

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

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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 in established use 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.

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²⁴ **Highlights**

- Multivariate exploratory analysis of Mesolithic assemblages in south-eastern Norway
- Explores patterns related to 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. This would in turn
53 give analytical access to the organisation of lithic technology and variation in past behaviour, adaptation and
54 demographic development (see for example Andrefsky 2009; Barton et al. 2011; Binford 1979; Dibble et al.
55 2017; Rezek et al. 2020). The most immediate danger of the approach outlined here is rather to be overly
56 naive in the causal significance and cultural importance that is ascribed to any identified pattern. As such,
57 the main aim of this analysis is to compare the results with findings reported in previous literature concerned
58 with the Mesolithic in southern Norway and have the generation of new hypotheses as a possible outcome. To
59 this end, the analysis follows two analytical avenues. The first involves an analysis of the assemblages using
60 the classification of the artefacts done for the original excavation reports. The second involves an analysis of
61 the assemblages in light of the so-called Whole Assemblage Behavioural Indicators (e.g. Clark and Barton
62 2017) and other factors that have been employed to align properties of lithic assemblages with land-use and
63 mobility patterns.

64 2 Archaeological context and material

65 The Early Mesolithic, or Flake Axe Phase, is defined as lasting from c. 9300–8200 BCE (Table 2), and is set
66 to start with the first recorded human presence in Norway (Damlien and Solheim 2018). Previous research
67 has typically proposed that the Early Mesolithic is characterised by a relatively high degree of mobility, and
68 low variation in site types and associated mobility patterns (e.g. Bjerck 2008; Breivik and Callanan 2016;
69 Fuglestvedt 2012; Nærøy 2018; but see Åstveit 2014; Viken 2018). Around the transition to the subsequent
70 Middle Mesolithic or Microlith Phase at c. 8200 BCE, pervasive changes in blade and axe technology occur
71 (Damlien 2016; Eymundsson et al. 2018; Solheim et al. 2020), which in turn has been associated with changes
72 in population genetics and related migration events hailing from the Eurasian steppes (Günther et al. 2018;
73 Manninen et al. 2021). The Microlith Phase is defined as lasting until around 7000 BCE, which is followed by
74 the Pecked Adze Phase, characterised by a more dominating presence of non-flint macro tools and associated
75 production waste in the assemblages (Reitan 2016). The next typological transition at c. 5600 BCE signifies
76 the onset of the Nøstvet Adze Phase. While previously defined as having a slightly longer duration, the
77 Nøstvet Phase has traditionally been seen as representing the onset of more varied settlement systems and
78 stable mobility patterns (e.g. Jakslund 2001; Lindblom 1984). In recent years it has been suggested that
79 the transition to a decrease in mobility and more varied land-use patterns can be traced back to the Middle
80 Mesolithic (Solheim and Persson 2016). The subsequent Transverse Arrowhead Phase (c. 4500–3900 BCE) is
81 characterised by a dramatic decrease in axe finds, and the introduction of new flint projectiles (Reitan 2016).
82 It has recently been suggested that a dispersal of people from southern Scandinavia into southern Norway
83 takes place in this period (Eigeland 2015:379; Nielsen 2021), which could follow after a preceding population
84 decline at c. 4300 BCE (Nielsen 2021; cf. Solheim 2020; Solheim and Persson 2018).

85 A defining characteristic of the Norwegian Mesolithic is that a clear majority of the known sites are located
86 in coastal areas (e.g. Bjerck 2008). Furthermore, these coastal sites appear to predominantly have been
87 located on or close to the contemporary shoreline when they were in use (Åstveit 2018; Breivik et al. 2018;

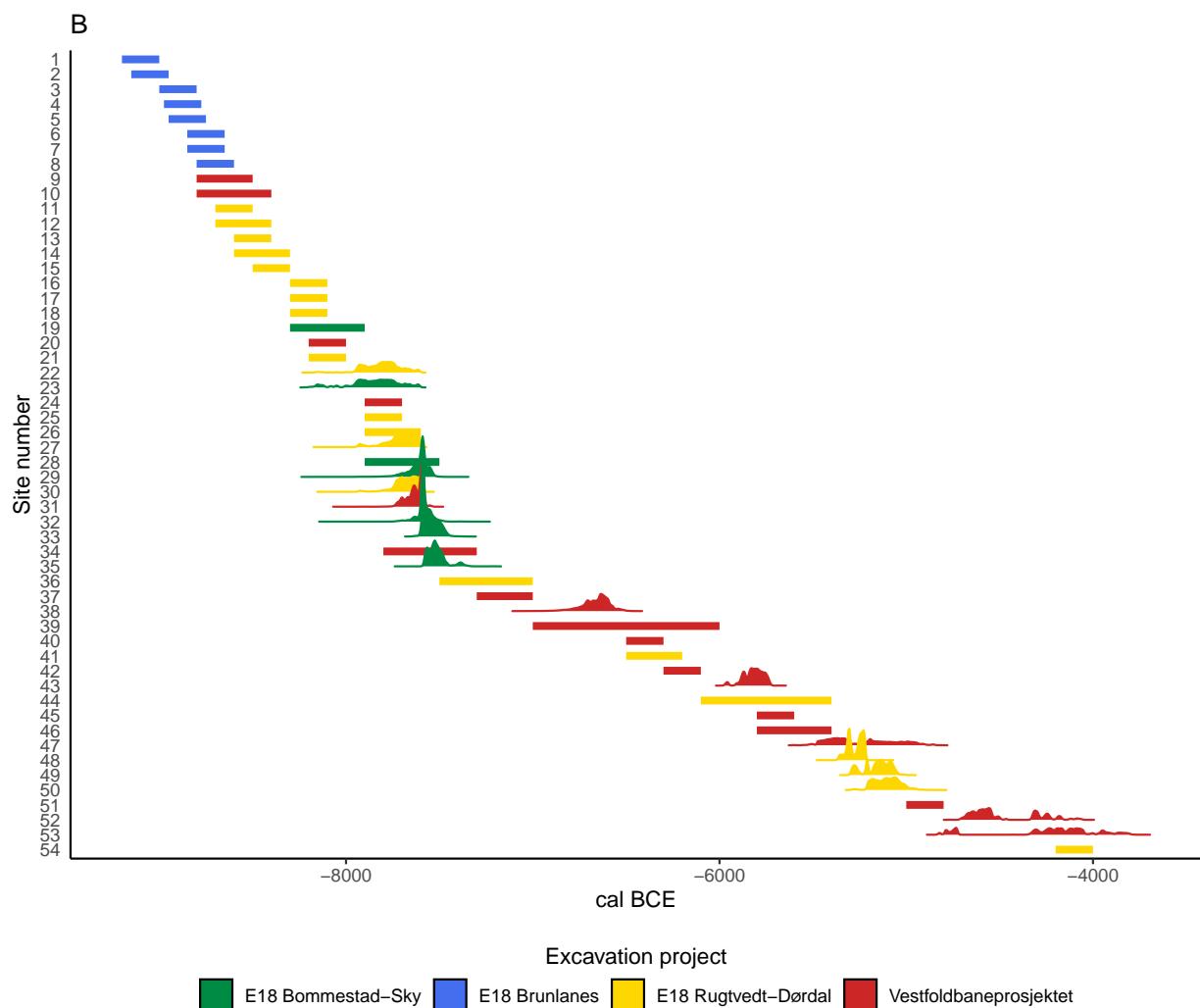


Figure 1: A) Spatial and B) temporal distribution of the sites chosen for analysis. Radiocarbon age determinations are given as the sum of the posterior density estimates. Solid lines indicate that the site has been dated with reference to relative sea-level change and typological indicators. These follow 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 Møller 1987; Solheim 2020). In south-eastern Norway, this pattern is combined with a continuous regression
 89 of the shoreline, following from isostatic rebound (e.g. Romundset et al. 2018; Sørensen 1979). The fairly
 90 rapid shoreline displacement means that the sites tend not to have retained their strategic or ecologically
 91 beneficial shore-bound location for long periods of time (cf. Perreault 2019:47). Consequently, the shore-bound
 92 settlement, combined with the rapid shoreline displacement has resulted in a relatively high degree of spatial
 93 separation of cumulative palimpsests, to follow the terminology of Bailey (2007), while the reconstruction of
 94 the trajectory of relative sea-level change allows for a relatively good control of when these accumulation
 95 events occurred. In other parts of the world, a higher degree of spatial distribution means that while the
 96 physical separation of material can help delineate discrete events, this typically comes at the cost of losing
 97 temporal resolution as any stratigraphic relationship between the events is lost (Bailey 2007).

98 The 54 coastal sites chosen for analysis here have a relatively limited geographical distribution (Figure 1A).
 99 The sites were excavated as part of four larger excavation projects that all took place within the last 15 years
 100 (Jaksland and Persson 2014; Melvold and Persson 2014; Reitan and Persson 2014; Solheim 2017a; Solheim
 101 and Damlien 2013). The sites included in the analysis consist of all Mesolithic sites excavated in conjunction
 102 with the projects that have assemblages holding more than 100 artefacts. The institution responsible for
 103 these excavations was the Museum of Cultural History in Oslo. This has led to a considerable overlap in the
 104 archaeological personnel involved, and comparable excavation practices across the excavations. Furthermore,
 105 with these projects, major efforts were made to standardise how lithic artefacts were to be classified at the
 106 museum (Koxvold and Fossum 2017; Melvold et al. 2014). As a result, this should reduce the amount of
 107 artificial patterning in the data incurred by discrepancies in the employed systems for categorisation (cf.
 108 Clark and Riel-Salvatore 2006; Dibble et al. 2017).

109 The lithic data analysed are based on the classification of the site assemblages done for the original excavation
 110 reports, and consists of 48 variables representing differentdebitage and tool types. The artefact data have
 111 been divided into flint and non-flint materials. Flint does not outcrop naturally in southern Norway, and is
 112 only available locally as nodules that have been transported and deposited by retreating and drifting ice (e.g.
 113 Berg-Hansen 1999). This means that the distribution and quality of flint has been impacted by a diverse set
 114 of climatic and geographical factors (Eigeland 2015:46). Thus, while flint is treated as a unified category here,
 115 the variability in quality could have been substantial. Furthermore, the various non-flint raw materials that
 116 have been lumped together have quite disparate properties, where fine-grained cryptocrystalline materials are
 117 often used as a substitute or supplement to flint, while other, coarser materials are usually associated with
 118 the production of axes and other macro tools. Given this differentiated use, these raw-material properties are
 119 expected to be reflected in the retaineddebitage and tool categories. An important benefit of combining all
 120 of the non-flint materials is that this reduces the dependency on whether or not these have been correctly and
 121 consistently categorised for the reports (cf. Frivoll 2017). Finally, while factors such as landscape changes
 122 through shoreline displacement can have led to variable raw-material availability at the analysed sites, for
 123 example by impacting accessibility by means of watercraft, the relatively constrained geographical distribution

¹²⁴ of the sites hopefully counteracts some environmentally given sources of 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

125 3 The analysis of lithic assemblages

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

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

162 However, for the most part we lack even a most basic understanding of what any individual lithic object
 163 in an assemblage has been used for (Dibble et al. 2017). For example, a vast amount of artefacts defined
 164 as debitage are likely to have fulfilled the function of tools, and both debitage and formal tool types could
 165 have had various different purposes and had a multitude of shapes throughout their use-life. This has major
 166 implications that the above-outlined analysis does not take properly into account, rendering it difficult to
 167 align any identified pattern with specific behavioural dimensions. As a consequence, the second part of
 168 the analysis employs a suite of measures developed for the classification of lithic assemblages with these

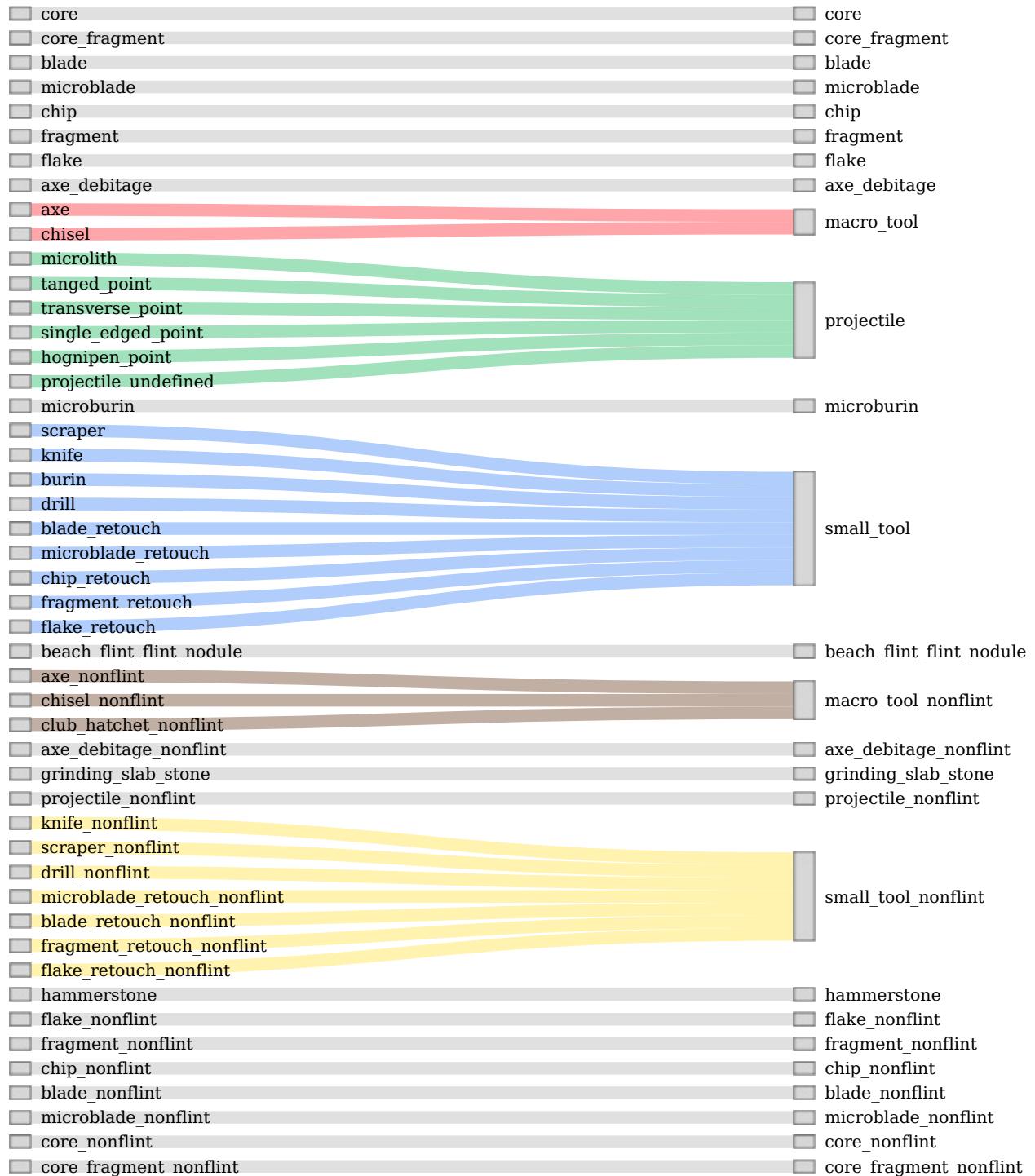


Figure 2: Aggregation of variables for the correspondence analysis. The column on the left shows the variables as originally compiled. The column on the right shows how these have been aggregated for the analysis.

169 inferential limitations in mind (Barton et al. 2011; Clark and Barton 2017, and below). The logic behind
170 these measures are founded on an understanding of technology as being organised along a continuum ranging
171 between curated and expedient (Binford 1973, 1977, 1979). An expedient technological organisation pertains
172 to the situational production of tools to meet immediate needs, with little investment of time and resources in
173 modification and rejuvenation, resulting in high rates of tool replacement. Curated technological organisation,
174 on the other hand, has been related to manufacture and maintenance of tools in anticipation of future use,
175 the transport of these artefacts between places of use, and the modification and rejuvenation of artefacts for
176 different and changing situations.

177 However, following not least from the ambiguous definition first put forward by Binford (1973), the theoretical
178 definition of curation, its archaeological correlates, and behavioural implications have been widely discussed
179 and disputed (e.g. Bamforth 1986; Nash 1996; Shott 1996; Surovell 2009:9–13). Still, that the distinction can
180 offer a useful analytical point of departure if clearly and explicitly operationalised seems more or less agreed
181 upon, and some dimensions of the concept are generally accepted. For example, although precisely how it is
182 measured may vary, the empirical correspondent to a curated technological organisation is typically defined
183 by high degrees of retouch, as this is commonly seen as a means of realising the potential utility of a tool—or
184 extending its use-life—by the repeated rejuvenation and modification of edges (e.g. Bamforth 1986; Dibble
185 1995; Shott and Sillitoe 2005).

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

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

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

221 **4 Methodology**

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

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

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

241 Following the WABI and other factors associated with mobility patterns, as presented above, the variables
242 employed in the second part of the analysis are relative frequency of secondarily worked lithics (RFSL),
243 defined as the proportion of the assemblages constituted by retouched or ground lithics; volumetric density
244 of lithics (VDL), defined as the total number of artefacts divided by total excavated m³ as taken from the
245 original reports; relative frequency of chips, defined as the proportion of artefacts with size < 1mm; relative
246 frequency of cores, the proportion of all artefacts classified as cores in the original reports; relative frequency
247 of blanks, here defined as the proportion of all artefacts classified as flakes, blades, micro-blades or fragments;
248 and finally relative frequency of non-flint material. Following Bicho and Cascalheira (2020), the analysis is
249 done using principal components analysis (PCA), leading to a shift in focus from the relative composition
250 emphasised by the CA, to having more weight placed on patterning in the most abundant occurrences (Baxter
251 1994:71–77).

252 A note should also be made on the fact that a few variables that are sometimes invoked for the classification of
253 sites in terms of associated mobility patterns are omitted here (e.g. Bergsvik 1995:116; Bicho and Cascalheira
254 2020; Breivik et al. 2016). For the assemblage data itself this especially pertains to diversity in tool-types
255 (Canessa 2021), which has been omitted in light of the above-mentioned Frison effect. Number of features on
256 the sites has also been disregarded as taphonomic loss is likely to have led to a chronological bias in their
257 preservation. Similarly, the number of activity areas, effectively number of artefact clusters, however defined,
258 has also been disregarded. This follows most notably from the fact that the impact of post-depositional
259 processes at Stone Age sites in Norway is arguably understudied (Jørgensen 2017). This pertains for example
260 to bio-turbation in the form of three-throws, which can have a detrimental effect on the original distribution
261 of artefacts, and which can be expected to have impacted several of the sites treated here (Darmark 2018;
262 Jørgensen 2017).

263 **5 Results**

264 The general impression from the CA is that a chronological dimension accounts for a substantial amount of
265 patterning in the data (Figure 3). This is indicated by the general transition across the colour scale in the
266 row plot (Figure 3A), as well as the horseshoe curve or Guttman effect evident in the column plot (Figure
267 3B, Baxter 1994:119–120; Lockyear 2000). The fact that the two first dimensions of the CA accounts for as

268 much as 80.53% of the inertia or variance also means that the structure of the data is well-represented in the
269 plots and that these therefore are likely reflect true patterning in the data.

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

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

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

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

318 There is a strong negative correlation between the two variables ($r = -0.5$) and a general tendency for younger

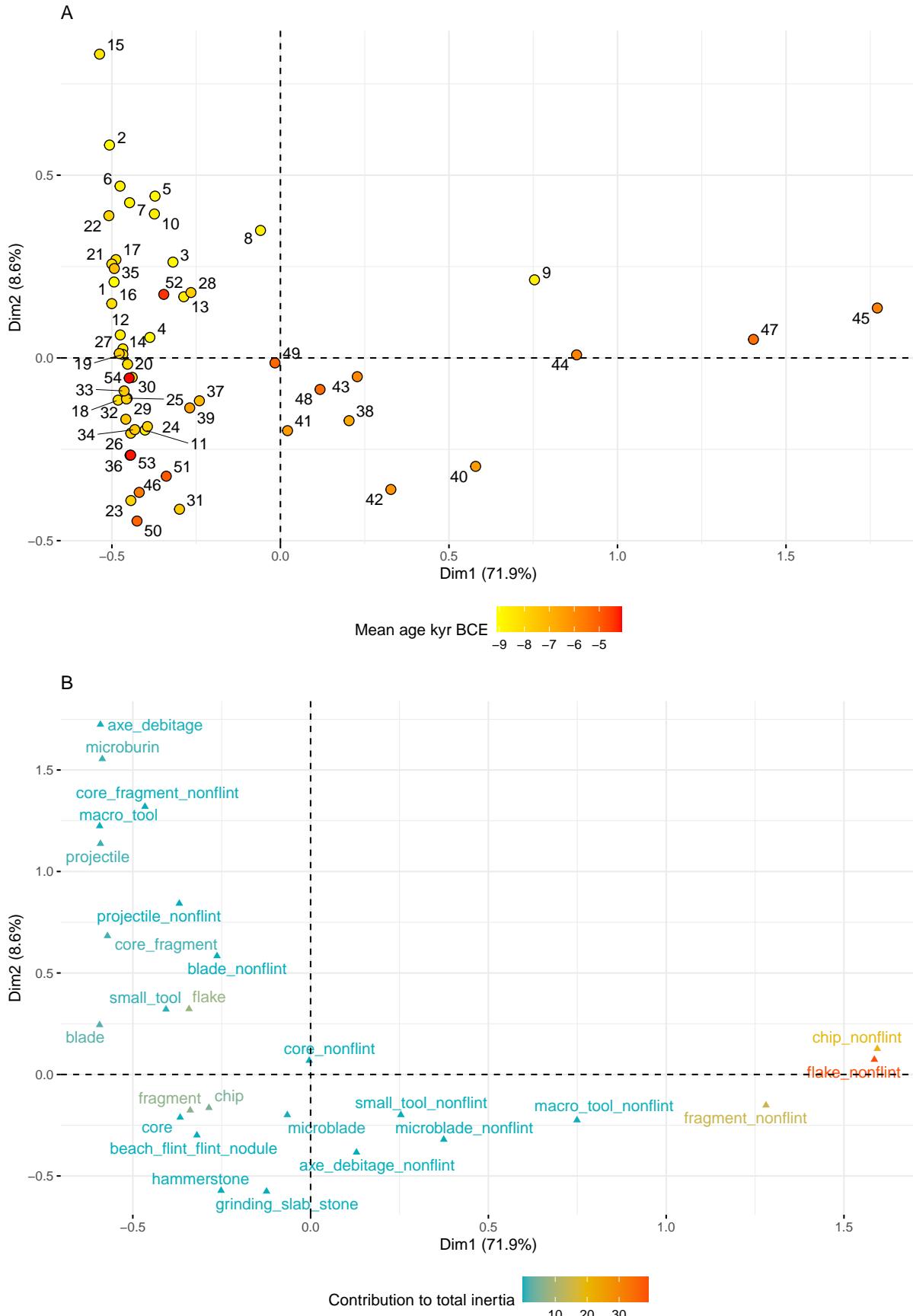


Figure 3: Correspondence analysis using the artefact count data. A) Row plot, B) Column plot. Points close together are more similar. By evaluating how the variables are distributed on the column plot it is possible to say how these define the two axes, in turn making it possible to relate the distribution 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.

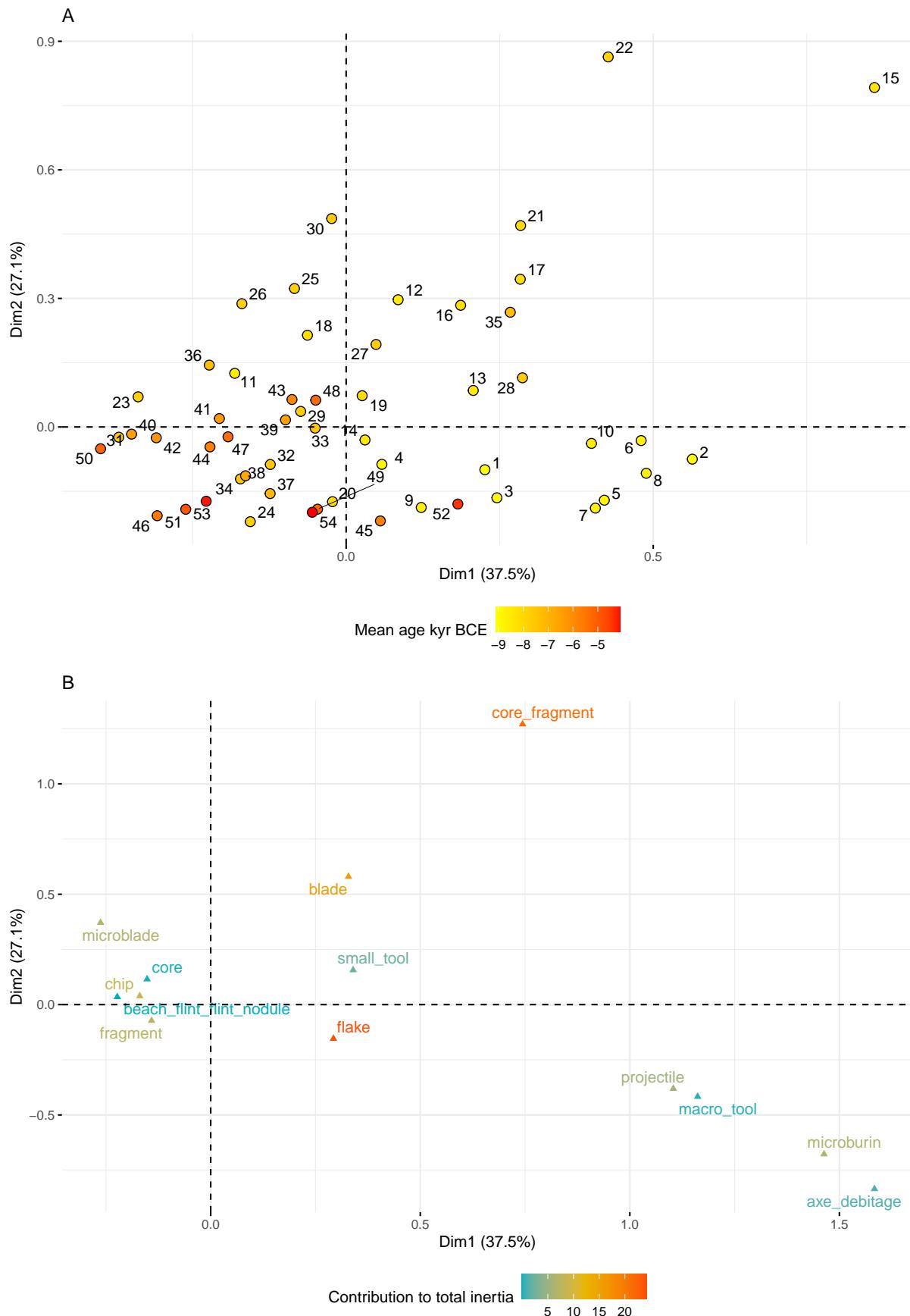


Figure 4: Correspondence analysis using the flint data. A) Row plot, B) Column plot.

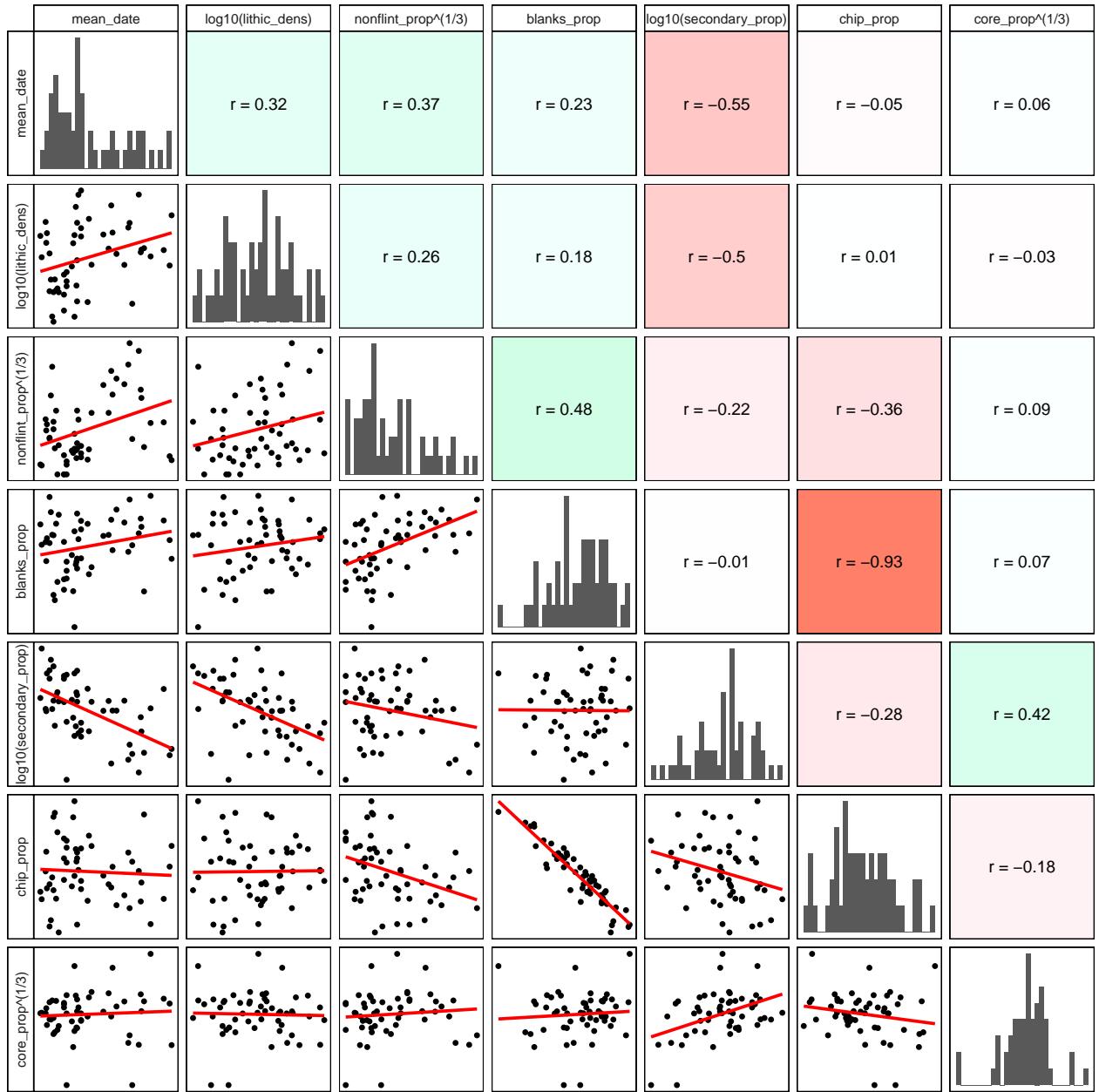


Figure 5: Correlation matrix showing transformation of skewed variables for the PCA. The mean age of the sites has also been included to visualise overall temporal trends. Cells below the diagonal display the bivariate distributions with a fitted OLS-regression. The cells above the diagonal display and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

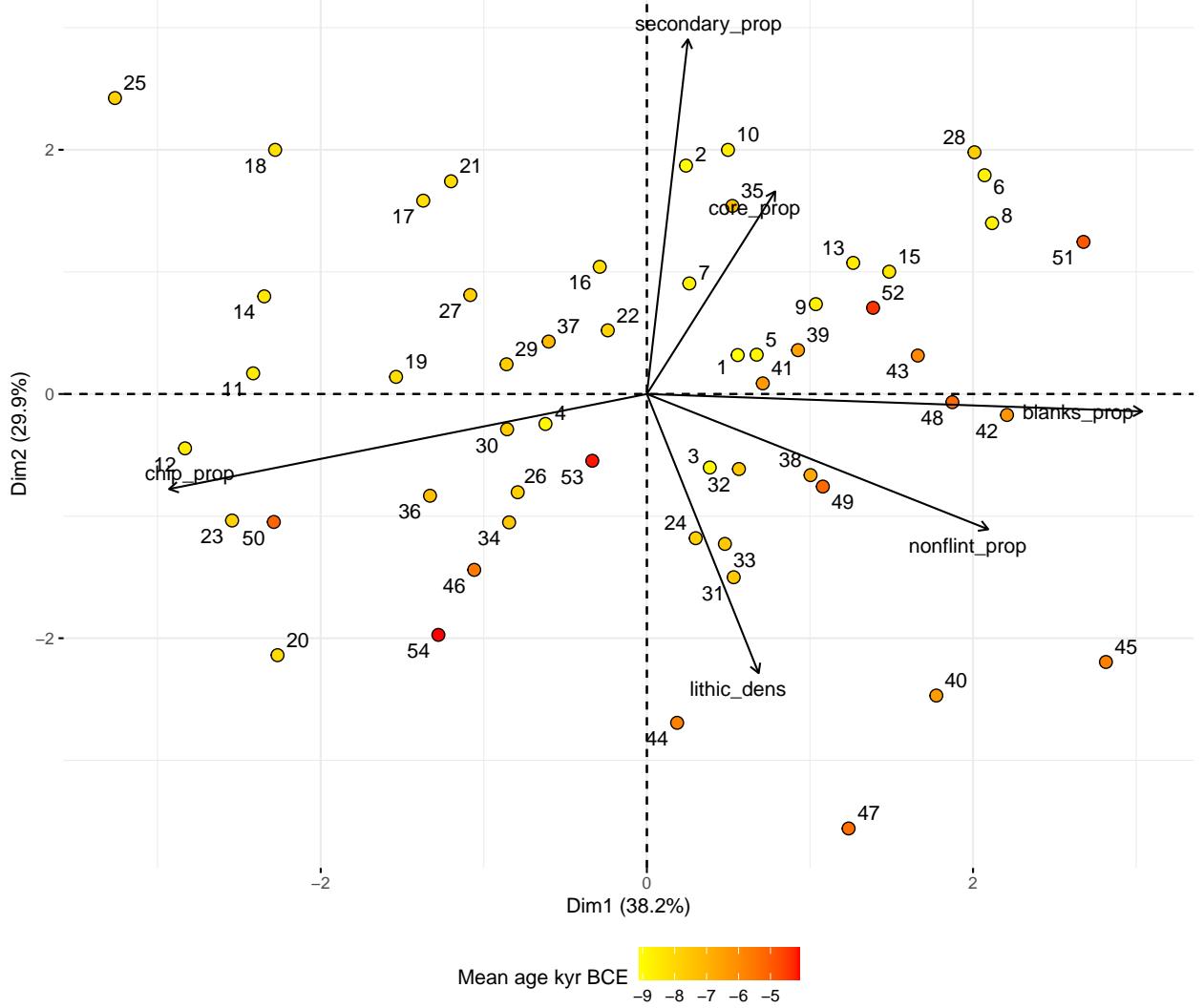


Figure 6: PCA biplot resulting from analysing variables that have been related to mobility patterns. Note that details on the transformation of the variables has been left out of the plot for clarity, but follow those given in Figure 5.

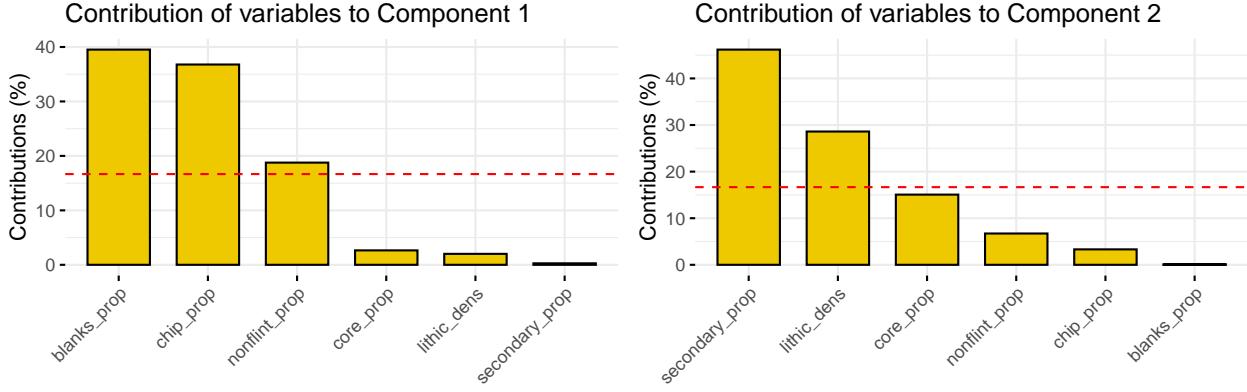


Figure 7: Contribution of variables to the first two components of the PCA. The dotted red line indicates the expected contribution from each variable given a uniform distribution of impact.

sites to be associated with a higher VDL and a lower RFSL than older sites (Figure 8A). The linear correlation is stronger between the mean site age and RFSL ($r = -0.51$), than between mean site age and VDL ($r = 0.22$). Variable non-flint availability and workability has also been suggested to potentially impact these dimensions (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.

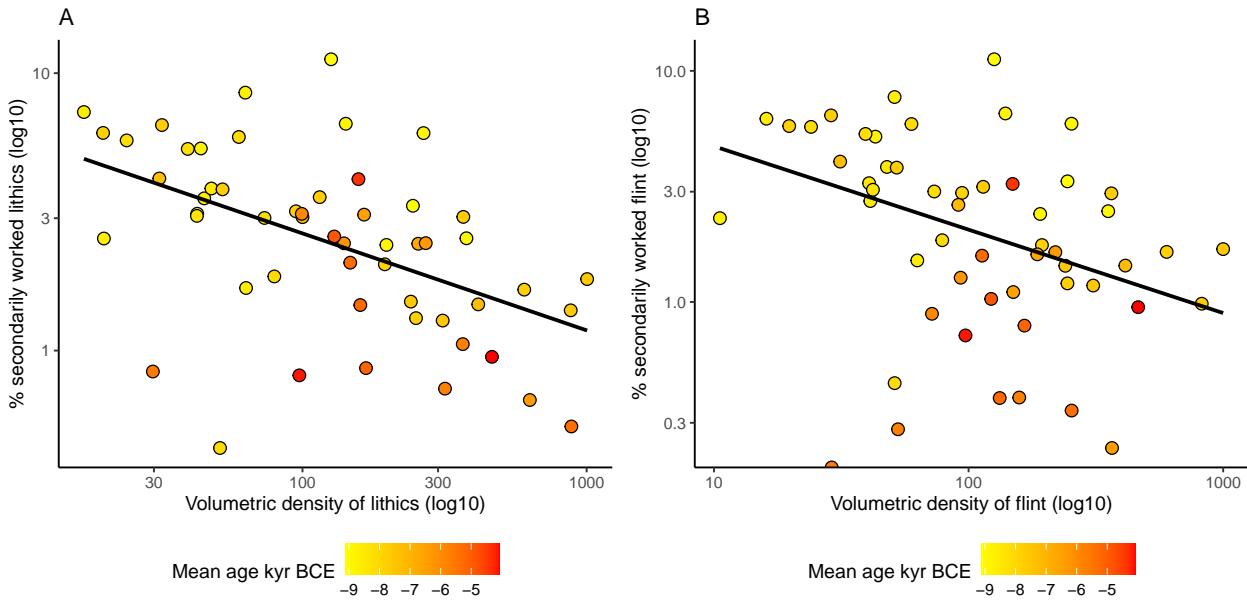


Figure 8: Relative frequency of secondarily worked lithics plotted against the volumetric density of artefacts for A) All lithics ($r = -0.5$), B) Flint ($r = -0.4$). The logarithm is taken to base 10 on all axes.

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.

331 The value for artefact density was then made negative to reflect its relationship with degree of curation. The
332 mean was then found for each site on these two normalised values. To account for the temporal uncertainty
333 associated with the dating of the sites, a simulation-based approach was also adopted (e.g. Crema 2012;
334 Orton et al. 2017). A LOESS curve was fit to the curation index and site age for each simulation run, where
335 the age of each site was drawn as a single year from their respective date ranges as provided in Figure 1. For
336 sites with radiocarbon age determinations the dates were drawn from the summed posterior density estimates,
337 while ages for sites dated with reference to relative sea-level change and typology were drawn uniformly from
338 the associated date range (Figure 9). This simulation was repeated 1000 times. Disregarding the edge-effects
339 at either end of the plot, the general tendency is a relatively high degree of curation among the earlier sites,
340 followed by a marked drop around 8000 BCE. This has stabilised by around 7000 BCE and remains stable
341 for the rest of the Mesolithic. The variation in degree of curation is also markedly higher after 8000 BCE.
342 Figure 9B displays the result of running the same procedure on the flint data. The general pattern follows
343 the same trajectory, but the result for some individual sites is noticeably different.

344 6 Discussion

345 The results of the CA appear to align well with previous research (e.g. Solheim 2017b, with references). In
346 the flint material the earliest sites are separated from the rest primarily based on the presence of macro tools,
347 microburins, projectiles, and, for slightly younger sites, core fragments and blades (cf. Bjerck 2017; Breivik
348 et al. 2018; Damlien and Solheim 2018; Fuglestvedt 2009; Jakslund and Fossum 2014). The importance of
349 the latter two can be associated with the blade technology that is introduced with the Middle Mesolithic,
350 characterised by blade production from conical and sub-conical cores with faceted platforms that involves the
351 removal of core tablets and rejuvenation flakes (Damlien 2016). When it comes to the non-flint material,
352 projectiles are to a larger extent a property of the earlier sites than later ones. The use of metarhyolite for
353 the production of axes is present at some earlier sites in addition to the previously mentioned Nedre Hobekk
354 2, and the production of non-flint hatchets and core axes is introduced in the Microlith Phase (Eymundsson
355 et al. 2018; Jakslund and Fossum 2014; Reitan 2016). However, in agreement with the literature, this is
356 evidently not as prominent a part of these assemblages.

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

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

376 The curation index has relatively high values until some time before 8000 BCE, before it drops and stabilises
377 around 7000 BCE. This pattern is evident in both the flint data and when all lithics are treated in aggregate.
378 Furthermore, the increased variation in degree of curation after around 8000 BCE could indicate that these
379 sites were associated with a more varied mobility pattern. The five sites that have values on the curation

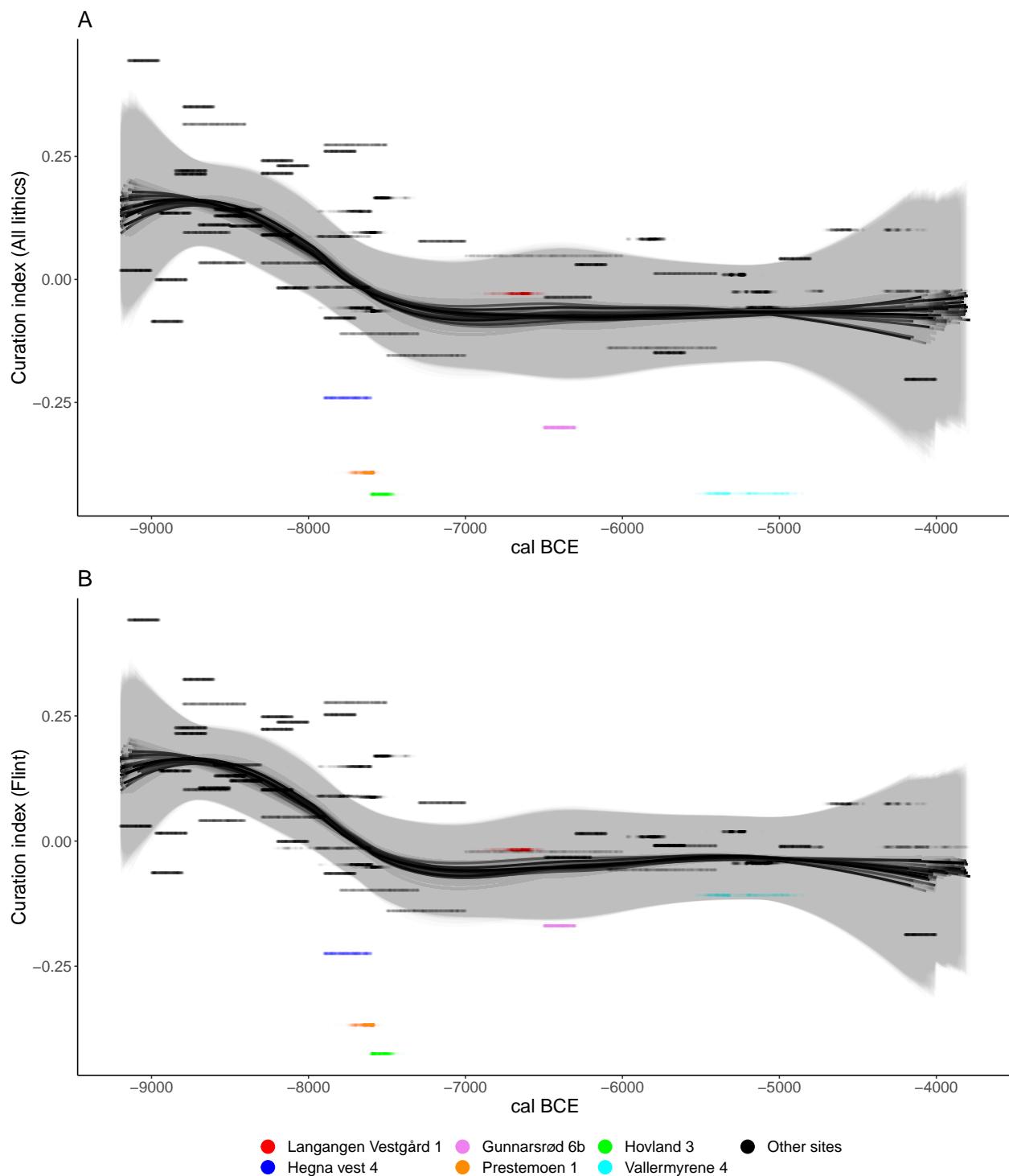


Figure 9: Temporal variation in the curation index for A) All lithics, and B) Flint. The temporal uncertainty is handled by means of a simulation approach where the site ages are drawn from their respective age determination probability density functions given in Figure 1B. A LOESS curve has been fit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

380 index below c. -0.25 could in this perspective have predominantly functioned as base-camps within a logistic
381 settlement pattern. That these assemblages reflect stays of a longer duration was suggested for all five sites
382 in the original reports (Carrasco et al. 2014; Eigeland and Fossum 2017; Persson 2014; Solheim and Olsen
383 2013), with the exception of for Vallermyrene 4, which was argued to be a specialised axe production site, not
384 necessarily associated with lower degrees of mobility (Eigeland and Fossum 2014). This highlights a possible
385 issue pertaining to raw-material variability, as the coarse non-flint material used for the production of axes
386 generally results in a relatively large amount of waste per produced tool, possibly skewing the curation index
387 when compared to assemblages dominated by flint. Referring back to the CA, the difference is most marked
388 for the sites in the later part of the Mesolithic where non-flint material become more dominating parts of the
389 assemblages. As can be seen in Figure 9B, the degree of curation is markedly higher for both Gunnarsrød 6b
390 and Vallermyrene 4 when the non-flint material is excluded, although they remain more expedient than that
391 of contemporary assemblages. Thus, the degree of expediency for assemblages dominated by non-flint might
392 be somewhat exaggerated when the non-flint material is included, while its exclusion would likely lead to its
393 underestimation. One possible approach could be to weigh the curation index by the proportion of non-flint
394 material in the assemblages. This is not explored further here, however, as the overall tendencies appear
395 robust to this effect.

396 Another case also worth commenting on is Langangen Vestgård 1, which, on the grounds of an overall large
397 number of artefacts and the possible presence of a dwelling structure was argued to reflect a more permanent
398 site location in the original report (Molvold and Eigeland 2014). However, the relatively high value on the
399 curation index could mean that the site reflects the aggregation of stays which predominantly have been of a
400 comparable duration to those on contemporary sites, while the possible dwelling structure, if taken as an
401 indication of longer stays, could in this perspective represent a remnant from one or a few visits of longer
402 duration that constitute a smaller fraction of the use-life of the site as a whole (cf. Barton and Riel-Salvatore
403 2014).

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

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

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

427 **7 Conclusion**

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

434 The temporal trends associated with the curation index corresponds surprisingly well with trajectories of
435 cultural development previously suggested in the literature, and does therefore, in my view, suggest that
436 shifts in land-use and mobility patterns are the main drivers behind this empirical pattern—in line with the
437 framework of Barton et al. (2011). Another perspective would be that this is not surprising at all (cf. Kuhn
438 and Clark 2015:14), and that the previously demonstrated relevance of these measures across a wide range
439 of contexts points to their pervasive relevance for the organisation of lithic technology, and, therefore, that
440 there should be little reason to think Mesolithic south-eastern Norway should be any different. However,
441 the conclusion that these measures apply to and appear to capture the dimensions of interest in a
442 relatively controlled empirical setting, reached by means of an exploratory analysis can only constitute a first
443 analytical step. As Elster (2015:12) has pointed out, the human mind seems to have a propensity to settle for
444 an explanation that *can* be true, as soon as this has been reached. This, however, can only constitute the
445 absolute minimum of what is required of a proposed explanation. Subsequent steps should be to probe and
446 challenge this explanatory framework, also in light of alternative hypotheses (e.g. Clark 2009:29–30; Perreault
447 2019). The empirical relationship does nonetheless hold great potential for large scale comparative studies in
448 Mesolithic Scandinavia and beyond. Furthermore, the curation index was here simply narratively associated
449 with the most immediate chronological trends emphasised in the literature concerned with the Mesolithic
450 of south-eastern Norway. The explicit quantification does, however, offer the possibility to conduct formal
451 comparisons with a wide range of environmental, demographic and cultural dimensions across multiple scales
452 of analysis.

453 **Declaration of interest**

454 The author has no conflicts of interest to declare.

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Supplementary material

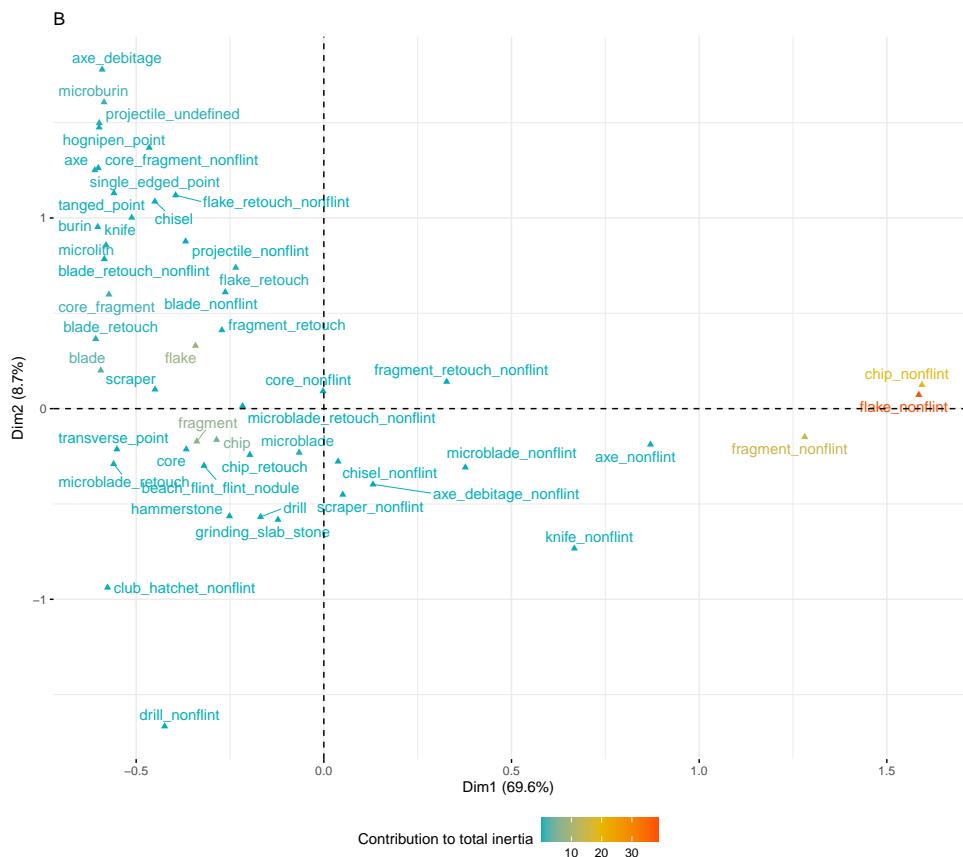
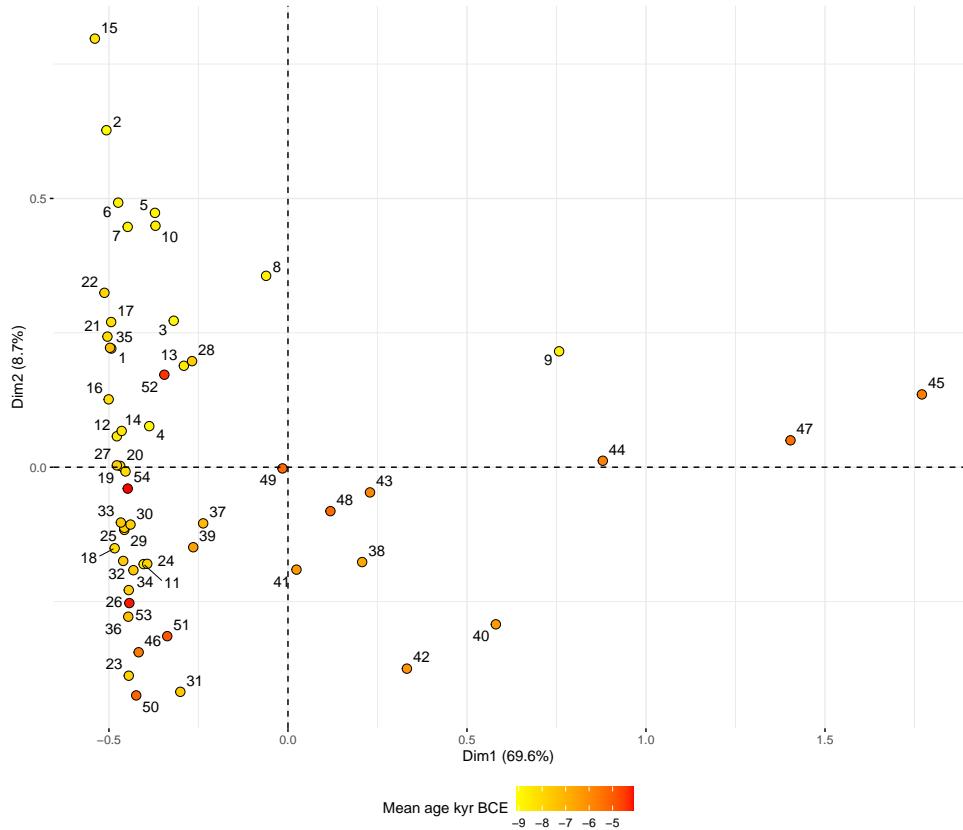


Figure 10: Correspondence analysis using all original artefact categories. A) Row plot, B) Column plot.

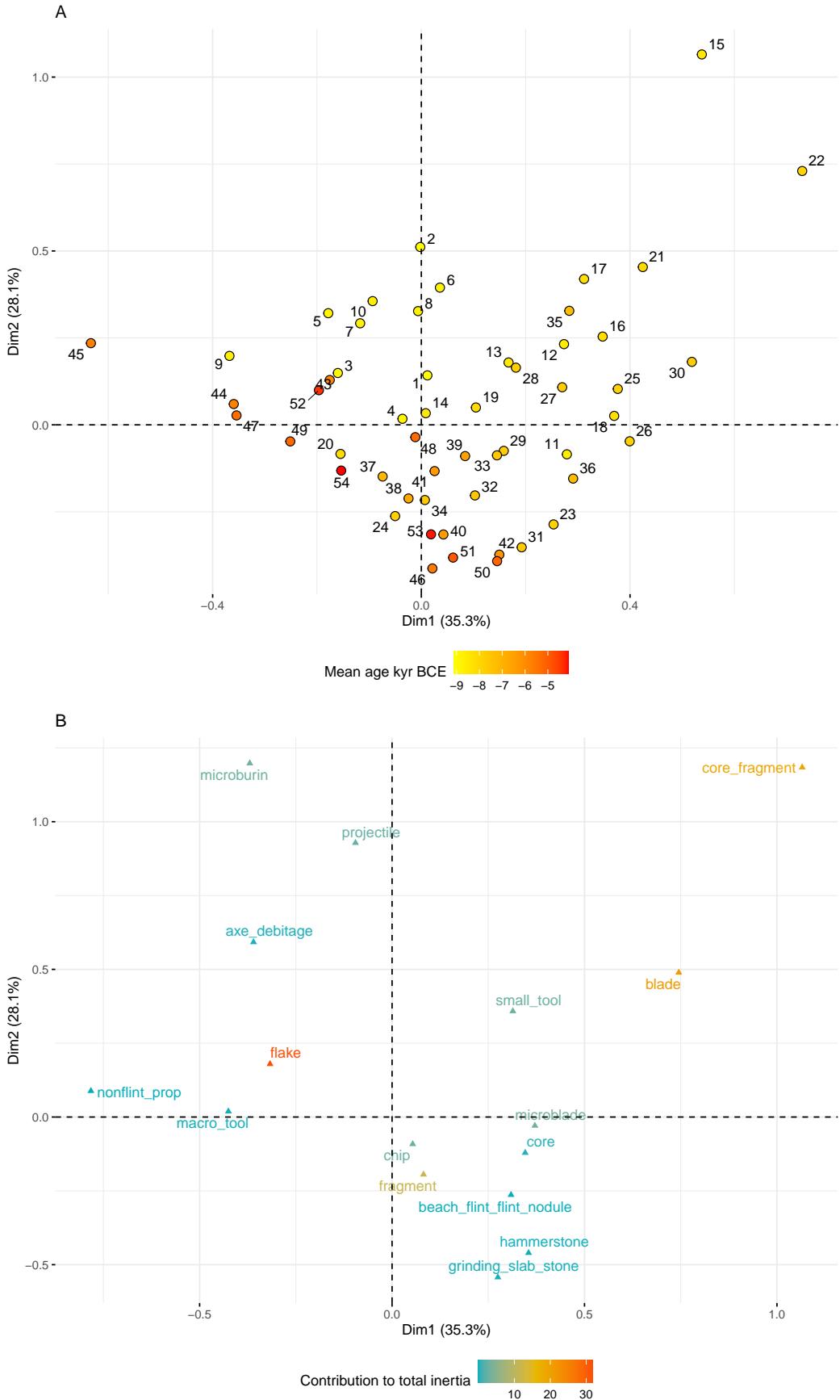


Figure 11: Correspondence analysis collapsing artefact types irrespective of raw-material and including proportion of non-flint as its own variable. A) Row plot, B) Column plot.

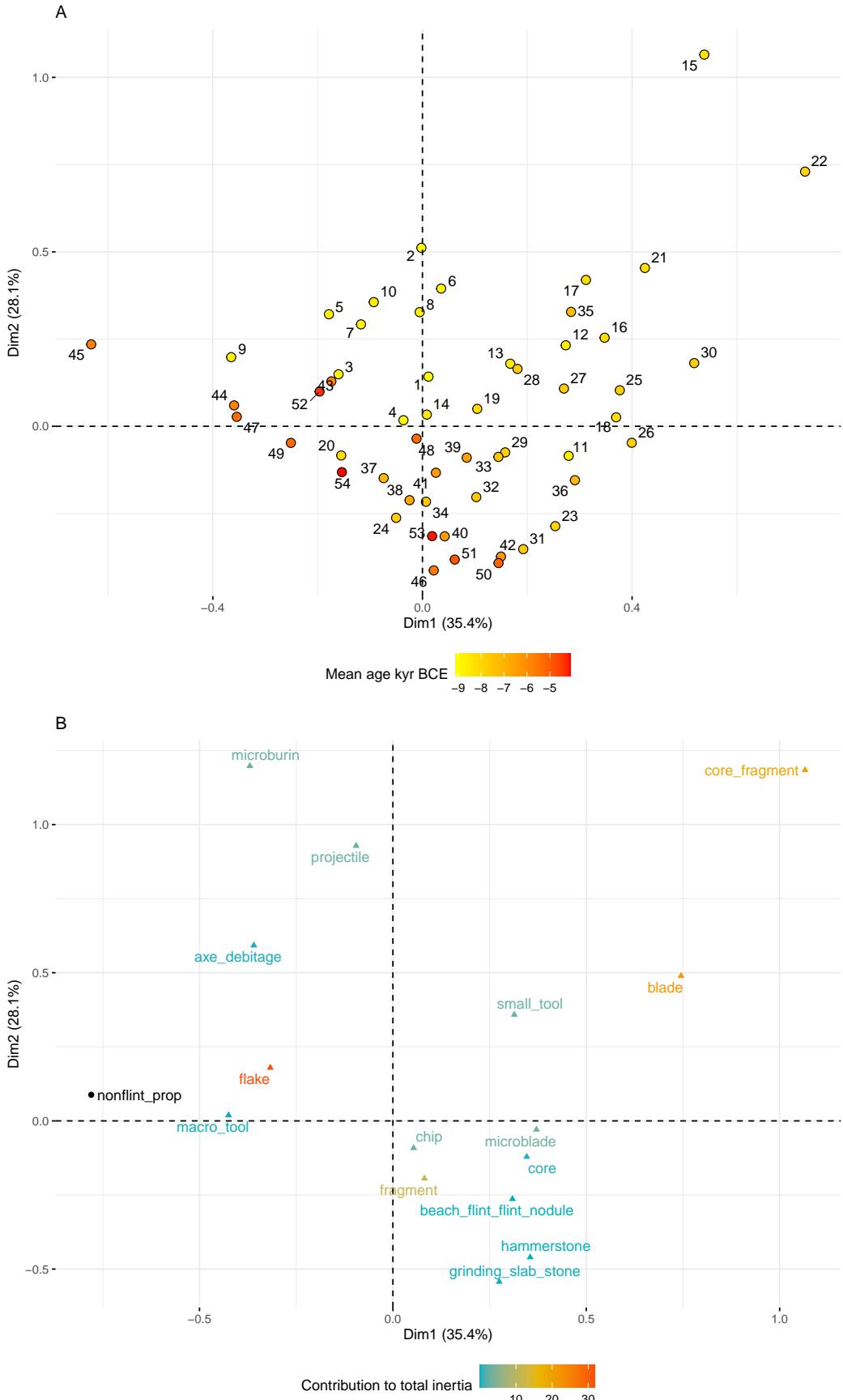


Figure 12: Same as above, only that here the proportion of non-flint is used as a supplementary column. The negligible difference between this CA and that above indicates that the flint/non-flint distinction is integrated in the different artefact types, and therefore that the effect of artefact types 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.