

¹ Exploring the Composition of Lithic Assemblages in Mesolithic
² South-Eastern Norway

³ Isak Roalkvam¹

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⁵ **Abstract**

This paper leverages multivariate statistics to explore the composition of 54 Mesolithic assemblages located in south-eastern Norway. To provide analytical control pertaining to factors such as variable excavation practices, systems for artefact categorisation and raw-material availability, the sites chosen for analysis have all been excavated relatively recently and have a constrained geographical distribution. The assemblages were explored following two strains of analysis. The first of these entailed the use of artefact categories that are established within Norwegian Mesolithic archaeology, while the other involved drawing on measures that have been linked directly to land-use and mobility patterns associated with lithic assemblages more widely. The findings pertaining to the established artefact categories largely reflect the temporal development previously reported in Norwegian Mesolithic research, which has been based on more subjectively driven methods. Furthermore, the chronological trends associated with variables taken from the so-called Whole Assemblage Behavioural Indicators (e.g. Clark and Barton 2017), originally devised for characterising Palaeolithic assemblages in terms of associated mobility patterns, also align with the development previously proposed in the literature. This provides an initial indication that these measures are applicable in a Norwegian Mesolithic setting as well, setting the stage for a more targeted and rigorous model evaluation outside this exploratory setting. Furthermore, this finding supports the notion that these measures can offer a powerful comparative tool in the analysis of lithic assemblages more generally.

²³ ¹ University of Oslo, Department of Archaeology, Conservation and History

²⁴ **Highlights**

- Multivariate exploratory analysis of Mesolithic assemblages in south-eastern Norway
- Explores relevance of established artefact categories in Norwegian archaeology
- Explores variables associated with mobility patterns in lithic assemblage studies
- Draws on the Whole Assemblage Behavioural Indicators (WABI)
- Relevance for Mesolithic Norway supports the notion that WABI are widely applicable

³⁰ Keywords: Mesolithic Scandinavia; Multivariate statistics; Mobility strategies; Whole Assemblage Behavioural
³¹ Indicators

³² **1 Introduction**

This study employs multivariate exploratory statistics to analyse lithic assemblages associated with 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

39 sizes at visits to the sites. The assemblages are also likely to be impacted by variation in lithic technology,
40 artefact function, use-life and discard patterns, as well as procurement strategies and access to raw materials.
41 Finally, analytic and methodological dimensions relating to survey, excavation and classification practices are
42 also fundamental to how the assemblages are defined. Consequently, the analysis conducted here is done
43 from an exploratory perspective, where all of these factors should be seen as potential contributors to any
44 observed pattern. In an attempt to limit the influence of some potentially confounding effects, the material
45 chosen for analysis has a constrained geographical distribution, and stems from recent investigations that
46 have employed comparable methods for excavation and classification within larger unified projects.

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

62 **2 Archaeological context and material**

63 The Early Mesolithic, or Flake Axe Phase, is defined as lasting from c. 9300–8200 BCE (Table 2), and is set
64 to start with the first recorded human presence in Norway (Damlien and Solheim 2018). Previous research
65 has typically proposed that the Early Mesolithic is characterised by a relatively high degree of mobility,
66 and low variation in site types and associated mobility patterns (e.g. Bjerck 2008; Breivik and Callanan
67 2016; Fuglestvedt 2012; Nærøy 2018; but see Viken 2018). Around the transition to the subsequent Middle
68 Mesolithic or Microlith Phase at c. 8200 BCE, pervasive changes in blade and axe technology occur (Damlien
69 2016; Eymundsson et al. 2018; Solheim et al. 2020), which in turn has been associated with changes in
70 population genomics and related migration events hailing from the Eurasian steppes (Günther et al. 2018;
71 Manninen et al. 2021). The Microlith Phase is defined as lasting until around 7000 BCE, which is followed by
72 the Pecked Adze Phase, characterised by a more dominating presence of non-flint macro tools and associated
73 production waste in the assemblages (Reitan 2016). The next typological transition at c. 5600 BCE signifies
74 the onset of the Nøstvet Adze Phase. While previously defined as having a slightly longer duration, the
75 Nøstvet Phase has traditionally been seen as representing the onset of more varied settlement systems and
76 stable mobility patterns (e.g. Jakslund 2001; Lindblom 1984). In recent years it has been suggested that
77 the transition to a decrease in mobility and more varied land-use patterns can be traced back to the Middle
78 Mesolithic (Solheim and Persson 2016). The subsequent Transverse Arrowhead Phase (c. 4500–3900 BCE) is
79 characterised by a dramatic decrease in axe finds, and the introduction of new flint projectiles (Reitan 2016).
80 It has recently been suggested that a dispersal of people from southern Scandinavia into southern Norway
81 takes place in this period (Eigeland 2015:379; Nielsen 2021), which could follow after a preceding population
82 decline at c. 4300 BCE (Nielsen 2021; cf. Solheim 2020; Solheim and Persson 2018).

83 A defining characteristic of the Norwegian Mesolithic is that a clear majority of the known sites are located
84 in coastal areas (e.g. Bjerck 2008). Furthermore, these coastal sites appear to predominantly have been
85 located on or close to the contemporary shoreline when they were in use (Åstveit 2018; Breivik et al. 2018;
86 Møller 1987; Solheim et al. 2020). In south-eastern Norway, this pattern is combined with a continuous
87 regression of the shoreline, following from isostatic rebound (e.g. Romundset et al. 2018; Sørensen 1979).

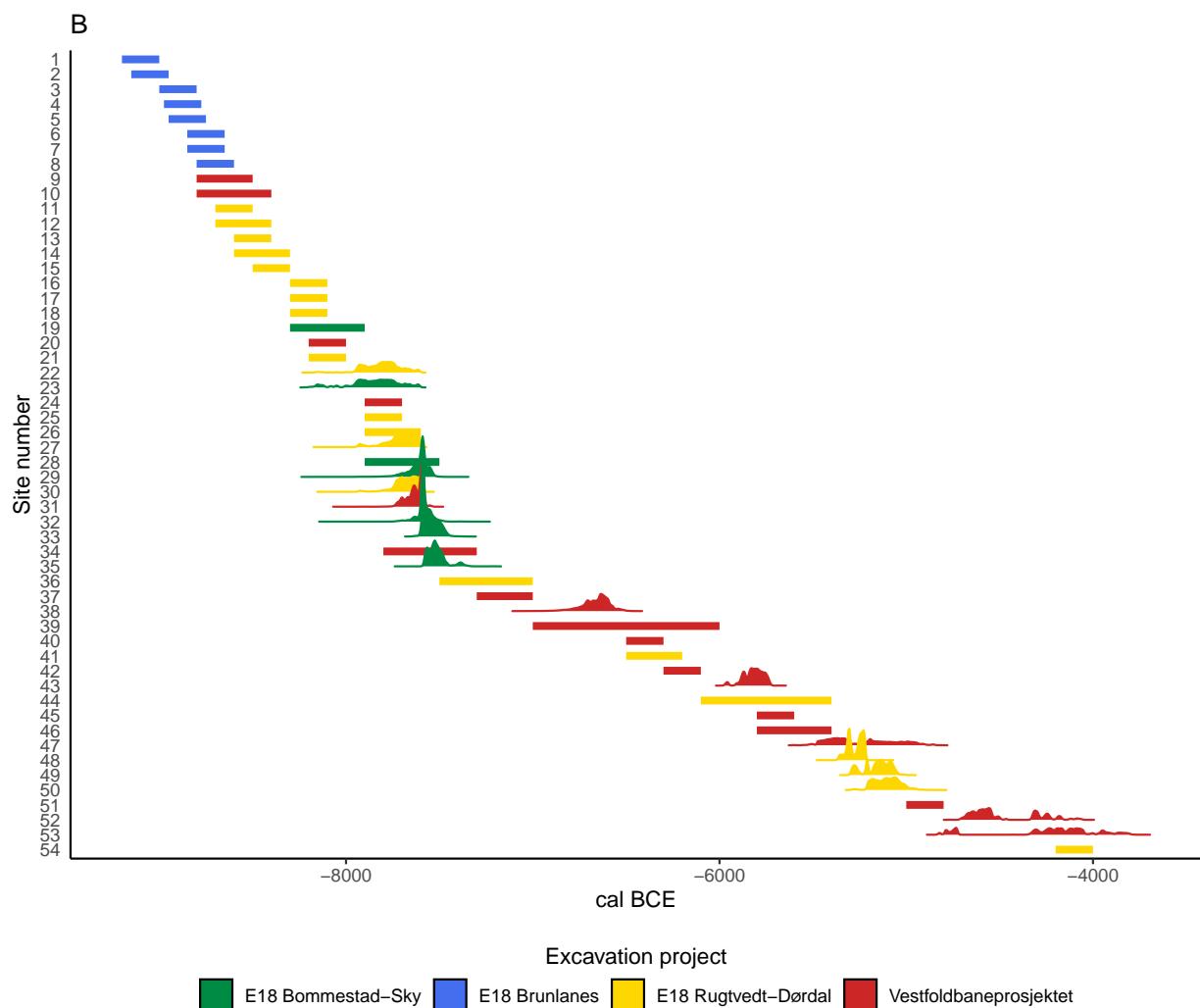


Figure 1: A) Spatial and B) temporal distribution of the sites chosen for analysis. Radiocarbon age determinations are given as the sum of the posterior density estimates. Solid lines indicate that the site has been dated with reference to relative sea-level change and typological indicators. These follow the original reports. Site numbers match those provided in Table 2.

Table 1: Chronological framework. Glørstad's (2010) division of phases reflects the more traditional framework, to which Reitan (2016) has recently suggested considerable changes.

Glørstad (2010)	
Early Mesolithic, Fosna Phase	9500–8200 BCE
Middle Mesolithic, Tørkop Phase	8200–6300 BCE
Late Mesolithic, Nøstvet Phase	6300–4600 BCE
Late Mesolithic, Kjeøy Phase	4600–3800 BCE
Reitan (2016)	
Flake Axe Phase	9300–8200 BCE
Microlith Phase	8200–7000 BCE
Pecked Adze Phase	7000–5600 BCE
Nøstvet Adze Phase	5600–4500 BCE
Transverse Arrowhead Phase	4500–3900 BCE

- 88 The fairly rapid shoreline displacement means that the sites tend not to have retained their strategic or
 89 ecologically beneficial shore-bound location for long periods of time (cf. Perreault 2019:47). Consequently,
 90 the shore-bound settlement, combined with the rapid shoreline displacement has resulted in a relatively high
 91 degree of spatial separation of cumulative palimpsests, to follow the terminology of Bailey (2007), while the
 92 reconstruction of the trajectory of relative sea-level change allows for a relatively good control of when these
 93 accumulation events occurred. In other parts of the world, a higher degree of spatial distribution means that
 94 while the physical separation of material can help delineate discrete events, this typically comes at the cost of
 95 losing temporal resolution as any stratigraphic relationship between the events is lost (Bailey 2007).
- 96 The 54 coastal sites chosen for analysis here have a relatively limited geographical distribution (Figure 1A).
 97 The sites were excavated as part of four larger excavation projects that all took place within the last 15 years
 98 (Jaksland and Persson 2014; Melvold and Persson 2014; Reitan and Persson 2014; Solheim 2017a; Solheim
 99 and Damlien 2013). The sites included in the analysis consist of all Mesolithic sites excavated in conjunction
 100 with the projects that have assemblages holding more than 100 artefacts. The institution responsible for
 101 these excavations was the Museum of Cultural History in Oslo. This has led to a considerable overlap in the
 102 archaeological personnel involved, and comparable excavation practices across the excavations. Furthermore,
 103 with these projects, major efforts were made to standardise how lithic artefacts were to be classified at the
 104 museum (Koxvold and Fossum 2017; Melvold et al. 2014). As a result, this should reduce the amount of
 105 artificial patterning in the data incurred by discrepancies in the employed systems for categorisation (cf.
 106 Clark and Riel-Salvatore 2006; Dibble et al. 2017).
- 107 The lithic data analysed are based on the classification of the site assemblages done for the original excavation
 108 reports, and consists of 48 variables representing different debitage and tool types. The artefact data have
 109 been divided into flint and non-flint materials. Flint does not outcrop naturally in southern Norway, and is
 110 only available locally as nodules that have been transported and deposited by retreating and drifting ice (e.g.
 111 Berg-Hansen 1999). This means that the distribution and quality of flint has been impacted by a diverse set
 112 of climatic and geographical factors (Eigeland 2015:46). Thus, while flint is treated as a unified category here,
 113 the variability in quality could have been substantial. Furthermore, the various non-flint raw materials that
 114 have been lumped together have quite disparate properties, where fine-grained cryptocrystalline materials are
 115 often used as a substitute or supplement to flint, while other, coarser materials are usually associated with
 116 the production of axes and other macro tools. Given this differentiated use, these raw-material properties are
 117 expected to be reflected in the retained debitage and tool categories. An important benefit of combining all
 118 of the non-flint materials is that this reduces the dependency on whether or not these have been correctly
 119 and consistently categorised for the reports (cf. Frivoll 2017). Finally, while factors such as landscape
 120 changes through shoreline displacement can have led to variable raw-material availability at the analysed sites,
 121 their relatively constrained geographical distribution hopefully counteracts some non-behavioural sources of
 122 variation.

Table 2: 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

123 3 The analysis of lithic assemblages

124 Studies concerned with chronological changes in the composition of lithic assemblages in southern Norway have
 125 typically had a focus on morphological variation among artefacts (e.g. Ballin 1999; Bjerck 1986; Reitan 2016)
 126 or been concerned with technological processes associated with certain sub-categories of the site inventories,
 127 such as the production of blades or axes (e.g. Berg-Hansen 2017; Damlien 2016; Eymundsson et al. 2018;
 128 Solheim et al. 2020). Studies that have involved entire assemblages have either been concerned with general
 129 compositional traits such as relative frequency of various tool types and raw-materials (Breivik 2020; e.g.
 130 Breivik and Callanan 2016; Reitan 2016; Viken 2018), or involved extremely in-depth studies of technological
 131 organisation associated with a handful of assemblages (e.g. Eigeland 2015; Fuglestvedt 2007; Mansrud and
 132 Eymundsson 2016). These studies are, however, based on non-quantitative and less formal methods, leaving
 133 the weighting of the different variables for the final interpretations unclear. To my knowledge, only a single
 134 study dealing with the composition of Mesolithic assemblages in southern Norway has involved the use
 135 of a multivariate quantitative framework, which was employed to structure the analysis of eight Middle
 136 Mesolithic assemblages (Solheim 2013; see Glørstad 2010:145–146 for a spatial application). In sum then,
 137 previous studies have typically either been limited to a small number of sites, to a subset of the inventories,
 138 to morphological characteristics, or to subjectively and narratively driven methods that are difficult to scale
 139 and consistently balance in the comparison of a larger number of artefact categories and assemblages.

140 The aim of the first part of the analysis conducted here is to evaluate the degree to which the composition
 141 of the assemblages align with earlier studies that have employed more informal methods. This therefore
 142 assumes that the artefact categories employed in Norwegian Stone Age archaeology are, at least to a certain
 143 extent, behaviourally meaningful. However, the approach taken is also partially informed by the so-called
 144 Frison effect (Jelinek 1976), which pertains to the fact that lithics studied by archaeologists can have had
 145 long and complex use-lives in which they took on a multitude of different shapes before they were ultimately
 146 discarded. Several scholars have built on this to argue that morphological variation in retouched lithics
 147 from the Palaeolithic cannot be assumed to predominantly be the result of the intention of the original
 148 knapper to reach some desired end-product, but rather that what is commonly categorised as discrete types
 149 of artefacts by archaeologists can instead in large part be related to variable degrees of modification through
 150 use and rejuvenation (e.g. Barton 1991; Barton and Clark 2021; Dibble 1995). Consequently, several artefact
 151 categories have here been collapsed for the CA (Figure 2) . This for example pertains to tool types such as
 152 scrapers, burins, drills, knives and otherwise indeterminate artefacts with retouch. That these categories are
 153 internally consistent and categorically exclusive in terms of fulfilled purpose is at best a dubious proposition, in
 154 turn potentially rendering their contribution as discrete analytic units misleading. An underlying assumption
 155 is therefore effectively that the retained categories represent artefact categories that have fulfilled different
 156 purposes or are related to different technological processes. While aggregating artefact categories in this
 157 manner could potentially subsume important variation, it does also reduce the possibility that any conclusions
 158 are not simply the result of employing erroneous units of analysis.

159 However, for the most part we lack even a most basic understanding of what any individual lithic object in
 160 an assemblage has been used for (Dibble et al. 2017). For example, a vast amount of artefacts defined as
 161 debitage are likely to have fulfilled the function of tools, and both debitage and formal tool types could have
 162 had various different purposes and had a multitude of shapes throughout their use-life. As a consequence, the
 163 second part of the analysis employs a suite of measures developed for the classification of lithic assemblages
 164 with these inferential limitations in mind (Barton et al. 2011; Clark and Barton 2017, and below). The logic
 165 behind these measures are founded on an understanding of technology as being organised along a continuum
 166 ranging between curated and expedient (Binford 1973, 1977, 1979). An expedient technological organisation
 167 pertains to the situational production of tools to meet immediate needs, with little investment of time and

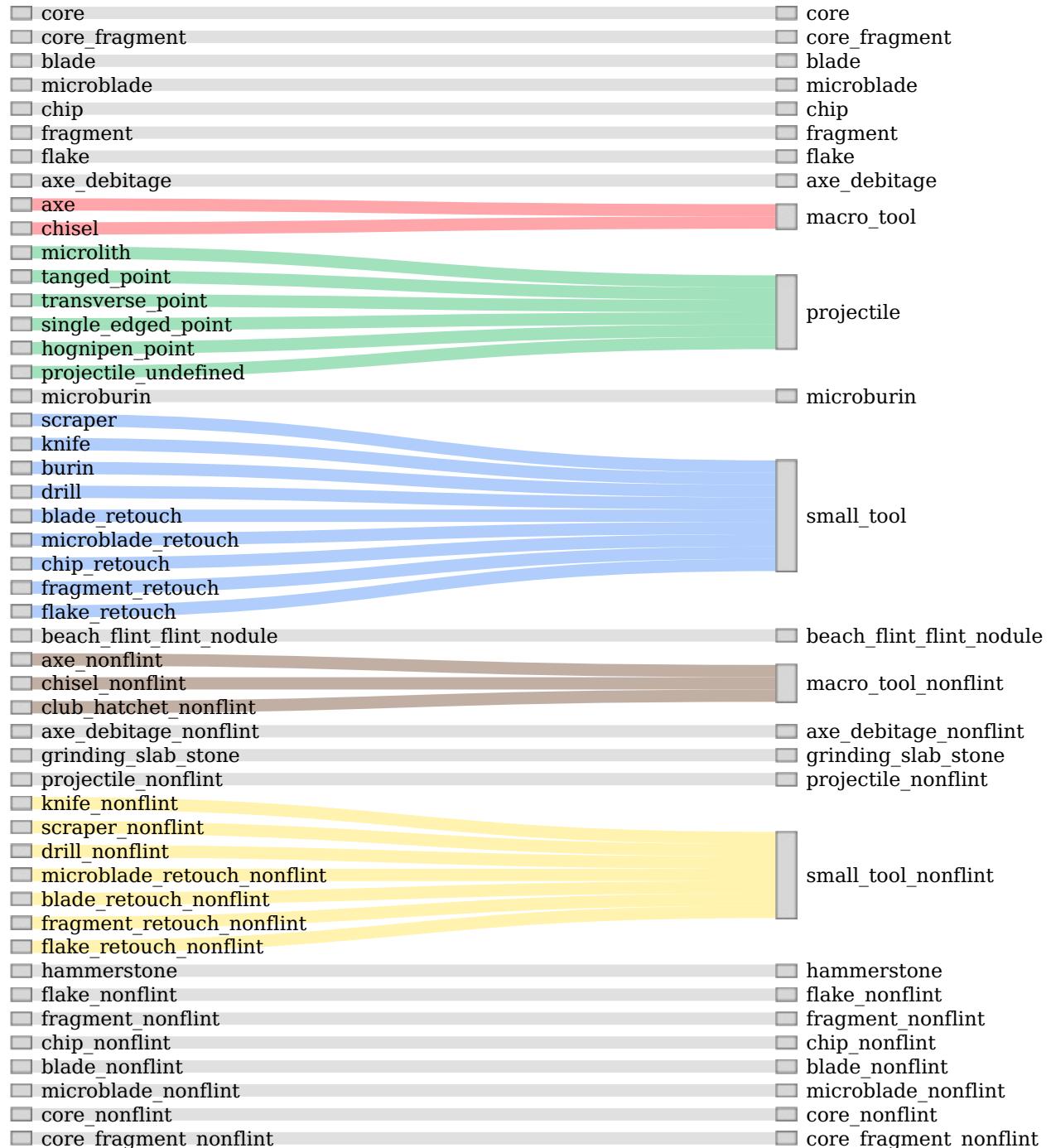


Figure 2: Aggregation of variables for the correspondence analysis. The column on the left shows the data as originally compiled. The column on the right shows how these have been aggregated for the analysis.

168 resources in modification and rejuvenation, resulting in high rates of tool replacement. Curated technological
169 organisation, on the other hand, has been related to manufacture and maintenance of tools in anticipation of
170 future use, the transport of these artefacts between places of use, and the modification and rejuvenation of
171 artefacts for different and changing situations.

172 However, following not least from the ambiguous definition first put forward by Binford (1973), the theoretical
173 definition of curation, its archaeological correlates, and behavioural implications have been widely discussed
174 and disputed (e.g. Bamforth 1986; Nash 1996; Shott 1996; Surovell 2009:9–13). Still, that the distinction can
175 offer a useful analytical point of departure if clearly and explicitly operationalised seems more or less agreed
176 upon, and some dimensions of the concept are generally accepted. For example, although precisely how it is
177 measured may vary, the empirical correspondent to a curated technological organisation is typically defined
178 by high degrees of retouch, as this is commonly seen as a means of realising the potential utility of a tool—or
179 extending its use-life—by the repeated rejuvenation and modification of edges (e.g. Bamforth 1986; Dibble
180 1995; Shott and Sillitoe 2005).

181 One concrete operationalisation of the terms has been forwarded by Barton (1998) and colleagues (e.g. Barton
182 et al. 1999, 2011, 2013; Barton and Riel-Salvatore 2014; Clark and Barton 2017; Riel-Salvatore and Barton
183 2004, 2007; Villaverde et al. 1998), who through a series of studies have shown that the relationship between
184 volumetric density of lithics and relative frequency of retouched artefacts in lithic assemblages have a consistent
185 negative relationship across a wide range of chronological and cultural context, ranging from Pleistocene and
186 Holocene assemblages in Europe and Asia, to assemblages associated with both Neanderthals and modern
187 humans (Barton et al. 2011; Riel-Salvatore et al. 2008). This relationship is taken to reflect degree of
188 curation, and is in turn mainly to follow from the accumulated nature of land-use and mobility patterns
189 associated with the assemblages (Barton and Riel-Salvatore 2014). Furthermore, the relationship between
190 curated and expedient technological organisation has been related to the continuum defined by Binford (1980)
191 between residentially mobile foragers and logically mobile collectors (Clark and Barton 2017; Riel-Salvatore
192 and Barton 2004; see also Bamforth 1986; Binford 1977). Residential mobility involves the relatively frequent
193 movement of entire groups between resource patches throughout the year, while logistic mobility entails the
194 use of central base-camps that are moved less often and from where smaller task-groups venture on targeted
195 forays to retrieve specific resources. A higher degree of logistic as opposed to residential mobility thus also
196 involves a wider range of site types and associated mobility patterns (Binford 1980).

197 Furthermore, in this model, higher degree of mobility would mean a higher dependency on the artefacts and
198 the material people could bring with them, and dimensions such as weight, reliability, repairability, and the
199 degree to which artefacts could be manipulated to fulfil a wide range of tasks are therefore assumed to have
200 been factors of concern. From this it follows that the empirical expectation for short-term camps is a curated
201 technological organisation with higher relative frequency of retouched artefacts, and a lower overall density of
202 lithics (Clark and Barton 2017). More time spent in a single location, on the other hand, is assumed to lead
203 to better control of raw-material availability and to allow for its accumulation. This should in turn lead to a
204 more expedient technological organisation with reduced necessity for the conservation of lithics and extensive
205 use of retouch. The empirical expectation for lower degree of mobility is therefore relatively high density of
206 lithics, a low relative frequency of retouched artefacts, as well as a higher number of unexhausted cores and
207 unretouched flakes and blades. These variables and underlying logic constitute what has been termed Whole
208 Assemblage Behavioural Indicators (WABI, Clark and Barton 2017), and is the main framework adopted
209 here.

210 As these measures are argued to predominantly be determined by land-use and mobility patterns, relative
211 frequency of chips and relative frequency of non-flint material are also included in the analysis, as these
212 measures have also been linked to mobility patterns (e.g. Bicho and Cascalheira 2020; Kitchel et al. 2021) and
213 are of central importance in Norwegian Stone Age archaeology (e.g. Breivik et al. 2016; Reitan 2016)—the
214 use of local non-flint material has been taken to indicate reduced mobility and increased familiarity with
215 local surroundings (Glørstad 2010:181; Jakslund 2001:112).

216 **4 Methodology**

217 The exploratory approach taken here means that a wide range of combinations and transformations of
218 variables has been explored to identify patterning in the data. While only parts of this process can sensibly
219 be reported upon, all data and employed R programming scripts (R Core Team 2020) are freely available as
220 a research compendium at <https://osf.io/ehjfc/>, following Marwick et al. (2018), allowing readers to explore
221 and scrutinise the data and the final analytical choices made (Marwick 2017).

222 The 54 analysed sites have been dated by reference to relative sea-level change, typology and/or radiocarbon
223 dates (Table 2). Date ranges for sites based on shoreline displacement and typology are taken from the original
224 reports and follow the evaluation done by the original excavators. Where radiocarbon age determinations
225 believed to be associated with the lithic material are available, these have been calibrated using the IntCal20
226 calibration curve (Reimer et al. 2020) and subjected to Bayesian modelling using OxCal v4.4.4 (Bronk
227 Ramsey 2009) through the oxcAAR package (Hinz et al. 2021) for R. The only constraint imposed for the
228 modelling of the dates was that the dates from each site are assumed to represent a related group of events
229 through the application of the Boundary function (Bronk Ramsey 2021). The resulting posterior density
230 estimates were then summed for each site.

231 The first part of the analysis involves employing the method of correspondence analysis (CA), using the lithic
232 count data as classified for the original excavation reports. As this part of the analysis partially draws on the
233 above-mentioned Frison effect, several artefact categories have been collapsed for the CA. A version of the
234 CA using the original artefact categories, as well as some additional configurations and ways to aggregate the
235 variables are also available in the supplementary material to the paper.

236 Following the WABI and other factors associated with mobility patterns, as presented above, the variables
237 employed in the second part of the analysis are relative frequency of secondarily worked lithics (RFSL),
238 defined as the proportion of the assemblages constituted by retouched or ground lithics; volumetric density of
239 lithics (VDL), defined as the total number of artefacts divided by total excavated m³ as given in the original
240 reports; relative frequency of chips, defined as the proportion of artefacts with size < 1 mm; relative frequency
241 of cores, the proportion of all artefacts classified as cores in the original reports; relative frequency of blanks,
242 here defined as the proportion of all artefacts classified as flakes, blades, micro-blades or fragments; and finally
243 relative frequency of non-flint material. Following Bicho and Cascalheira (2020), the analysis is done using
244 principal components analysis (PCA), leading to a shift in focus from the relative composition emphasised by
245 the CA, to having more weight placed on patterning in the most abundant occurrences (Baxter 1994:71–77).

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

256 **5 Results**

257 The general impression from the CA is that a chronological dimension accounts for a substantial amount of
258 patterning in the data (Figure 3). This is indicated by the general transition across the colour scale in the
259 row plot (Figure 3A), as well as the horseshoe curve or Guttman effect evident in the column plot (Figure
260 3B, Baxter 1994:119–120; Lockyear 2000). The fact that the two first dimensions of the CA accounts for as
261 much as 80.53 % of the inertia or variance also means that the structure of the data is

262 The column plot reveals that the earliest sites are characterised by the flint artefact categories microburins,
263 projectiles, as well as flint macro tools and associated debitage. These assemblages are also to a larger extent
264 characterised by core fragments, both in flint and non-flint materials, rather than cores. The non-flint material
265 on the earliest, or among the earliest sites, appears to be centred around the production of projectiles, as
266 both projectiles and non-flint blades are important constituents of the assemblages at these sites. The first
267 dimension, which is pulling some of the later sites towards the right of the plot, is mainly defined by macro
268 tools and associated debitage in non-flint materials that are negatively correlated with more flint dominated
269 assemblages. Site number 9, Nedre Hobekk 2, located in the upper right quadrant of the row plot represents
270 a somewhat curious case in that it is an early assemblage characterised by axe production in metarhyolite
271 (Eigeland 2014). However, the site had been quite heavily impacted by modern disturbances that could have
272 impacted the lithic material and which could explain its position as an outlier in the plot (Eigeland 2014).
273 Finally, although the sample size is quite strained and the discussion of finer chronological points might not
274 be warranted, the first dimension does appear to be of less importance for the absolute latest sites, as
275 indicated by their location to the left of the plot.

276 As most of the variation in the data is accounted for by the dominating non-flint material in later assemblages,
277 this suppresses and makes it difficult to discern patterns in the flint data. A second CA was therefore
278 performed, excluding the non-flint material (Figure 4). While not as substantial, there is clear temporal
279 patterning in the flint data as well. This is most marked for the earliest sites which are pulled away from the
280 main cluster, as projectiles, microburins, macro tools and debitage from their production characterises these
281 sites. Slightly younger sites appear more impacted by core fragments and blades. The temporal transition in
282 the main cluster is not as marked, but clearly present, and is driven by a larger proportion of blades, flakes
283 and small tools in the earliest assemblages of the cluster, which is opposed to chips, fragments and partly
284 micro-blades.

285 Moving on to the PCA of measures that have been linked to mobility, some of the variables with severely
286 skewed distributions were initially transformed (Figure 5). Figure 6 displays the resulting PCA. There is
287 a general temporal transition from the upper left to the bottom right of the plot. The second dimension
288 is mainly defined by a negative correlation between the VDL and RFSL (Figure 7). Almost orthogonal
289 to this is the strong negative correlation between relative frequency of chips and blanks. While there is
290 a slight tendency for blanks to be more associated with younger sites, frequency of chips appears to be
291 largely independent of time. However, this almost suspiciously strong negative correlation can perhaps have
292 a practical explanation. Seeing as the frequency of non-flint material is positively correlated with blanks and
293 negatively correlated with chips (Figure 5), one explanation to this pattern could be that smaller non-flint
294 pieces are simply more difficult to identify and separate from naturally fragmented stone during excavation
295 and classification. This could conceivably have led to an over-representation of blanks as compared to chips in
296 assemblages with a high proportion of non-flint material. While this is not necessarily the entire explanation,
297 this does make it difficult to place much analytical weight on this pattern. Relative frequency of cores is not
298 especially impactful in the PCA, and appears to be independent of the temporal dimension as well. That is
299 not to say that cores may not be indicative of or related to mobility patterns, but to get at this may require
300 further analysis beyond their simple classification as cores (Kitchel et al. 2021).

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

310 There is a strong negative correlation between the two variables ($r = -0.5$) and a general tendency for younger
311 sites to be associated with a higher VDL and a lower RFSL than older sites (Figure 8A). The linear correlation
312 is stronger between the mean site age and RFSL ($r = -0.51$), than between mean site age and VDL ($r = 0.22$).
313 Variable non-flint availability and workability has also been suggested to potentially impact these dimensions

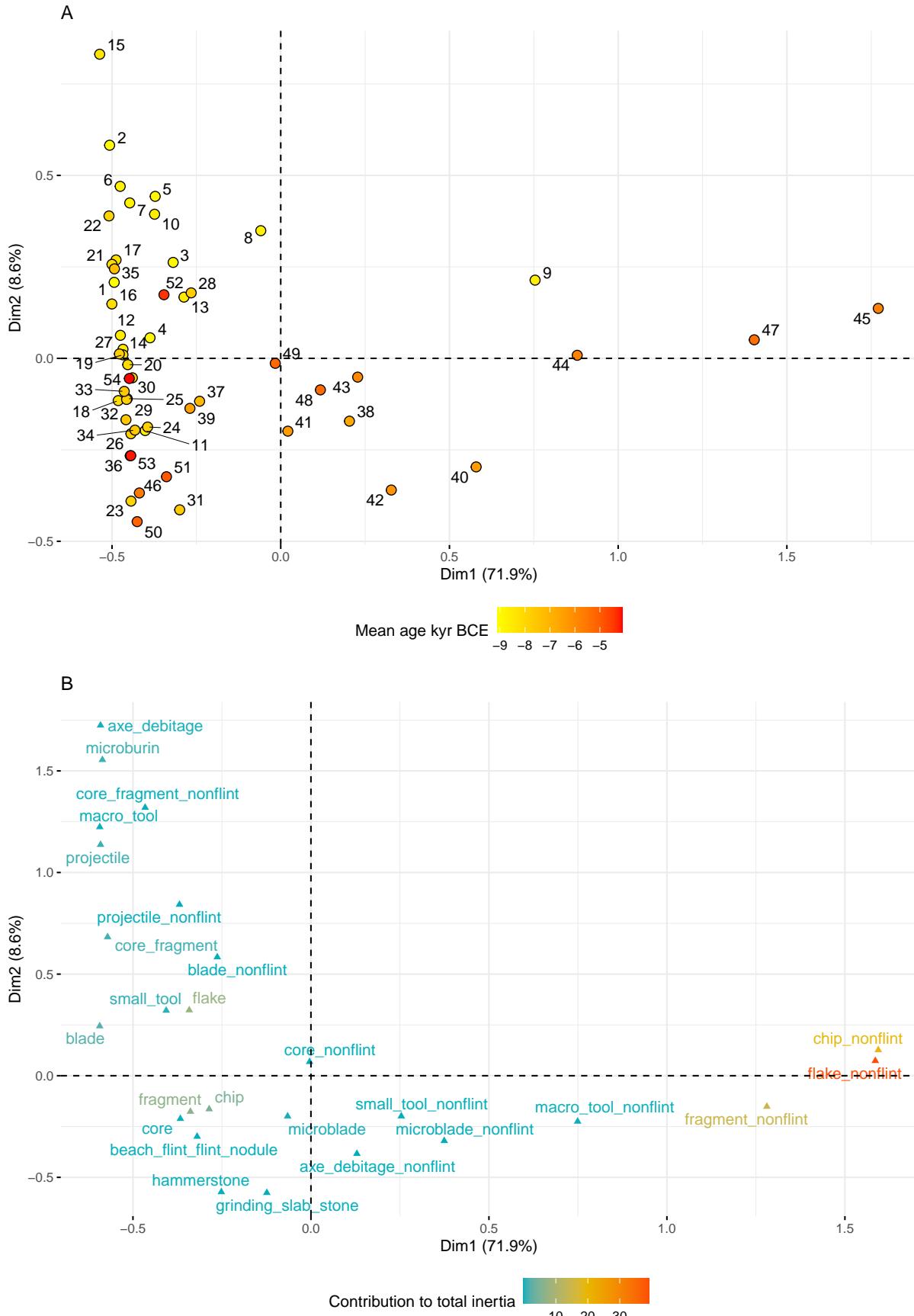


Figure 3: Correspondence analysis using the artefact count data. A) Row plot, B) Column plot. Points close together are more similar. By evaluating how the variables are distributed on the column plot it is possible to say how these define the two axes, in turn making it possible to relate the distribution of the sites in the row plot to the variables. As these are symmetrical plots, only general statements concerning the interrelation between the rows and the columns across the two plots can be made.

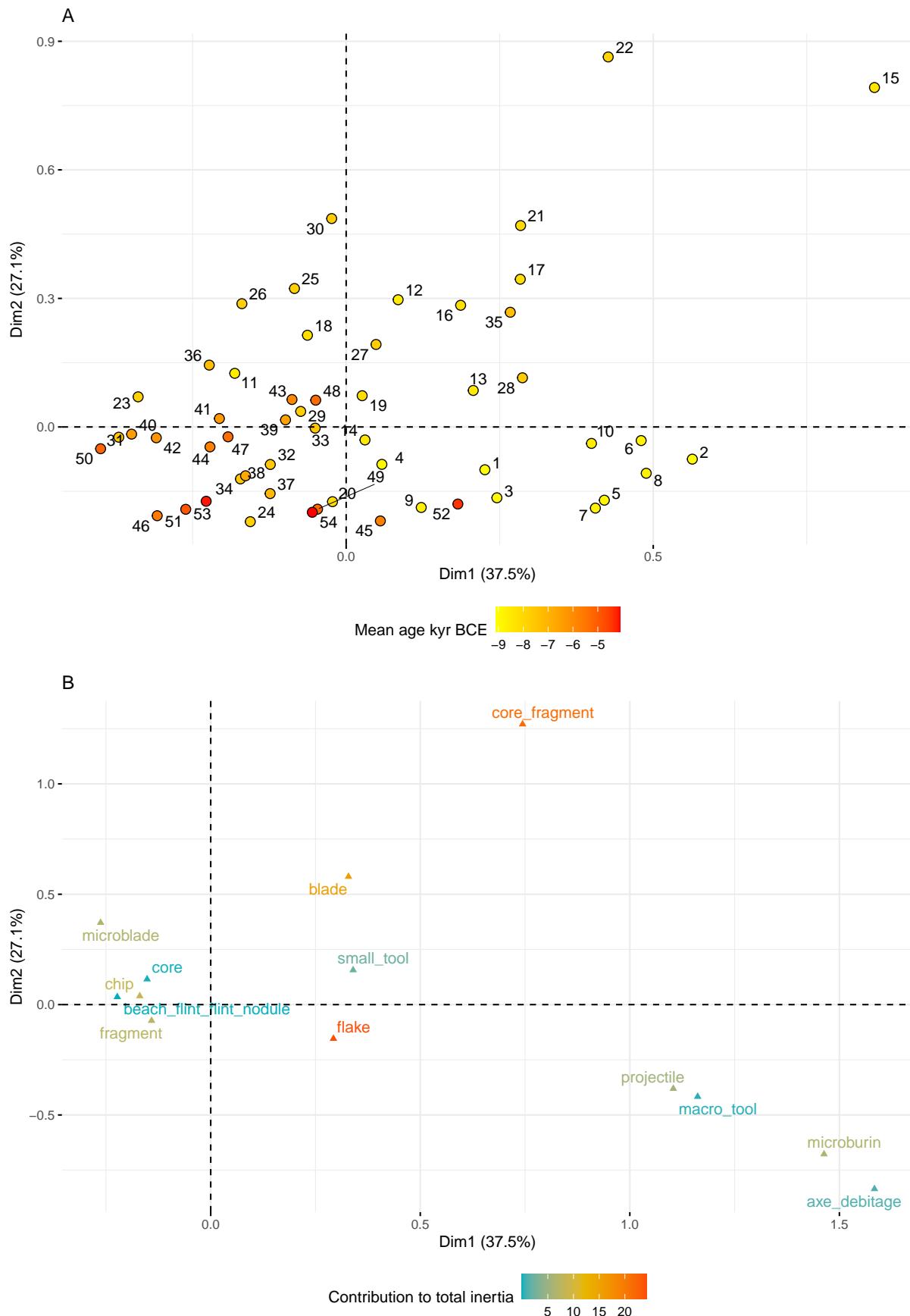


Figure 4: Correspondence analysis using the flint data. A) Row plot, B) Column plot.

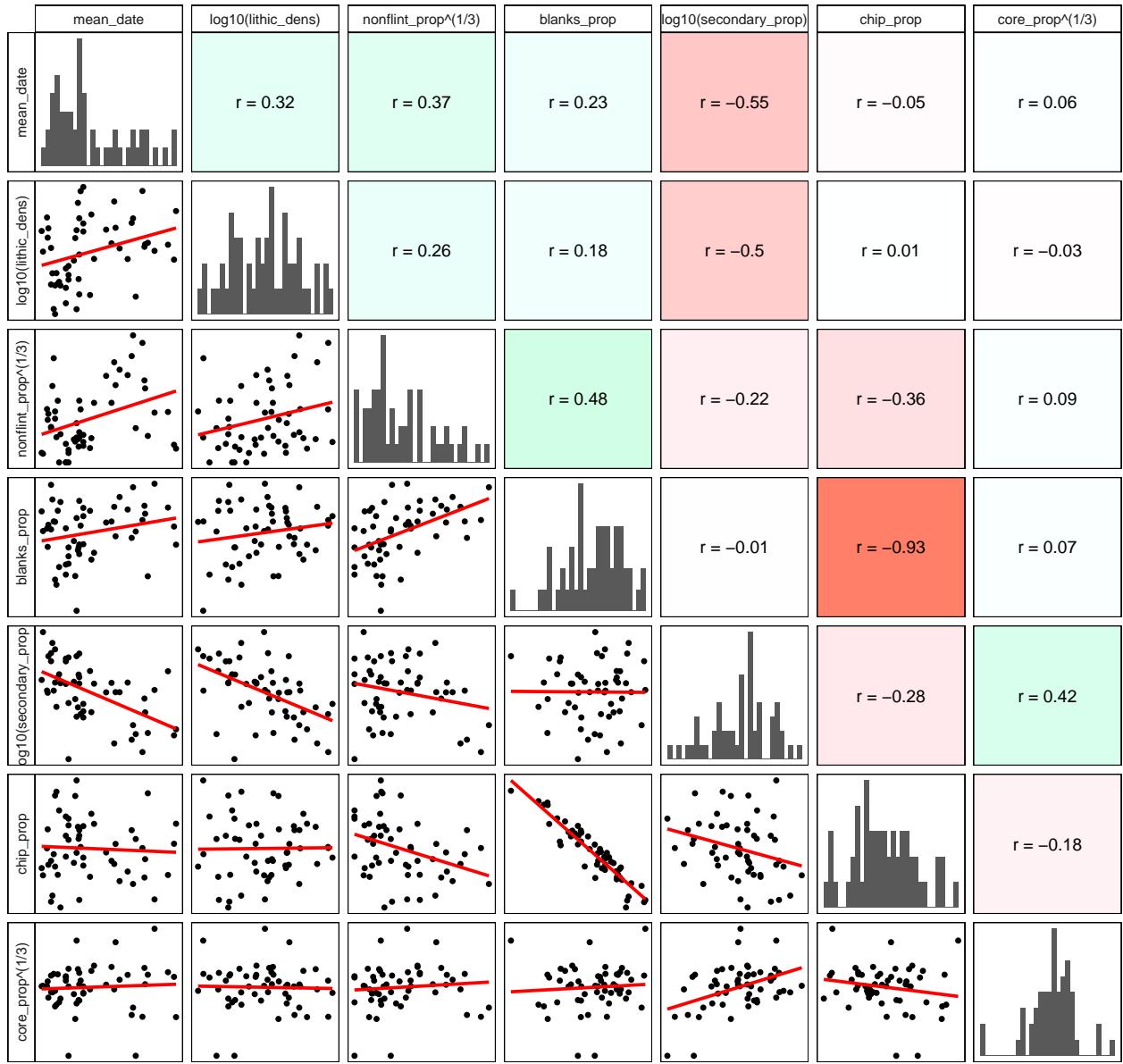


Figure 5: Correlation matrix showing transformation of skewed variables for the PCA. The mean age of the sites has also been included to visualise overall temporal trends. Cells below the diagonal display the bivariate distributions with a fitted OLS-regression. The cells above the diagonal display and are coloured by the corresponding Pearson's correlation coefficient.

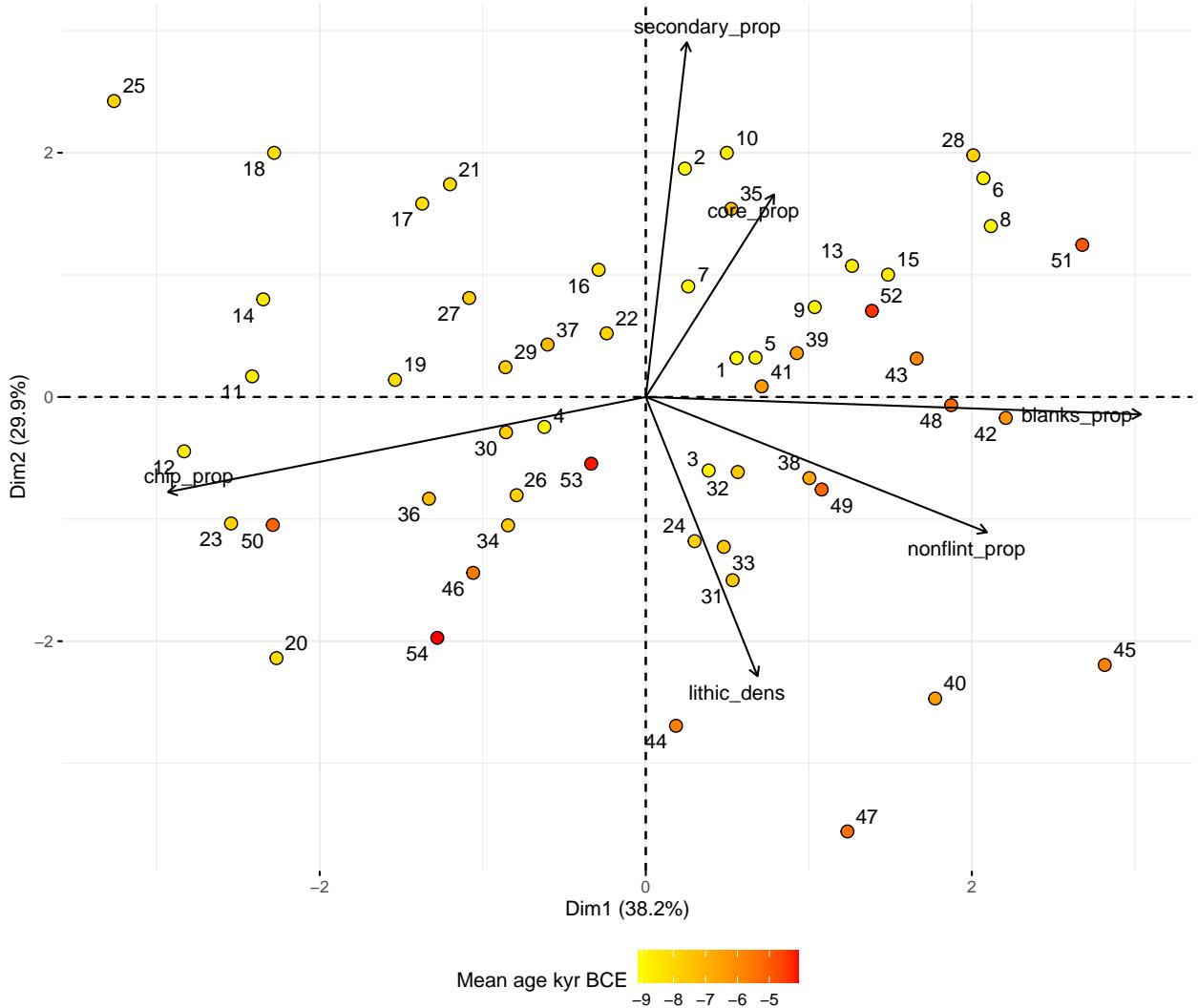


Figure 6: PCA using variables that have been related to mobility patterns. Note that details on the transformation of the variables has been left out of the plot for clarity, but follow those given in Figure 4.

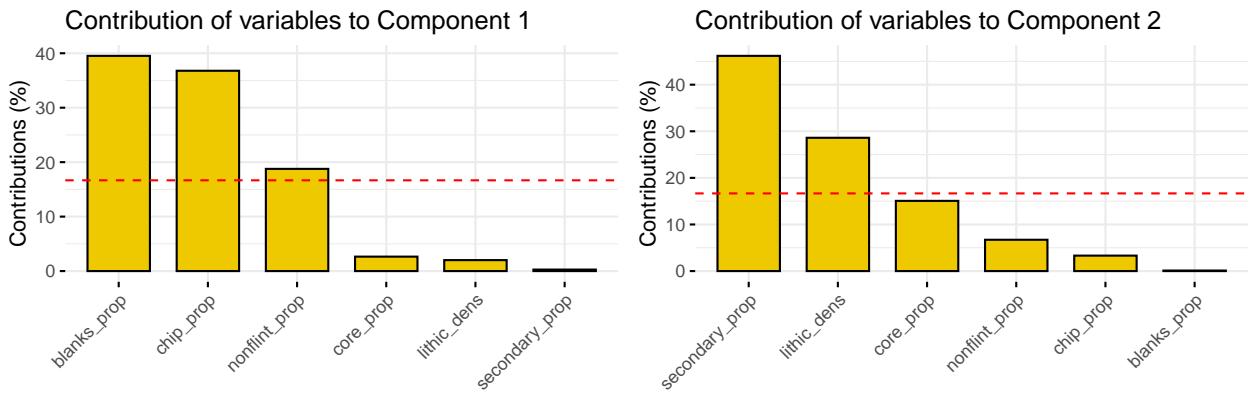


Figure 7: Contribution of variables to the first two components of the PCA. The dotted red line indicates the expected contribution from each variable given a uniform distribution of impact.

(cf. Manninen and Knutsson 2014), but while the negative correlation is slightly less marked when only the flint data is considered ($r = -0.4$), the general pattern is the same (Figure 8B). 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.

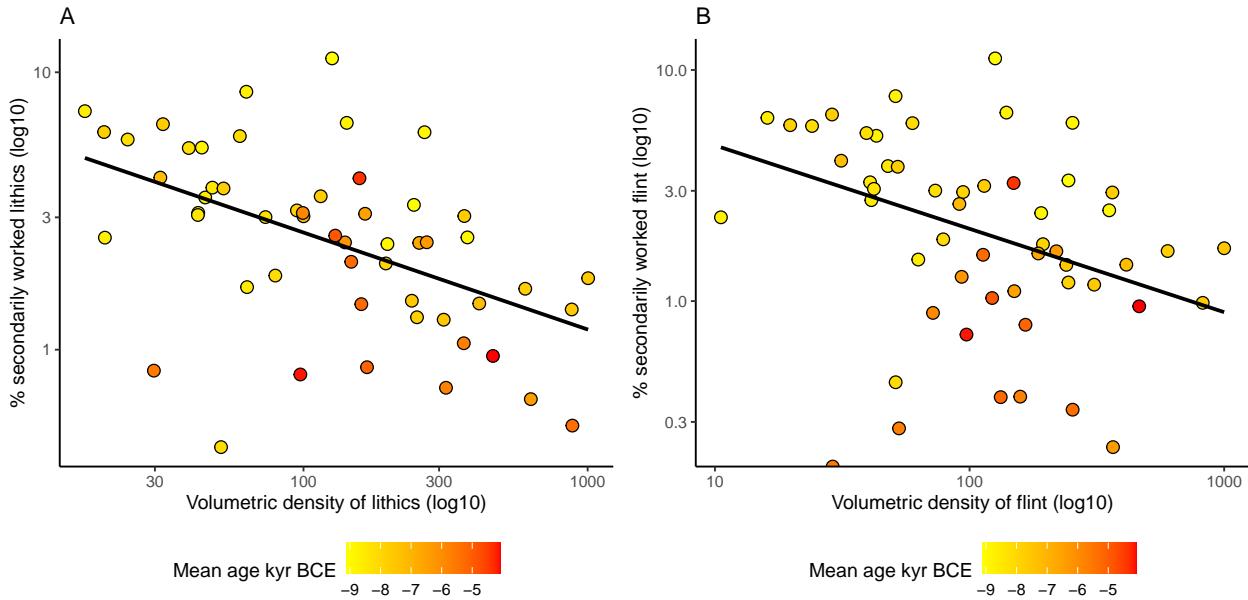


Figure 8: Relative frequency of secondarily worked lithics plotted against the volumetric density of artefacts for A) All lithics ($r = -0.5$), B) Flint ($r = -0.4$). The logarithm is taken to base 10 on all axes.

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 value for artefact density was then made negative to reflect its relationship with degree of curation. The 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. 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 their respective date ranges as provided in Figure 1. For sites with radiocarbon age determinations the dates were drawn from the 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 (Figure 9). This simulation was repeated 1000 times. 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 for the rest of the Mesolithic. The variation in degree of curation is also markedly higher after 8000 BCE. Figure 9B 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 noticeably different.

6 Discussion

The results of the CA appear to align well with previous research (e.g. Solheim 2017b, with references). In the flint material the earliest sites are separated from the rest primarily based on the presence of macro tools, microburins, projectiles, and, for slightly younger sites, core fragments and blades (cf. Bjerck 2017; Breivik

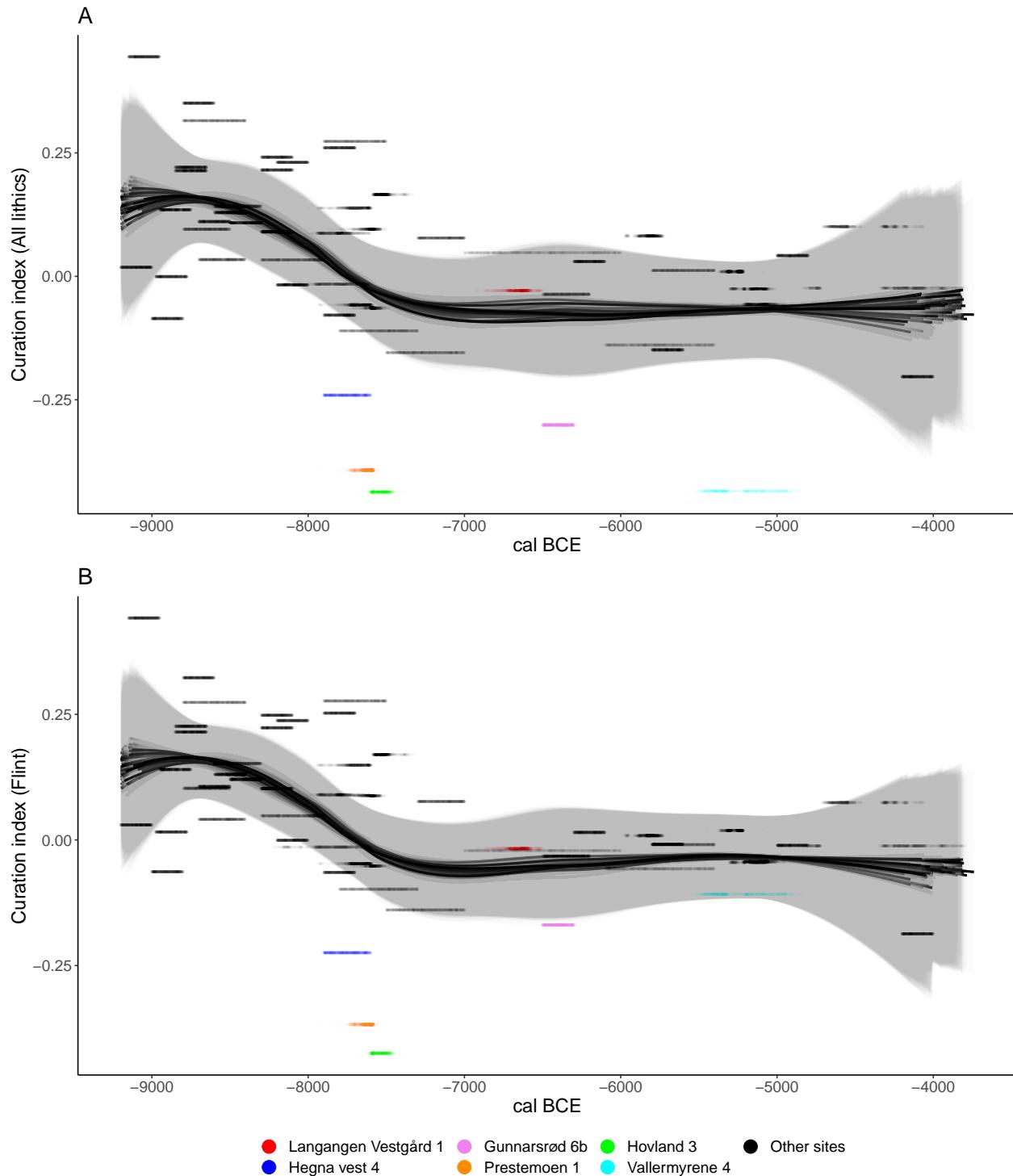


Figure 9: Temporal variation in the curation index for A) All lithics, and B) Flint. The temporal uncertainty is handled by means of a simulation approach where the site ages are drawn from their respective age determination probability density functions given in Figure 1B. A LOESS curve has been fit 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.

340 et al. 2018; Damlien and Solheim 2018; Fuglestvedt 2009; Jaksland and Fossum 2014). The importance of
341 the latter two can be associated with the blade technology that is introduced with the Middle Mesolithic,
342 characterised by blade production from conical and sub-conical cores with faceted platforms that involves the
343 removal of core tablets and rejuvenation flakes (Damlien 2016). When it comes to the non-flint material,
344 projectiles are to a larger extent a property of the earlier sites than later ones. The use of metarhyolite for
345 the production of axes is present at some earlier sites in addition to the previously mentioned Nedre Hobekk
346 2, and the production of non-flint hatchets and core axes is introduced in the Microlith Phase (Eymundsson
347 et al. 2018; Jaksland and Fossum 2014; Reitan 2016). However, in agreement with the literature, this is
348 evidently not as prominent a part of these assemblages.

349 The flint material of the later sites are to larger extent characterised by micro-blades, which corresponds to
350 the transition to micro-blade production from handle cores (e.g. Solheim et al. 2020). A more fragmented
351 flint material, as indicated by the relative importance of flint chips and fragments, is also a previously noted
352 property of some later Mesolithic, as well as early Neolithic sites (e.g. Fossum 2017; Stokke and Reitan 2018).
353 The most defining material for the later sites, however, is non-flint macro tools and associated debitage, which
354 is dominating some of these assemblages. It was noted above that this material does not seem to impact
355 the latest sites, which would indicate that specialised axe production sites disappear towards the end of the
356 Mesolithic, a notion that would be in line with previous suggestions (e.g. Glørstad 2011; Reitan 2016).

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

368 The curation index has relatively high values until some time before 8000 BCE, before it drops and stabilises
369 around 7000 BCE. This pattern is evident in both the flint data and when all lithics are treated in aggregate.
370 Furthermore, the increased variation in degree of curation after around 8000 BCE could indicate that these
371 sites were associated with a more varied mobility pattern. The five sites that have values on the curation
372 index below c. -0.25 could in this perspective have predominantly functioned as base-camps within a logistic
373 settlement pattern. That these assemblages reflect stays of a longer duration was suggested for all five sites
374 in the original reports (Carrasco et al. 2014; Eigeland and Fossum 2017; Persson 2014; Solheim and Olsen
375 2013), with the exception of for Vallermyrene 4, which was argued to be a specialised axe production site, not
376 necessarily associated with lower degrees of mobility (Eigeland and Fossum 2014). This highlights a possible
377 issue pertaining to raw-material variability, as the coarse non-flint material used for the production of axes
378 generally results in a relatively large amount of waste per produced tool, possibly skewing the curation index
379 when compared to assemblages dominated by flint. Referring back to the CA, the difference is most marked
380 for the sites in the later part of the Mesolithic where non-flint material become more dominating parts of the
381 assemblages. As can be seen in Figure 9B, the degree of curation is markedly higher for both Gunnarsrød 6b
382 and Vallermyrene 4 when the non-flint material is excluded, although they remain more expedient than that
383 of contemporary assemblages. Thus, the degree of expediency for assemblages dominated by non-flint might
384 be somewhat exaggerated when the non-flint material is included, while its exclusion would likely lead to its
385 underestimation. One possible approach could be to weigh the curation index by the proportion of non-flint
386 material in the assemblages. This is not explored further here, however, as the overall tendencies appear
387 robust to this effect.

388 Another case also worth commenting on is Langangen Vestgård 1, which, on the grounds of an overall large
389 number of artefacts and the possible presence of a dwelling structure was argued to reflect a more permanent
390 site location in the original report (Melvold and Eigeland 2014). However, the relatively high value on the
391 curation index could mean that the site reflects the aggregation of stays which predominantly have been of a

392 comparable duration to those on contemporary sites, while the possible dwelling structure, if taken as an
393 indication of longer stays, could in this perspective represent a remnant from one or a few visits of longer
394 duration that constitute a smaller fraction of the use-life of the site as a whole (cf. Barton and Riel-Salvatore
395 2014).

396 While there are certainly nuances in the material that might lead one to question the applicability of the
397 VDL and RFSL measures for any individual site, the overall pattern for curation does appear robust. The
398 curation index is relatively high and uniform until some time before 8000 BCE. This corresponds well with
399 the view that the Early Mesolithic is characterised by a high and uniform degree of mobility. This is followed
400 by a marked increase in expedience, which has stabilised by around 7000 BCE. Again, this corresponds well
401 with the employed chronological framework. Referring back to the demographic changes that are to take
402 place around this transition, the Microlith phase could thus represent a period where migrating people and
403 new living practices were propagating through societies in south-eastern Norway—a process that in light of
404 the curation data would have concluded around 7000 BCE.

405 The curation index then remains stable for the rest of the Mesolithic. This suggests that the transition to
406 mobility patterns traditionally ascribed to the Nøstvet Phase can indeed be traced back to the Microlith
407 Phase (cf. Solheim and Persson 2016). The continued stability of the curation index could also indicate that
408 the demographic changes suggested to take place in the Transverse Arrowhead Phase are not related to major
409 shifts in land-use and mobility patterns. However, it is worth highlighting the strained sample size for the
410 later parts of the Mesolithic, which could mean that the effect is simply missed.

411 As it stands, the main hypotheses resulting from the present analysis would be that settlement patterns in
412 the earliest parts of the Mesolithic were characterised by relatively high and uniform degrees of mobility,
413 which then drop before levelling off at around 7000 BCE. These then remain stable throughout the rest of
414 the period, despite variation pertaining to other aspects of the lithic inventories, as evidenced by the CA.
415 The fall in curation levels and parallel increase in variation would seem to correlate well with a transition
416 from a predominantly residential to logistical settlement system (Binford 1980). This indicates, in turn, that
417 the measures represent an empirical link between technological organisation and economic behaviour and
418 mobility patterns (Riel-Salvatore and Barton 2004).

419 7 Conclusion

420 The results of the CA align well with results of previous research in south-eastern Norway, indicating that
421 meaningful chronological patterning is associated with the employed artefact categories. These tendencies are
422 already well-established when it comes to the formal tool types and some debitage categories, but have been
423 given less focus in light of entire assemblages. Precisely what behavioural implication the development in the
424 occurrences of the tool and debitage categories have are less clear, but appears to follow a different and more
425 complex development over time than that of curation, as operationalised here.

426 The temporal trends associated with the curation index corresponds surprisingly well with trajectories of
427 cultural development previously suggested in the literature, and does therefore, in my view, suggest that
428 shifts in land-use and mobility patterns are the main drivers behind this empirical pattern—in line with the
429 framework of Barton et al. (2011). Another perspective would be that this is not surprising at all (cf. Kuhn
430 and Clark 2015:14), and that the previously demonstrated relevance of these measures across a wide range
431 of contexts points to their pervasive relevance for the organisation of lithic technology, and, therefore, that
432 there should be little reason to think Mesolithic south-eastern Norway should be any different. However,
433 the conclusion that these these measures apply to and appear to capture the dimensions of interest in a
434 relatively controlled empirical setting, reached by means of an exploratory analysis can only constitute a first
435 analytical step. As Elster (2015:12) has pointed out, the human mind seems to have a propensity to settle
436 for an explanation that *can* be true, as soon as this has been reached. This, however, can only constitute
437 the absolute minimum of what is required of a proposed explanation. Subsequent steps should be to probe
438 and challenge this explanatory framework, also in light of alternative hypotheses (e.g. Clark 2009; Perreault
439 2019). The empirical relationship does nonetheless hold great potential for large scale comparative studies in

⁴⁴⁰ Mesolithic Scandinavia and beyond. Furthermore, the curation index was here simply narratively associated
⁴⁴¹ with the most immediate chronological trends emphasised in the literature concerned with the Mesolithic
⁴⁴² of south-eastern Norway. The explicit quantification does, however, offer the possibility to conduct formal
⁴⁴³ comparisons with a wide range of environmental, demographic and cultural dimensions across multiple scales
⁴⁴⁴ of analysis.

445 Declaration of interest

446 The author has no conflicts of interest to declare.

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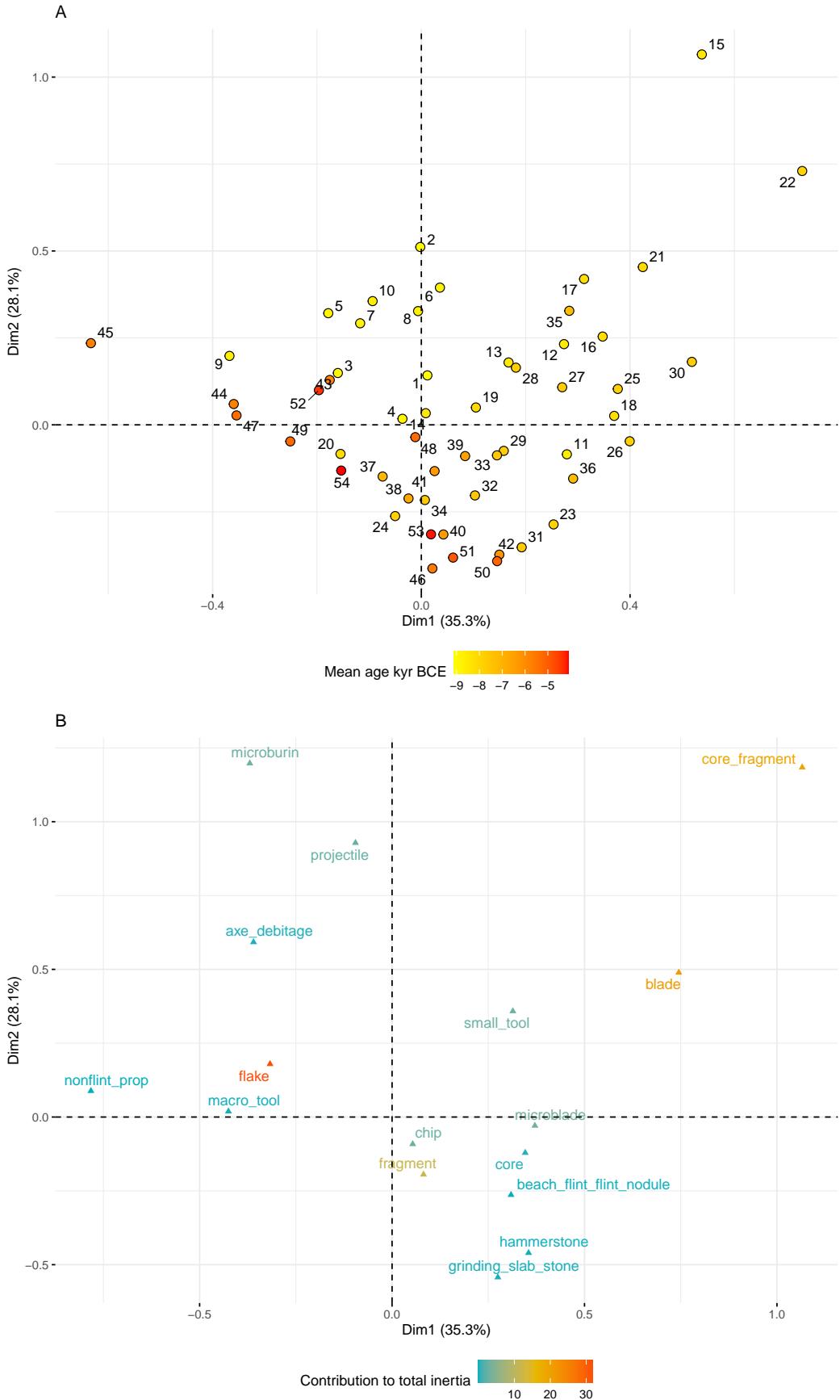


Figure 10: Correspondence analysis collapsing artefact types irrespective of raw-material and including proportion of non-flint as its own variable. A) Row plot, B) Column plot.

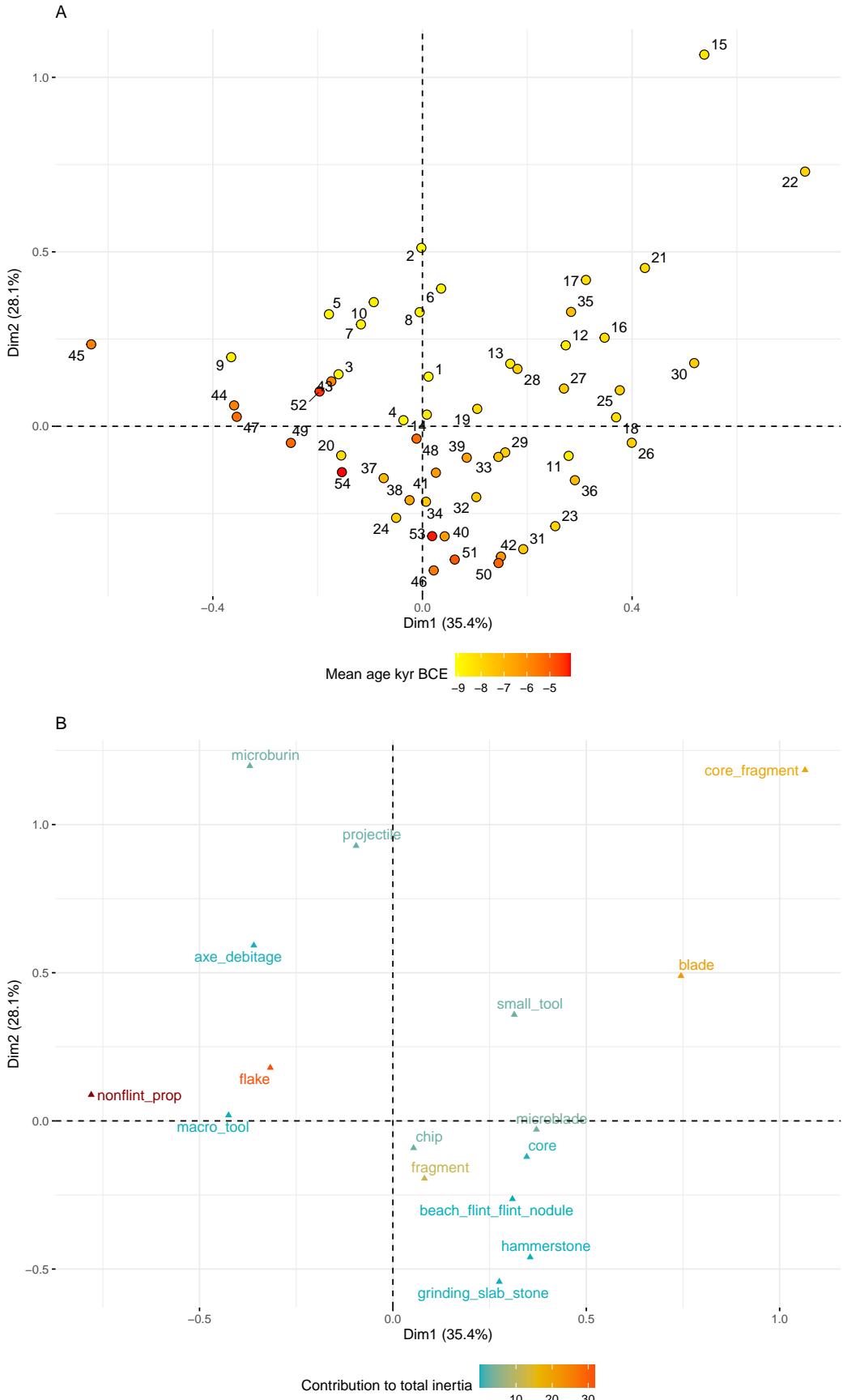


Figure 11: Same as above, only that here the proportion of non-flint is used as a supplementary column. The negligible difference between this CA and that above indicates that the raw material variability is integrated in the different artefact types, and therefore that the effect of artefact types and raw material cannot be separated. These plots thus hide important variability that is captured in the ones presented in the main text. A) Row plot, B) Column plot.

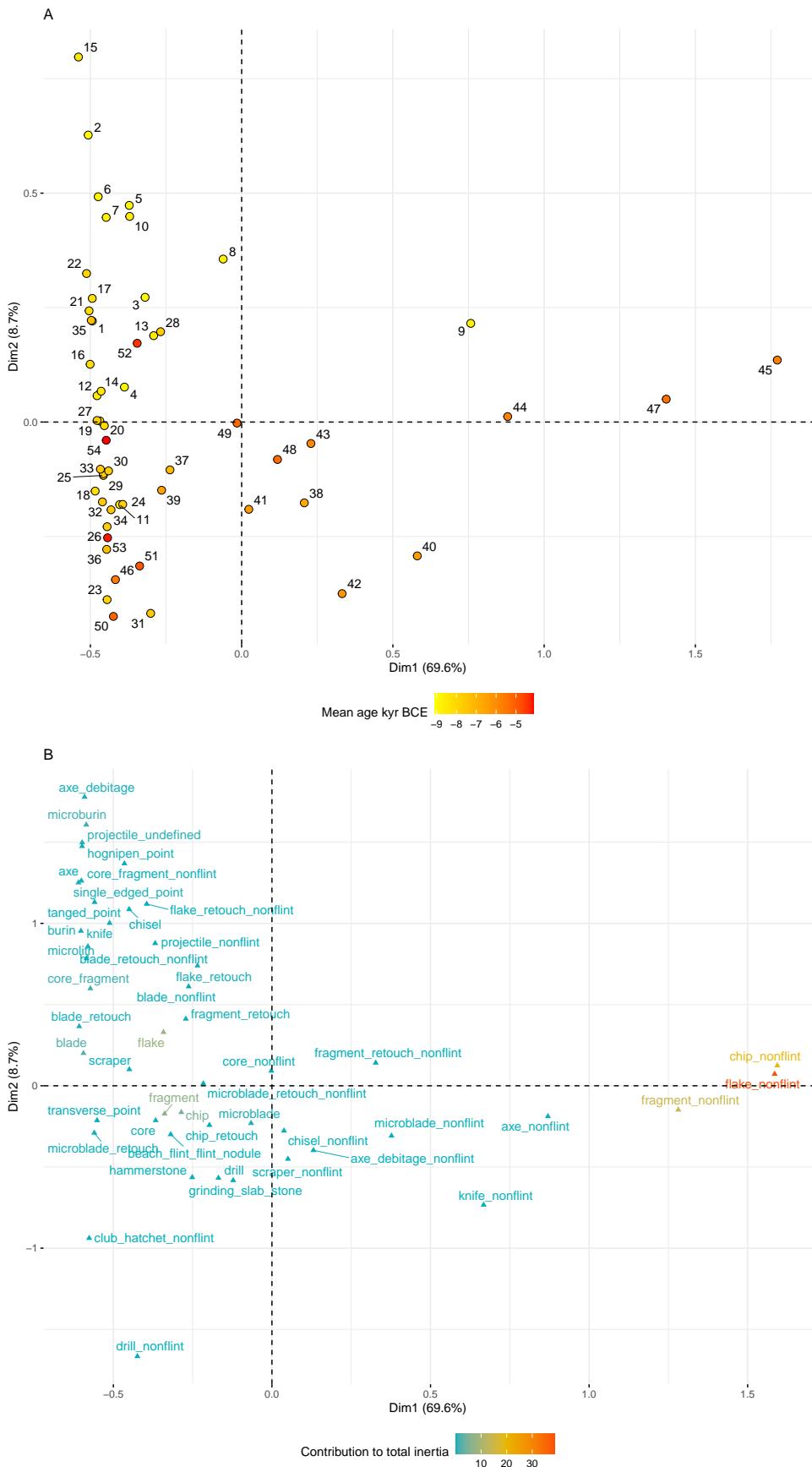


Figure 12: Correspondence analysis using all original artefact categories. A) Row plot, B) Column plot.