projectiles, as both the projectiles themselves and non-flint blades are important constituents of the assemblages at these sites. Site number 9, Nedre Hobekk 2, located in the upper right quadrant of the row plot represents a somewhat curious case in that its assemblage is dominated by axe production in metarhyolite (Eigeland, 2014). However, as the site had been quite heavily impacted by modern disturbances, this led Eigeland (2014, p. 124) to suggest that the material might have been compromised. This could explain its position as an outlier in the plot. The use of metarhyolite for the production of axes is present at other contemporary sites as well, but is evidently not as prominent a part of these assemblages (Jaksland and Fossum, 2014). In sum, the findings for the earliest sites are in large part in line with previous research (Breivik et al., 2018; Damlien and Solheim, 2018; e.g. Jaksland and Fossum, 2014).

The first dimension, which is pulling some of the later sites towards the right of the plot, is mainly defined by macro tools and associated debitage in non-flint materials that are negatively correlated with more flint dominated assemblages. Sites with high values on the first dimensions are later Mesolithic sites associated with axe production in non-flint materials, but the later sites occur along the entire dimension, indicating that while these axe production sites are a feature of the later Mesolithic, there is marked variation among the sites. Although the sample size is quite strained and the discussion of finer chronological points might not be warranted, the first dimension does appear to be of of less importance for the absolute latest sites, as indicated by their location to the left of the plot. This could indicate that specialised axe production sites disappear towards the end of the Mesolithic, a notion that would be in line with previous research (e.g. Eigeland, 2015, p. 370; Glørstad, 2011; Reitan, 2016).

As most of the variation in the data is accounted for by the dominating non-flint material in later assemblages, this suppresses and makes it difficult to discern patterns in the flint data. A second CA was therefore run excluding the non-flint material (Figure 3). While not as substantial, there is clear temporal patterning in the flint data as well. This is most marked for the very earliest sites which are pulled away from the main cluster, as projectiles, microburins, macro tools, debitage from their production, and flakes characterises these sites. Slightly younger sites appear more impacted by core fragments and blades. The temporal transition in the main cluster is not as marked, but clearly present, and is driven by a larger proportion of blades, flakes and small tools in the earliest assemblages of the cluster, which is opposed to chips, fragments and partly micro-blades. Apart from the impact of core fragments, this must be considered very much in agreement with previous research (e.g. Solheim, 2017b, with references). The comparatively limited impact of the flint material can possibly be the result of the aggregation of categories that leads to an suppression of otherwise temporally distinct patterns, and there are technological nuances in the flint material that is temporally contingent but not recorded during a regular classification of the material (e.g. Damlien, 2016; Eigeland, 2015; Solheim et al., 2020) . However, while the former pertains to the analytical trade-off between robustness and sensitivity, the latter is likely to be true for the non-flint material as well (Eigeland, 2007). The overall pattern does speak to the impact the properties of the raw-material has for the general composition of the assemblages (cf. Manninen and Knutsson, 2014).

Moving on to the PCA of measures that have been linked to mobility, some of the variables with severely skewed distributions were initially transformed. These are displayed in the correlation matrix in in Figure 4. Figure 5 displays the resulting PCA. There is a general temporal transition from older to younger sites from the upper left to the bottom right of the plot. The second dimension is mainly defined by a negative correlation between the VDL and RFSL (Figure 6). Almost orthogonal to this is the strong negative correlation between relative frequency of chips and blanks. While there is a slight tendency for blanks to be more associated with younger sites, frequency of chips appears to be largely independent of time. However, the almost suspiciously strong negative correlation between chips and blanks can perhaps have a practical explanation. Seeing as the frequency of non-flint material is positively correlated with blanks and negatively correlated with chips (Figure 4), one explanation to this pattern could be that smaller non-flint pieces are simply more difficult to identify and separate from naturally fragmented stone during excavation and classification. This could conceivably have led to an over-representation of blanks as compared to chips in assemblages with a high proportion of non-flint material. While this is not necessarily the entire explanation behind the relationship, this does make it difficult to place much analytical weight on this pattern. Relative frequency of cores is not especially impactful in the PCA, and appears to be independent the temporal dimension as well. That is not to say that cores may not be indicative or related to mobility patterns, but to get at this may require further analysis beyond their simple classification as cores (Kitchel et al., 2021).

Thus, while some secondary expectations of the WABI does not seem to apply to the present material, it is difficult to say to what degree this is caused by idiosyncrasies in the Norwegian system for classification of lithics and properties of the lithic material itself. The relationship between VDL and RFSL does correspond to the model and follows a clear temporal trend that is also correlated with the increased use of local raw material. Thus, if the relationship between VDL and RFSL is accepted as a proxy for curation, and is related to land-use and mobility patterns, these findings would be in line with previous research into the Mesolithic of Norway, indicating that earlier sites are associated with higher degree of mobility than sites from later phases (e.g. Bergsvik, 2001; Bjerck, 2008; Glørstad, 2010; Jaksland, 2001). To explore this proposition further, these two variables are subjected to more detailed scrutiny below.

Figure 7A illustrates the negative correlation between the two variables (r = -0.5) while also displaying a general tendency for younger sites to be associated with a higher volumetric density of lithics and a lower relative frequency of secondarily worked lithics than older sites. The linear correlation is stronger between the mean site age and RFSL (r = -0.51), than between mean site age and VDL (r = 0.22). As variable non-flint availability and workability has also been suggested to potentially impact these measures (Manninen and Knutsson, 2014), Figure 7B displays the same relationship, but exclusively for the flint data. While the negative correlation is slightly less marked when only the flint data is considered (r = -0.4), the general pattern is the same. The relationship between mean site age and relative frequency of secondarily worked flint is even stronger (r = -0.57), but as indicated by the more spread out distribution along the x-axis, the volumetric density of flint is not temporally contingent (r = 0.1). As was also indicated by the CA, this follows from the fact that non-flint materials make up a higher share of the assemblages for some of the later Mesolithic sites, and is a point returned to below where the temporal dimension of the relationship between VDL and RFSL is explored further.

To get more directly at this temporal trend, a curation index based on VDL and RFSL was devised by first performing a min-max normalisation of the two variables, scaling them to take on values between 0 and 1. The values for artefact density was then made negative to reflect its relationship with degree of curation. The

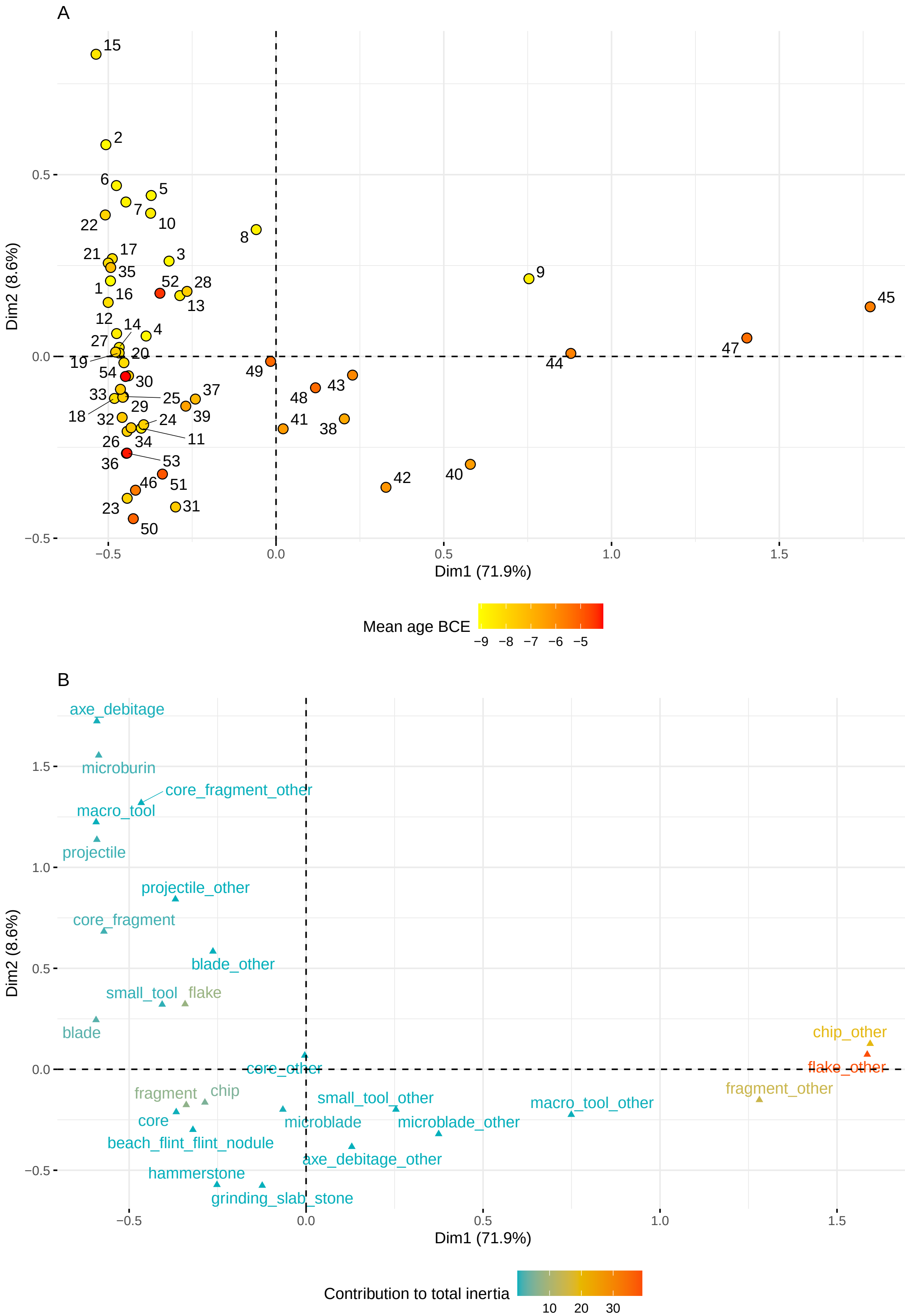

Figure 2: Correspondence analysis using the artefact count data. A) Row plot, B) Column plot.

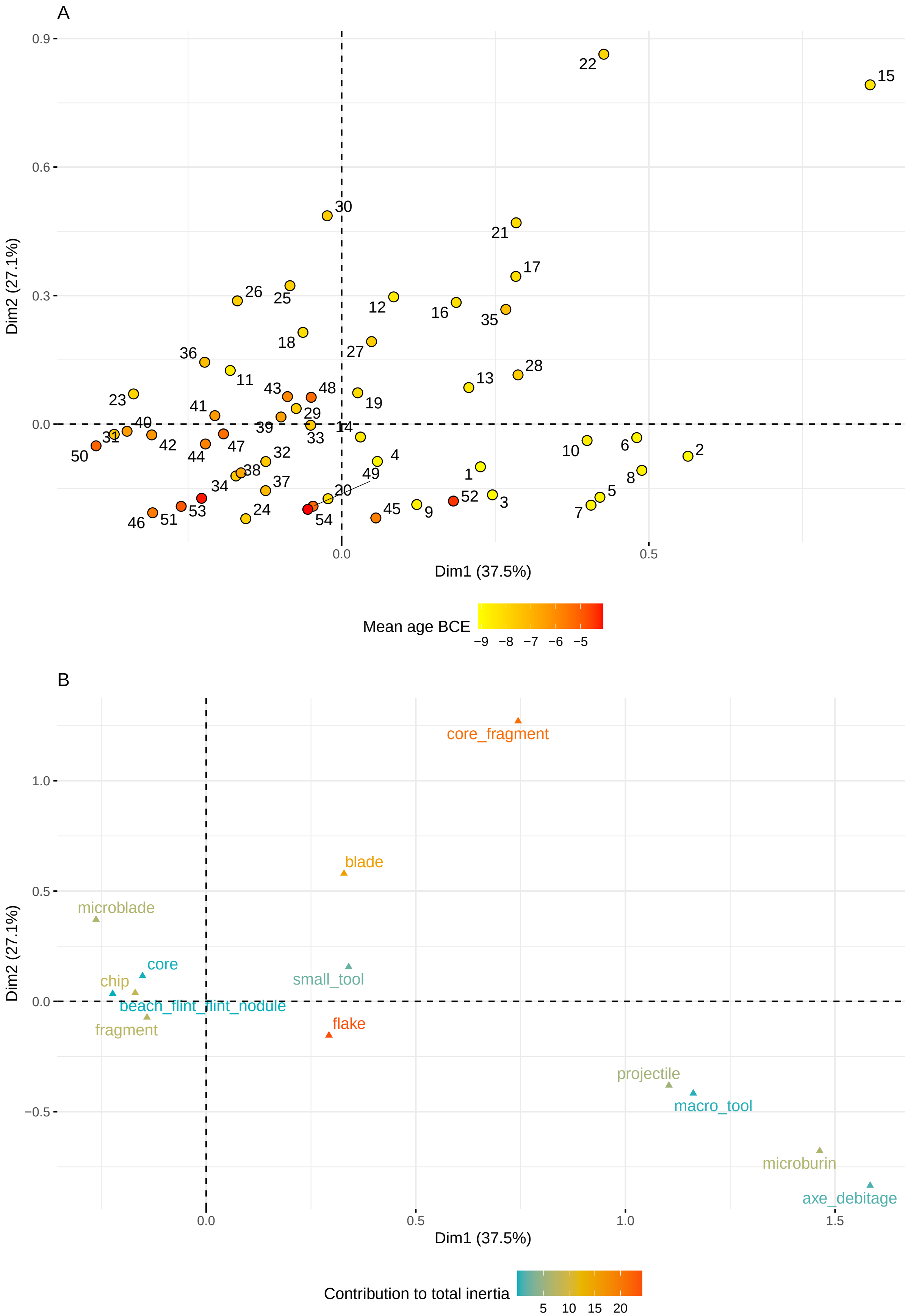

Figure 3: Correspondence analysis using the flint data. A) Row plot, B) Column plot.

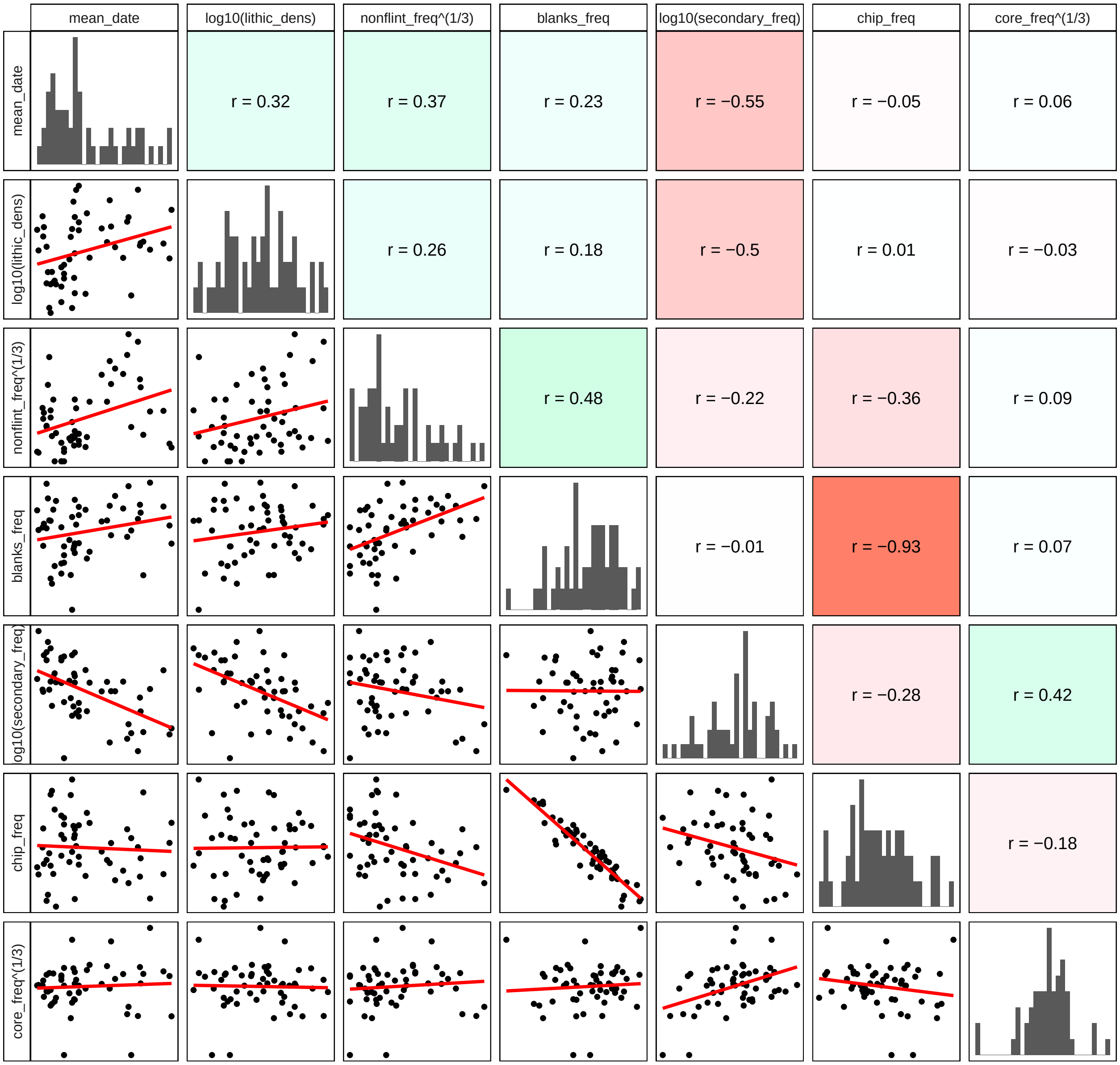

Figure 4: Correlation matrix showing transformation of skewed variables for the PCA. The mean age of the sites has also been included to visualise overall temporal trends. Cells below the diagonal display the bivariate distributions with a fitted OLS-regression. The cells above the diagonal display and are coloured by the corresponding Pearsons correlation coefficient.

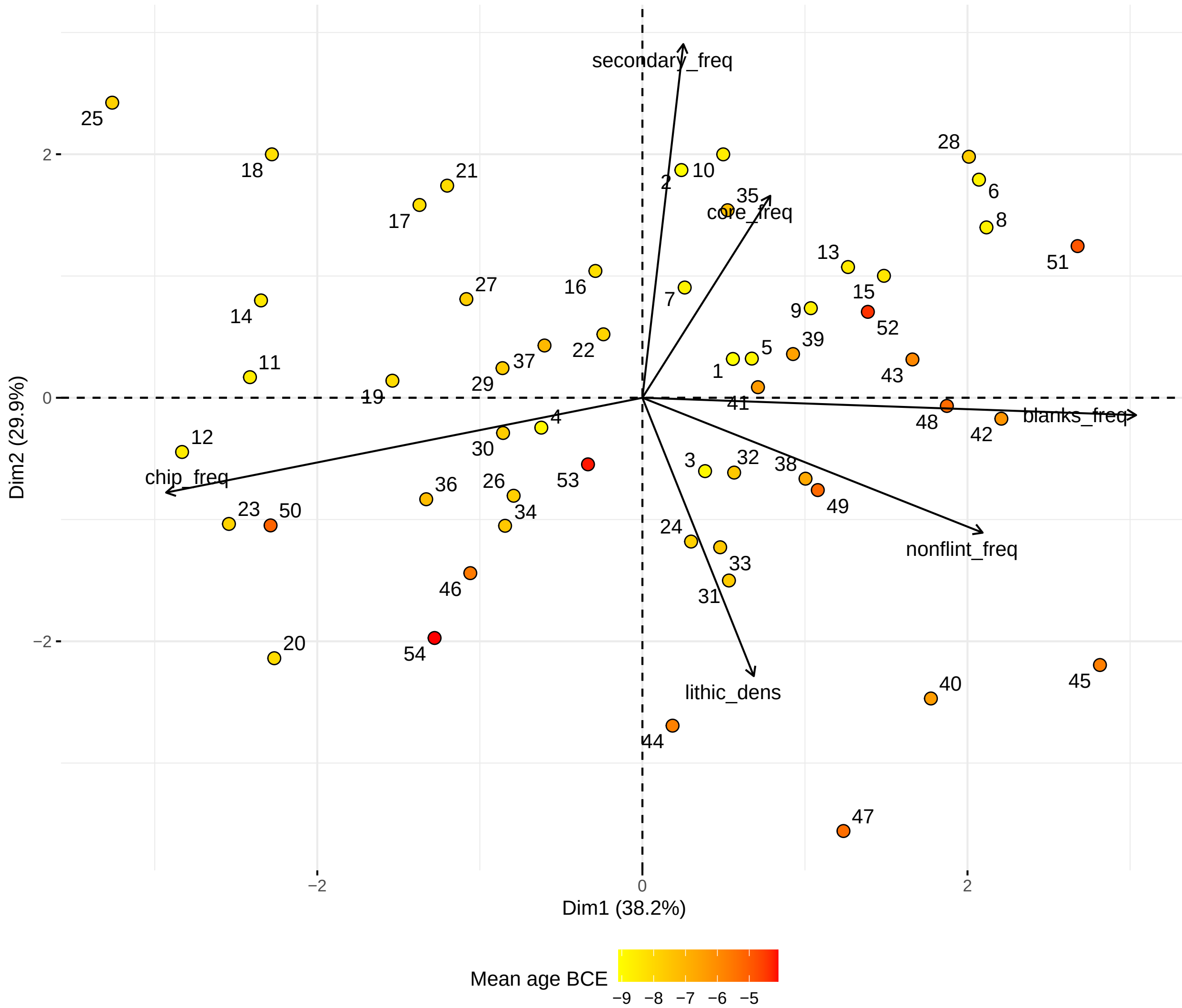

Figure 5: PCA using variables that have been related to mobility patterns. Note that details on the transformation of the variables has been left out of the plot for clarity, but follow those given in Figure 4.

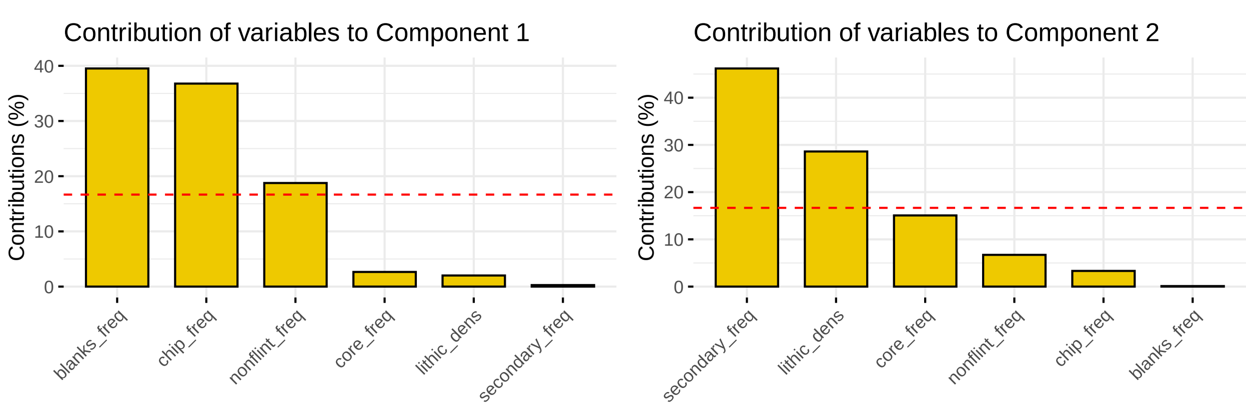

Figure 6: Contribution of variables to the components of the PCA. The dotted red line indicates the expected contribution from each variable given a uniform distribution of impact.

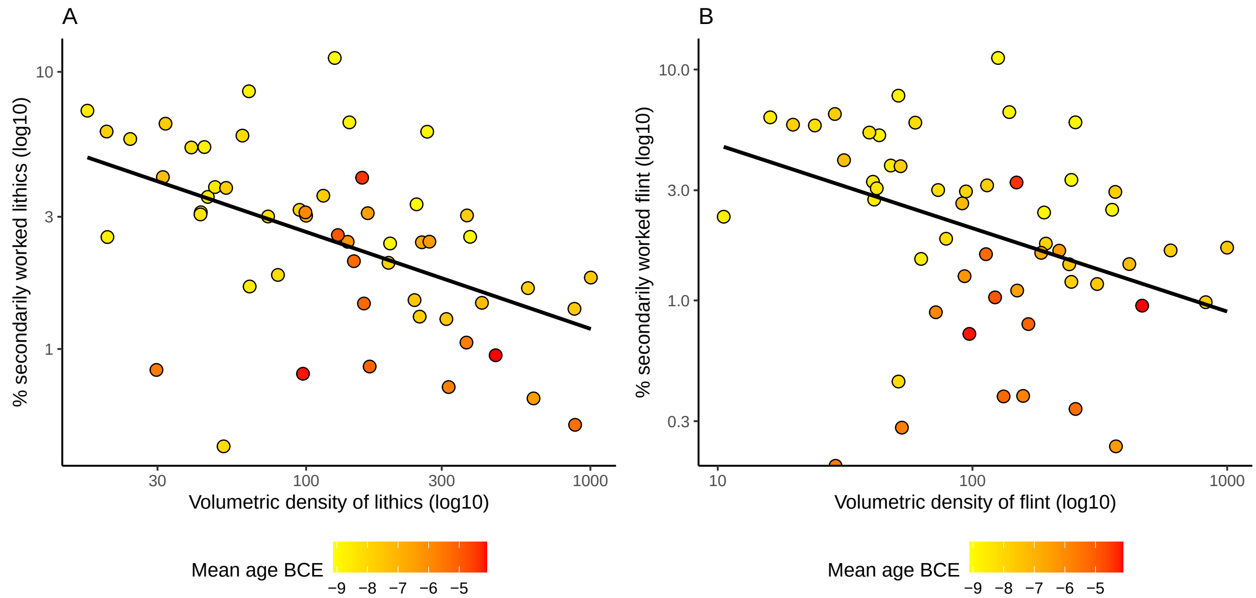

Figure 7: Relative frequency of secondarily worked lithics plotted against the volumetric density of artefacts (artefact count / excavated m^3) for A) All lithics, B) Flint. The logarithm is taken to base 10 on all axes.

mean was then found for each site on these two normalised values. To account for the temporal uncertainty associated with the dating of the sites, a simulation-based approach was also adopted (e.g. Baxter and Cool, 2016; Crema, 2012; Orton et al., 2017). A LOESS curve was fit to the curation index and site age for each simulation run, where the age of each site was drawn as a single year from the date ranges associated with the sites as provided in Figure 1. For sites with radiocarbon age determinations the dates were drawn from the associated summed posterior density estimates, while ages for sites dated with reference to relative sea-level change and typology were drawn uniformly from the associated date range. This simulation was repeated 1000 times, the results of which is visualised in Figure 8A. Disregarding the edge-effects at either end of the plot, the general tendency is a relatively high degree of curation among the earlier sites, followed by a marked drop around 8000 BCE. This has stabilised by around 7000 BCE and remains stable without any major fluctuations for the rest of the Mesolithic. The variation in degree of curation is also markedly higher after 8000 BCE, potentially reflecting variation associated mobility patterns. Figure 8B displays the result of running the same procedure on the flint data. The general pattern follows the same trajectory, but the result for some individual sites is markedly different. This is discussed below.

5 Discussion

The results of the CA does appear to align well with previous research, and the employed artefact categories are clearly capturing a temporal component. One possible implication of this could be that the aggregation of artefact categories might have been overly conservative. However, it is also evidently clear, in the words of Kruskal (1971, p. 22), that 'time is not the only dimension.' The results of the CA do most certainly correspond to more pervasive cultural change than a purely typo-chronological development of artefact morphology, which is also made evident by some of significant deviances from the overall pattern. Unpicking and aligning these patterns with any specific behavioural and technological dimensions using the coarse CA results is, however, another task entirely. This follows most clearly from the fact that for the most part we do not know what individual lithic objects in the assemblages has been used for, leaving the behavioural and social significance of the employed units of analysis unclear. The results of the CA can, however, be used in conjunction with the part of the analysis that has attempted to get at more specific behavioural dimensions to nuance or explain discrepancies in this data.

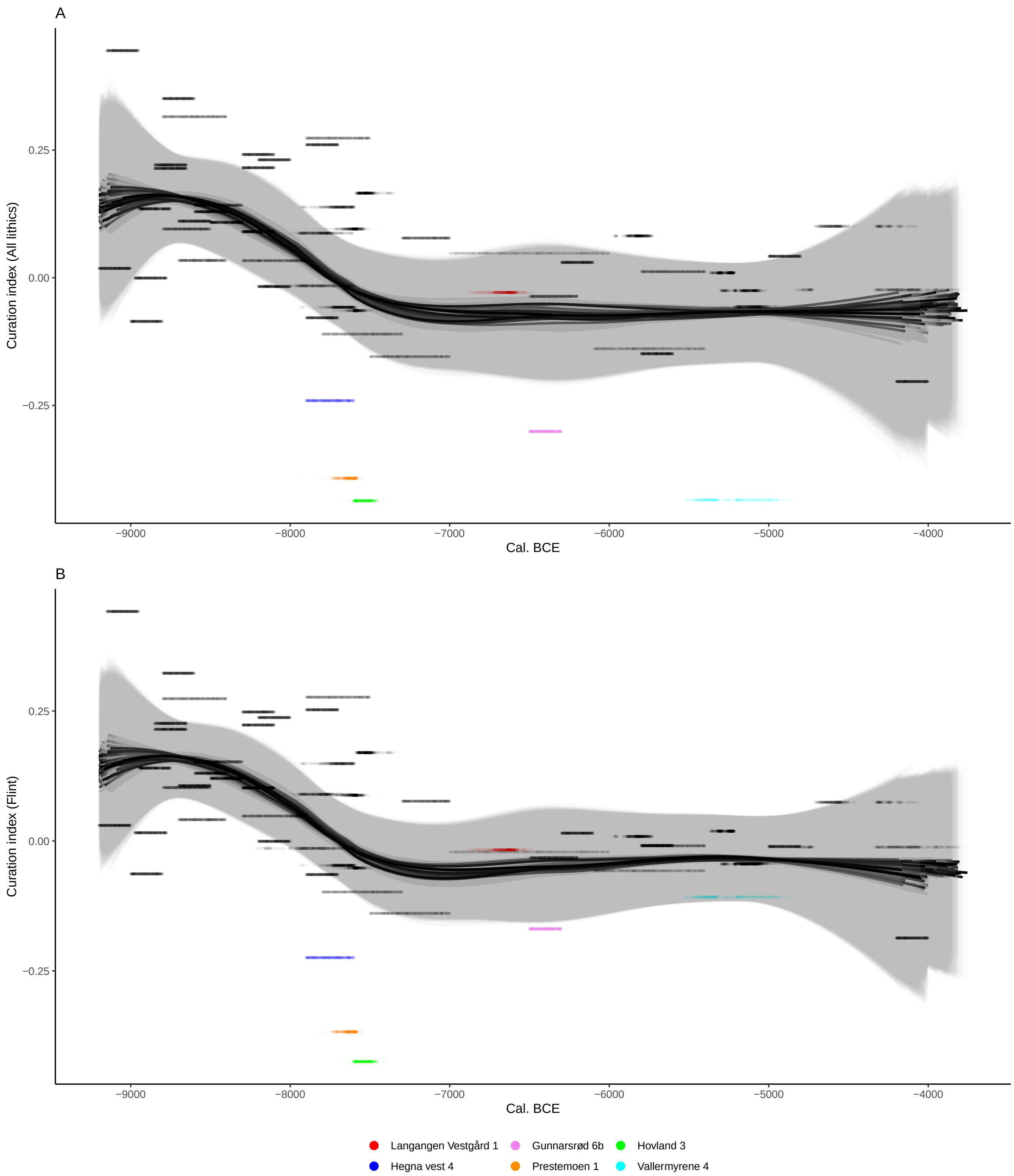

Figure 8: Temporal variation in the curation index for A) All lithics, and B) Flint. The temporal uncertainty is handled by means of a simulation approach where the site ages are drawn from their repspective age determination probability density functions given in Figure 1B. A LOESS curve has been fit to the distribution for each of the 1000 simulation runs. Each simulation run is plotted with some transparency. Sites mentioned in the text are given colour.

The relevance of the relationship between frequency of secondarily worked lithics and volumetric density of lithics was here identified by means of an exploratory approach, and is in part investigated further because they align with suggestions from previous research — clearly representing a possible case of both confirmation bias and circular reasoning. However, some inferential merit can be achieved by invoking what has been termed consilience. Consilience involves "the interlocking or coherence of causal explanations across multiple problem domains" through a clear operationalisation of explanatory terms and concepts (Clark, 2009, p. 30). Thus, the overlap in results presented here and those repeatedly reported from a range of different context does speak to the general applicability and comparability offered by the measures, and gives an initial indication that they might be capturing the social dimensions of interest also in a Norwegian Mesolithic setting.

The curation index has relatively high values until some time before 8000 BCE, before it drops and stabilises around 7000 BCE for the rest of the Mesolithic. This pattern is evident in both the flint data and when all lithics are treated in aggregate. Furthermore, the variation in degree of curation in Figure 8A could indicate that the sites were associated with a more varied mobility pattern after around 8000 BCE. The five sites that have values on the curation index below c. -0.25 could in this perspective have predominantly functioned as base camps within a logistic settlement pattern (*sensu* Binford, 1980). That these assemblages reflect stays of a longer duration was suggested for all five sites in the original reports (Carrasco et al., 2014; Eigeland and Fossum, 2017; Persson, 2014; Solheim and Olsen, 2013), with the exception of for Vallermyrene 4, which was argued to be a specialised axe production site, not necessarily associated with lower degrees of mobility (Eigeland and Fossum, 2014). This highlights a possible issue pertaining to raw-material variability, as the coarse non-flint material used for the production of axes generally results in a relatively large amount of waste per produced tool, possibly skewing the curation index when compared to assemblages dominated by flint. Referring back to the CA, the difference is most marked for the sites in the later part of the Mesolithic where non-flint material become more dominating parts of the assemblages. As can be seen in Figure 8B, the degree of curation is markedly higher for both Gunnarsrød 6b and Vallermyrene 4 when the non-flint material is excluded, although they remain more expedient than that of contemporary assemblages. Thus, the degree of expediency for assemblages dominated by non-flint materials might be somewhat exaggerated when the non-flint material is included, while its exclusion would likely lead to its underestimation. One possible approach could be to weigh the curation index by proportion of non-flint material in the assemblages. This is not explored further here, however, as the overall tendencies are relatively robust to this effect. Another case also worth commenting on is Langangen Vestgård 1, which, on the grounds of an overall large number of artefacts and the possible presence of a dwelling structure was argued to reflect a more permanent site location in the original report (Melvold and Eigeland, 2014). However, the relatively high value on the curation index could mean that Langangen Vestgård 1 reflects the aggregation of stays which predominantly have been of a comparable duration to those on contemporary sites, while the possible dwelling structure, if taken as an indication of longer stays, could in this perspective represent a remnant from one or a few visits of longer duration that constitute a smaller fraction of the use-life of the site as a whole (cf. Barton and Riel-Salvatore, 2014).

While there are certainly nuances in the material that might lead one to question the applicability of the VDL and RFSL measures for any individual site, the overall pattern for curation does appear relatively robust. It seems clear that there is a marked drop starting some time just before 8000 BCE, which has stabilised around 7000 BCE. This corresponds well with a chronological framework where the end of the Early Mesolithic, or Flake axe phase, is set to c. 8200 BCE (Reitan, 2016). Previous research has proposed that the Early Mesolithic is characterised by a relatively high degree of mobility, and low variation in site types and associated mobility patterns (e.g. Bjerck, 2008; Fuglestvedt, 2012). This corresponds very well with the findings reported here, where the earliest assemblages are characterised by relatively high and uniform values on the curation index. The transition to the subsequent Middle Mesolithic, or Microlith phase, at around 8200 BCE has been linked to changes in blade (Damlien, 2016) and subsequently axe technology (Eymundsson et al., 2018; Solheim et al., 2020), which in turn has been associated with changes in population genomics and related migration events hailing from the Eurasian Steppes (Günther et al., 2018; Manninen et al., 2021). The radiocarbon record points towards a coinciding population decline in Southern Norway around this time (Nielsen, 2021). Although this does not appear to be evident in the regional data for south-eastern Norway, taphonomic loss associated with these early dates is an issue (Nielsen, 2021; Solheim, 2020; Solheim and Persson, 2018). In the chronological framework of Reitan (2016), the Microlith phase is defined as lasting until around 7000 BCE. Referring back to the increasing expediency in the curation data between c. 8200 and 7000 BCE, the Microlith phase could thus represent a transitional phase where migrating people and new living practices were propagating through societies in South-Eastern Norway — a process that in light of the curation data would have concluded around 7000 BCE.

The Microlith phase is followed the Pecked adze phase, characterised by a more dominating presence of non-flint macro tools and associated production waste in the assemblages (Reitan, 2016). As is evident from both the CA and the curation data, if we disregard Nedre Hobekk 2, the earliest of the assemblages treated here with this kind of compositional profile is site 40, Gunnarsrød 6b, dated to c. 6500–6300 BCE (Carrasco et al., 2014). The curation data remains stable from around 7000 BCE through the next typological transition at c. 5600 BCE, which, following Reitan (2016), signifies the onset of the Nøstvet adze phase. While previously defined as having a slightly longer duration, the Nøstvet phase has traditionally been seen as representing the onset of more varied settlement systems and stable mobility patterns in south-eastern Norway (e.g. Jaksland, 2001; Lindblom, 1984), and has been explicitly linked to an expedient technological organisation (Glørstad, 2011; 2010, p. 161) — albeit with the term being somewhat vaguely invoked (Eigeland, 2015, pp. 127–130). In recent years it has been suggested that the transition to a decrease in mobility and more varied land-use patterns can be traced back to the Middle Mesolithic (Solheim and Persson, 2016). The curation index employed here clearly supports this notion, and suggests that the mobility patterns of the Nøstvet phase were well established in preceding periods.

The subsequent Transverse arrowhead phase (c. 4500–3900 BCE) is characterised by a dramatic decrease in axe finds, and the introduction of tranverse-, tanged -and single-edged points (Reitan, 2016). It has recently been suggested that a dispersal of people from southern Scandinavia into southern Norway takes place in this period (Eigeland, 2015, p. 379; Nielsen, 2021), which could follow after a preceding population decline at c. 4300 BCE (Nielsen, 2021). The continued stability of the curation index could indicate that these changes are not related to major shifts in land-use and mobility patterns in the material treated here. However, it is also worth highlighting the strained sample size for the later parts of the Mesolithic, which could mean that the effect is missed, especially if the signal is weaker than that for the transition from the Early Mesolithic.

As it stands, however, the main hypotheses resulting from the analysis would be that settlement patterns in the earliest parts of the Mesolithic were characterised by relatively high and unform degrees of mobility, which then drop before leveling off at around 7000 BCE. These then remain relatively stable throughout the rest of the period, despite variation pertaining to other aspects of the lithic inventories, as evidenced by the CA. Although the precise nature of this transition would require further consideration, the quite dramatic fall in curation levels and parallel increase in variation would seem to correlate well with a transition from a predominantly residential to logistical settlement system (Barton et al., 2011; Binford, 1980).

6 Conclusion

The results of the CA align more or less with results of previous research in south-eastern Norway. This would indicate that in general, meaningful chronological patterning is associated with the employed artefact categories. These tendencies are already well-established when it comes to the formal tool types, but have been given less focus in light of entire assemblages. Precisely what behavioural implication the development in the use and occurrences of the tool and debitage categories are less clear, but appears to follow a different, and more complex trajectory than that of curation, as operationalised herge.

The temporal trends associated with the curation index corresponds surprisingly well with trajectories of cultural development previously suggested in the literature, and does therefore, in my view, suggest that shifts in mobility patterns has caused this empirical pattern, in line with the framework of Clark and Barton (2017). Another perspective would be that this is not surprising at all, and that its previously demonstrated relevance across a wide range of contexts rather points to its pervasive relevance for the organisation of lithic technology, and that there as a consequence should be little reason to think that a the setting of Mesolithic south-eastern Norway should be any different. In any case, if its applicability and relevance for this setting is accepted, the relationship does hold great potential for large scale comparative studies in Mesolithic Norway and beyond. Futhermore, while the temporal trends associated with the curation index was here narratively associated with the most immediate chronological trends that have frivolously been associated with the Mesolithic in south-eastern Norway, the explicit quanitiication offers the possibility of more formal comparisons with a wide range of environmental, demographic and cultural dimensions across multiple scales.

However, the role of non-flint material, variability of flint quality. Furthermore, precisely how this mobility pattern has. Here Binfords model of briefly invoked, but there exists a wide range of possible configurations and mobility strategies that

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7.0.1 Colophon

This report was generated on 2021-06-11 01:59:33 using the following computational environment and dependencies:

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#> - Session info ---------------------------------------------------------------
#>  setting  value
#>  version  R version 4.1.0 (2021-05-18)
#>  os       Linux Mint 19.3
#>  system   x86_64, linux-gnu
#>  ui       X11
#>  language en_US
#>  collate  en_US.UTF-8
#>  ctype    en_US.UTF-8
#>  tz       Europe/Oslo
#>  date     2021-06-11
#>
#> - Packages -------------------------------------------------------------------
#>  package       * version date       lib source
#>  abind           1.4-5   2016-07-21 [1] CRAN (R 4.1.0)
#>  assertthat      0.2.1   2019-03-21 [1] CRAN (R 4.1.0)
#>  backports       1.2.1   2020-12-09 [1] CRAN (R 4.1.0)
#>  bitops          1.0-7   2021-04-24 [1] CRAN (R 4.1.0)
#>  bookdown        0.22    2021-04-22 [1] CRAN (R 4.1.0)
#>  broom           0.7.6   2021-04-05 [1] CRAN (R 4.1.0)
#>  cachem          1.0.5   2021-05-15 [1] CRAN (R 4.1.0)
#>  callr           3.7.0   2021-04-20 [1] CRAN (R 4.1.0)
#>  car             3.0-10  2020-09-29 [1] CRAN (R 4.1.0)
#>  carData         3.0-4   2020-05-22 [1] CRAN (R 4.1.0)
#>  cellranger      1.1.0   2016-07-27 [1] CRAN (R 4.1.0)
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#>  class           7.3-19  2021-05-03 [4] CRAN (R 4.0.5)
#>  classInt        0.4-3   2020-04-07 [1] CRAN (R 4.1.0)
#>  cli             2.5.0   2021-04-26 [1] CRAN (R 4.1.0)
#>  cluster         2.1.2   2021-04-17 [4] CRAN (R 4.0.5)
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#>  crayon          1.4.1   2021-02-08 [1] CRAN (R 4.1.0)
#>  curl            4.3.1   2021-04-30 [1] CRAN (R 4.1.0)
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#>  devtools        2.4.1   2021-05-05 [1] CRAN (R 4.1.0)
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#>  testthat        3.0.2   2021-02-14 [1] CRAN (R 4.1.0)
#>  tibble        * 3.1.2   2021-05-16 [1] CRAN (R 4.1.0)
#>  tidyr         * 1.1.3   2021-03-03 [1] CRAN (R 4.1.0)
#>  tidyselect      1.1.1   2021-04-30 [1] CRAN (R 4.1.0)
#>  tidyverse     * 1.3.1   2021-04-15 [1] CRAN (R 4.1.0)
#>  units           0.7-1   2021-03-16 [1] CRAN (R 4.1.0)
#>  usethis         2.0.1   2021-02-10 [1] CRAN (R 4.1.0)
#>  utf8            1.2.1   2021-03-12 [1] CRAN (R 4.1.0)
#>  vctrs           0.3.8   2021-04-29 [1] CRAN (R 4.1.0)
#>  withr           2.4.2   2021-04-18 [1] CRAN (R 4.1.0)
#>  xfun            0.23    2021-05-15 [1] CRAN (R 4.1.0)
#>  xml2            1.3.2   2020-04-23 [1] CRAN (R 4.1.0)
#>  yaml            2.2.1   2020-02-01 [1] CRAN (R 4.1.0)
#>  zip             2.1.1   2020-08-27 [1] CRAN (R 4.1.0)
#>
#> [1] /home/isak/R/x86_64-pc-linux-gnu-library/4.1
#> [2] /usr/local/lib/R/site-library
#> [3] /usr/lib/R/site-library
#> [4] /usr/lib/R/library
```

The current Git commit details are:

```
#> Local:    master /home/isak/phd/dialpast_r/dialpastrepository
#> Remote:   master @ origin (https://github.com/isakro/dialpastrepository.git)
#> Head:     [c9486ed] 2021-06-10: Implementing suggestions from PhD-seminar.
```