INTRASITE SPATIAL ANALYSIS AND THE MAGLEMOSIAN SITE OF BARMOSE I

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ABSTRACT: The Maglemosian site of Barmose I in Denmark (Blankholm, 1991) is analysed by the ring and sector method. This is a simple method for within-site spatial analysis, based on the use of rings and sectors around hearths. The results of the analysis are contrasted with the ideas put forward by Blankholm. The ring and sector method makes it possible to demonstrate whether a hearth was inside a dwelling or in the open. Contrary to the assumption by Blankholm, it was found that the hearth of Barmose I must have been located in the open air, not inside a hut, despite the presence of bark flooring. A general conclusion is that complex computerized procedures, such as several of the clustering techniques applied by Blankholm, are not well suited to analyse open-air sites of this type, consisting of a central hearth with an artefact concentration around it. Their level of resolution is set too high for such situations, where many different activities were performed in a small area near the hearth, overlapping each other in space. Indications are that Barmose I was a hunting camp, occupied by a small group of men; there are no good arguments for the presence of women.

KEYWORDS: Intrasite spatial analysis, ring and sector method, Mesolithic, Maglemosian, dwelling structures.

1. INTRODUCTION

Intrasite spatial analysis, the study of spatial patterns within a site, has developed into a somewhat schizophrenic field. On the one hand, there are archaeologists who try to analyse distribution maps by visual inspection and simple descriptive means. On the other hand, a whole series of complicated mathematical and statistical techniques, which generally require the help of computers, have been developed by several archaeologists since about 1970. In general, these two groups of archaeologists hardly communicate with each other in any fruitful way. The first group mostly consists of field archaeologists, who themselves excavated the sites under discussion. The second group is composed of statistically oriented archaeologists, who play computer games with sites that more often than not were excavated by colleagues not well-versed in mathematics.

The 'mathematicians' attempt to quantitatively describe spatial patterns, by contouring, clustering, establishing patterns of covariation between artefact types, etcetera. They expect to recognize spatial patterns that, so it is claimed, are difficult to ascertain in any other way, and to do so 'objectively'. In most cases, the outcomes of the mathematical procedures are eventually rephrased in a descriptive way, and interpreted in terms of 'activity areas'. For more details about the techniques currently in use, the reader is referred to several recent publications (Hietala, 1984; Carr, 1984; 1985; Whallon, 1984; Kent, 1987; Blankholm, 1991).

In many cases the mathematical/statistical techniques are quite complicated, which has discouraged many archaeologists from applying them, or even from trying to understand them. Moreover, quite a few of these techniques do not seem to work well, producing results

TERMS AND ATTRIBUTES

D: Distance to the centre of the hearth.

R: The 'richest site-half'. The site-half with the highest number of tools. At Barmose I: sectors 5, 6, 7 and 8.

P: The 'poorest site-half'. The site-half with the lowest number of tools. At Barmose I: sectors 1, 2, 3 and 4.

A: The quarter within R with the highest proportion (with respect to the total number of tools per quarter) of 'projectiles' (in the case of Barmose I: microliths). At Barmose I: sectors 7 and 8.

B: The quarter within R with the lowest proportion of 'projectiles'. At Barmose I: sectors 5 and 6.

Asymmetry index: The proportion of tools present in R to the total amount of tools. At Barmose I: 63.0%.

Centrifugal index: Mean D of the cores/mean D of the tools. At Barmose I: 1.07.

Scraper/projectile D index: Mean D of the scrapers/mean D of the 'projectiles'. At Barmose I: 1.14.

Tools/cores in R index: % of N tools in R/% of N cores in R. At Barmose I: 1.19.

Core index: N cores/N tools. At Barmose I: 0.20.

Projectile/burin index: N 'projectiles'/N burins. In the case of Barmose I 'projectiles' are microliths. At Barmose I: 1.83.

A/B Fisherp: The p according to the Fisher Exact Probability Test (Siegel, 1956) for the difference in proportions of 'projectiles' to 'other tools' between the quarters A and B. In the case of Barmose I 'other tools' are: scrapers, burins, core/flake axes, denticulated/notched pieces, and blade/flake knives. At Barmose I: 0.32.

that either are hardly interpretable or could easily have been obtained by simpler means. It is also true to say that many mathematical techniques have underlying models or assumptions that are not really adapted to the analysis of archaeological residues. Therefore, complex techniques will at best produce a mixture of potentially valuable information and meaningless 'artefacts' created by the mathematical procedures, and it may be impossible to disentangle these components. Uncritical application of these techniques thus may easily lead to serious cases of over- or misinterpretation. It is unrealistic to believe that a mathematical or statistical procedure can be developed that brings out all spatial patterns existing at a given site. These are of many kinds, because many different site-formation processes have played a part (e.g. Schiffer, 1976; Binford, 1983). We should be pleased whenever a technique demonstrates at least some interpretable patterns in a satisfactory way.

Given the situation described above, there is no reason to abandon the use of simple approaches to intrasite spatial analysis alongside those involving complex computerized procedures. In this article one such method is introduced, which is based on the use of rings and sectors around 'domestic hearths' (Stapert, 1989; 1990a; 1990b; Stapert & Terberger, 1989). The idea behind this method is that the domestic hearth was a focal point, attracting many activities – irrespective of whether it was inside or outside a dwelling (e.g. Binford, 1983; Olive & Taborin, 1989; Yellen, 1977). The ring and sector method is therefore feature-oriented. It should be clear that this method does not claim to detect all possible spatial patterns in sites. It is directed at describing and interpreting global spatial patterns that relate to the domestic hearth. It is essentially a way of partitioning space (in two related ways: rings and sectors), which seems more suited than any regular grid structure to analyse sites where the global spatial structure is determined by the presence of a central hearth.

So far, the method has been applied to twelve concentrations of Pincevent (Late Magdalenian), four concentrations of Gönnersdorf (Late Magdalenian), and to several other Late Palaeolithic and Mesolithic sites in northwestern Europe. In this article I will use the ring and sector method to analyse the Maglemosian site of Barmose I in Denmark, and the outcomes will be contrasted with the results of Blankholm (1991), who analysed the same site using four different computerized procedures. It should be stressed that the main goal of this article is not so much to contribute to the knowledge about the Maglemosian, though I hope it will, but to explore the potential of the ring and sector method, compared to other techniques of spatial analysis.

2. THE SITE OF BARMOSE I

A book by Blankholm (1991) on intrasite spatial analysis appeared recently. Blankholm's text is especially useful as a technical compendium: no fewer than ten different mathematical/statistical techniques are described and illustrated in much detail. Four of these techniques, considered by Blankholm to be the most effective (k-means analysis, unconstrained clustering, correspondence analysis, and his own 'presab'), are applied by him to the early Maglemosian site of Barmose I. Most of the other techniques described in his book seem to have disappointed Blankholm: "A perusal (...) rules out Index of Segregation/Aggregation, DANOVA, Morisita's Index, Hodder and Okell's A-index and Carr's Coefficient of Polythetic Association from further consideration. None of these methods have, in fact, proven capable of revealing anything of significance at all." (Blankholm, 1991: p. 167).

The site of Barmose I was discovered in 1966, and excavated by A.D. Johansson in 1967-1971. It is dated to 9170 BP by five accelerator dates (Fischer, 1991). In the middle of the find concentration was a large hearth, measuring about 2.5×1.7 m (see fig. 1), with sand and clay and quite a lot of charcoal. Around the hearth, remnants of sheets of bark were found. To the NNE of the hearth, about 1.6 m outside its periphery, a large stone was encountered (a sitting stone? see also section 11).

A first test pit is not indicated on the drawing in figure 1, because its position is not exactly known. It was probably located in the northwestern part of the site (Blankholm, 1991: pp. 185, 204), but elsewhere it is stated to have been in the northeastern part (Blankholm, 1991: p. 186). It only partly disturbed the culture layer, and the amount of artefacts from this test pit is not fully

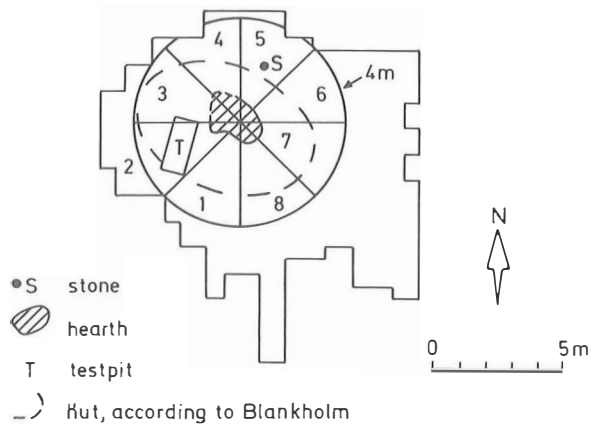


Fig. 1. Barmose I, general site plan. The area within 4 m from the hearth centre is analysed by the ring and sector method: it is divided into 8 sectors. Note the test pit in sector 2, and the large stone in sector 5. Also indicated is the outline of the hut, as assumed by Blankholm (1991: map overlay 2).

known (Blankholm, 1991: p. 186). A second, more regular test pit was located to the SW of the hearth. It measured 2×1 m (see fig. 1), according to Blankholm's drawing (Blankholm, 1991: map overlay 2), not 3×1 m as stated in his text (Blankholm, 1991: p. 186). The artefact content of this test pit was not considered by Blankholm, and is not plotted on his distribution maps; the number of artefacts is merely said to be low (Blankholm, 1991: p. 204). In my opinion, the disturbing effect of these two test pits on any kind of spatial analysis is taken too lightly in Blankholm's discussion of the results (Blankholm, 1991, p. 204), especially as he fails to inform us of their artefact contents.

Blankholm's 'presab' technique produces clusters, and the best solution according to Blankholm consists of a configuration of 19 clusters (which are not homogeneous in space: see fig. 2). The contents of these clusters are given in a table in the form of presence/absence data (Blankholm, 1991: Table 70). For example, cluster 2 is characterized only by burins, cluster 17 by notch remnants ('microburins'), splintered pieces ('square knives'), denticulated/notched pieces, and cores. Subsequently, these clusters, which are widely scattered in space, are grouped into 15 'activity areas'. This is essentially an intuitive procedure; it is not at all clear how this grouping is achieved. It can be seen in Blankholm's picture (fig. 2) that very different clusters (in terms of content) are grouped together. One wonders why Blankholm should first do a lot of calculating if in the end, to make some sense of the results, he resorts to intuitive grouping in a way that is not at all different from what an 'old-fashioned' archaeologist would do on the basis of the distribution maps. The resulting 15 'activity areas' are then loosely described and interpreted, for example as 'general work areas'. To my mind the results of such procedures are rather disappointing, and I find output such as figure 2 very hard to interpret; such pictures seem to obfuscate rather than clarify.

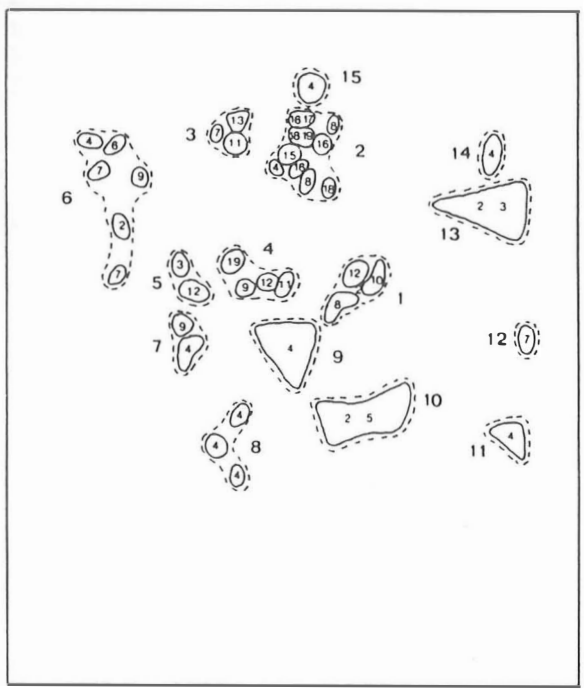


Fig. 2. Barmose I. The result of the spatial analysis by Blankholm (1991), on the basis of his 'presab' technique. Nineteen 'clusters', which are not homogeneous in space, are grouped into fifteen 'activity areas'. The represented area of 12x14 m was only partially excavated (see fig. 1). After Blankholm, 1991: fig. 125.

Even more disturbing is the fact that Blankholm's analysis proceeds on the basis of several unproven assumptions, which are not critically tested. The most important of these is the idea that a hut was present at the site, with the hearth located at the centre of its interior. The demonstration that a dwelling was present should be one of the goals of intrasite spatial analysis, not an assumption to start with! It will be realized that the interpretation of any 'patterns', established with the help of whatever mathematical technique, will be very different, depending on whether or not the presence of a dwelling is assumed. Blankholm's arguments for the presence of a hut are: "... the sharp inflection in the debitage distribution, the remnants of horizontal bark flooring, and a hearth of sand and clay with conspicuous amounts of charcoal and burnt flint ..." (Blankholm, 1991: pp. 184, 185). The hut is indicated on a drawing (Blankholm, 1991: map overlay 2) as an oval outline, with a diameter of 6.9×4.7 m (see fig. 1); the entrance is supposed to have been to the east (Blankholm, 1991: p. 204).

Blankholm's arguments are not conclusive, however. The presence of bark flooring is not necessarily indicative of a dwelling (see also Bokelmann, 1986; and section 6). An abrupt change in local artefact density, as indicated by Blankholm in the northeastern part of the site, is also not a conclusive argument: there are many other mechanisms that could have caused such a pattern. Moreover, this phenomenon does not show up clearly either on the artefact density map (fig. 3) or in the ring diagrams (to be discussed in later sections). It is also completely unclear to me why the presence of a large hearth, with sand and clay and a lot of charcoal, should be regarded as evidence for a dwelling around it. In fact, one would expect such large and dirty hearth areas to be located outside, in the open air (e.g. Binford, 1983). Another argument of Blankholm's is the supposed 'marginal distribution' of the cores (Blankholm, 1991: p. 185). It is true that in many Late Palaeolithic and Mesolithic sites the cores are located more peripherally, with respect to the central hearth, than tools. This tendency, called the 'centrifugal effect', however, is no proof of the existence of a dwelling. At many sites with open-air hearths, the centrifugal effect can be shown to have been operative (Stapert, 1989). Moreover, at

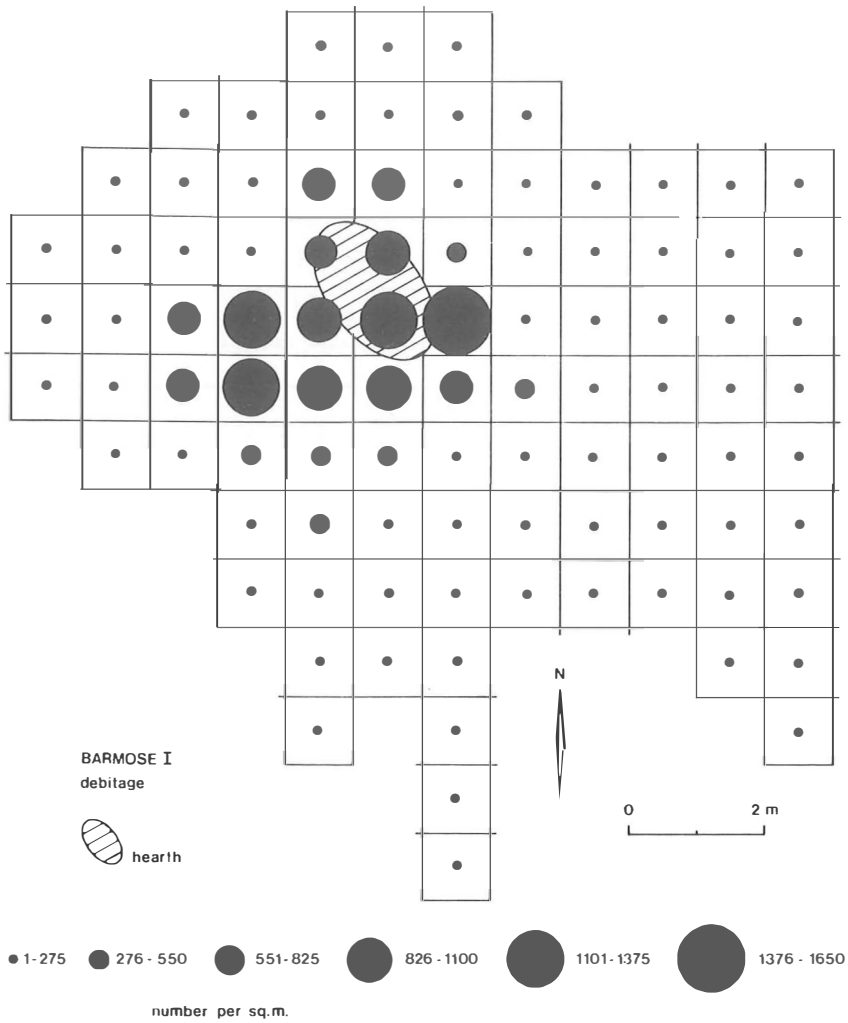


Fig. 3. Barmose I. Density of flint 'debitage'. This map is organized according to the principles outlined by Cziesla (1990). Based on data in Blankholm, 1991: fig. 100.

Barmose I the centrifugal effect is rather weakly developed (see section 4): the cores cannot be said to be located significantly farther away from the hearth than the tools.

In his book Blankholm mentions his 'standard method for delineation of Maglemosian hut floors' (Blankholm, 1991: p. 185; see also Blankholm, 1984; 1987); this method seems to consist of simply equating a selected density contour line with the outline of a supposed hut.[1] Such procedures are meaningless. We need solid arguments for assuming the presence of a dwelling structure around a hearth, not conjectures without any foundation.

It is my opinion that the hearth of Barmose I was in the open air, and I will present arguments for this hypothesis in following sections of this article.

Not surprisingly, Blankholm's summary of his analyses of Barmose I clearly is determined by his idea that the hearth was inside a dwelling: "Basically what we can see is first a distinction between use of inside and outside space. As to the inside, there is generally indication of at least three general multipurpose work areas around the hearth in the central and eastern part (where the entrance presumably has been) of the dwelling, whereas there are several indications suggesting that the western end of the floor was an area of low activity of different kinds, storage or sleeping. As to the outside, the content of the activity is more varied and thus indicates more differentiated uses." (Blankholm, 1991: p. 204; note the accumulation of vague terms in a single sentence).

For me it is hard to find such results very interesting. Most of Blankholm's picture simply reflects his unfounded assumption of a dwelling structure around the hearth. The 'area of low activity' in the west is no more than another way of telling us that the density of artefacts is low there. All in all, my impression is that the four computerized procedures applied by Blankholm did not perform very well; in my opinion at least we have not learned very much about Barmose I. A general problem with this kind of approach seems to be that

there are no guidelines for interpreting the results of such rather mechanical mathematical operations. These do not seem to be directed at answering specific questions, and we are essentially left in the dark as to what the outcomes might mean. See section 11 for a further discussion.

3. RINGS AND SECTORS

If the domestic hearth is taken as the focal point, two ways of partitioning space are appropriate: using rings and sectors around the centre of the hearth, as depicted schematically in figure 4. The ring method is extremely simple: frequencies of artefacts are counted in rings of 0.5 m width around the hearth centre. It is advisable to count the ring frequencies per sector, because it may be fruitful to combine the sector and ring approaches, as we will see below. The distribution of artefact frequencies in the rings can be illustrated in the form of histograms, in which 0 on the X-axis is the centre of the hearth. It is important to note that we are not discussing densities here, in terms of numbers of artefacts per square metre. The rings only serve as a graphical illustration of the method, and in fact it would be more precise to speak of distance classes. The distance between an artefact location and the hearth centre is called 'D'.

The sector method investigates frequencies in sectors around the hearth centre. The choice of the number of sectors employed is arbitrary; in my experience a number of eight in most cases is adequate. The sectors should of course be equally large. With the sectors we are dealing with data that are much weaker than the distance data used in the ring method. Distance data can be considered as measurements in the ratio scale (Siegel, 1956), allowing many statistical manipulations (though in general nonparametric statistics are preferable). Frequencies in sectors around the hearth, on the other hand, constitute measurements in the nominal scale, despite the fact that the frequencies themselves are counted in the ratio scale. The same is true for frequencies in cells of a grid structure of whatever kind. For more details about the ring and sector method, and its problems and applications, the reader is referred to previous publications (Stapert, 1989; 1990b; Stapert & Terberger, 1989).[2]

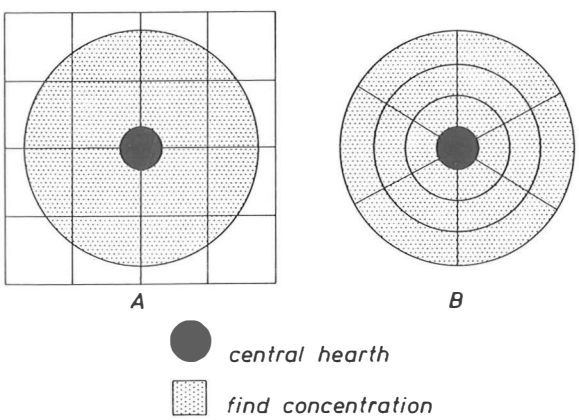


Fig. 4. Schematic representation of two different approaches to intrasite spatial analysis of flint concentrations around a central hearth. Many conventional analyses are based on a regular grid, as in A. In this article B is advocated, the ring and sector method. The latter system of subdividing space seems much more appropriate for the analysis of more-or-less circular artefact concentrations around a central hearth. The analysis of system B takes place in two phases. In the first, distances are measured between the locations of artefacts and the centre of the hearth. This is usually done in classes (rings) of 0.5 m width. In the second phase the numbers of artefacts per sector are counted. In most cases a number of eight sectors works best. Combining the ring and sector data may be fruitful; therefore, it is advisable to measure the distances per sector.

In the case of Barmose I, the rings up to 4 m from the hearth centre are approximately complete (fig. 1). Therefore, it was decided to limit the analysis to that area. Artefacts found farther away are omitted, but they are relatively few. In total, 322 tools of 7 types were present within 4 m from the hearth centre, and only 41 were found beyond the 4 m limit (11.3% of total). Within 4 m from the hearth centre the frequencies and percentages of the 7 tool types are as follows:

	N	%	% of N 6 types (N = 149)
Splintered pieces ('square knives')	173	53.7	–
Scrapers	35	10.9	23.5
Microliths	33	10.2	22.1
Core axes (4) and flake axes (23)	27	8.4	18.1
Denticulated/notched pieces	20	6.2	13.4
Burins	18	5.6	12.1
Blade/flake knives	16	5.0	10.7
Total	322	100.0	99.9

Splintered pieces (which Blankholm calls 'square knives') are very numerous, and in fact do not constitute a formal tool class, as the splintering is no intentional retouch but probably the result of some heavy use, the nature of which is unclear to us (Blankholm suggests: 'light duty and precision work on bone/antler, wood and hides': Blankholm, 1991: p. 189; see also Eickhoff, 1988). Therefore, the percentages of the 6 formal tool types, based on their total of 149, are also given in the above list.

Apart from the tools, the ring and sector distributions of cores and 'microburins' (notch remnants) too are studied. There were 66 cores within 4 m from the hearth centre. Beyond the 4 m limit, 15 cores were present (18.5% of total). This is a higher proportion than in the case of the tools, indicating that, on average, cores indeed tend to be located somewhat further from the

hearth than the tools. The difference is not significant, however. According to the chi-square two-sample test (Siegel, 1956), $0.1 < p$ (two-tailed) < 0.2.

None of the small 'microburins' (N = 16) were located more than 4 m from the hearth centre. They were probably left on the spot at the place where microliths were manufactured. This work was done close to the hearth, to the east of it (see section 8 and table 4).

The location of the first test pit and its contents are unknown to us. Therefore, it is impossible to estimate to what degree this pit affects our analysis. The contents of the regular 2x1 m test pit are also unknown, but its location is known. I have positioned the ring and sector system in such a way that only one sector is affected by this test pit: sector 2 (fig. 1). All ring diagrams in this article are based exclusively on the seven other sectors (the data from sector 2 are omitted). Concerning the sector data, it should be remembered throughout this article that the frequencies in sector 2 must be considered as minimum estimates.

4. THE CENTRIFUGAL EFFECT

Binford (1983) provided useful descriptions about people's spatial behaviour in relation to outdoor hearths, which can be summarized in his 'hearth model' (fig. 5). He distinguishes 'drop' and 'toss zones'. Drop zones are found close to the hearth in the form of a semicircle, where small debris fall to the ground during all sorts of activities, and generally are left lying.[3] Larger pieces of refuse end up in the toss zones. Two toss zones are distinguished: a 'backward toss zone' which lies in the form of an arc around the drop zone (on the same side of the hearth), and a 'forward toss zone' on the opposite, unoccupied side of the hearth. Near an open-air hearth, the drop zone and the backward toss zone are located on the side where the people sat and worked, to windward of the hearth. An important point to note is that pieces of refuse arrive in the toss zones individually, by being tossed or kicked away, gradually accumulating there in the course of the occupation period. This is in contrast to dumps, where waste is discarded collectively. Dumps are mostly found at some distance from the hearth, and it seems that at Barmose I dumps were absent (or, alternatively, located outside the excavated area).

There are two important differences between the drop zone and the toss zones. The first is that toss zones are clearly more peripheral with respect to the hearth, at any rate in an overall sense. There is a certain overlap, however, in terms of distance to the hearth, between the drop zone and the forward toss zone (indicated by means of broken lines in fig. 5). The second is the size of the items that end up in them: small objects in the drop zone, larger ones in the toss zones. Hence we are dealing with a size-sorting process: a tendency towards spatial segregation of finer and coarser refuse. On the whole the coarser items have a greater chance than the small ones of ending up in the periphery of the site. This pattern has since long been known to archaeologists: many distribution plans show that cores (mostly the largest flint artefacts) mainly occur in the periphery of sites. The tendency for larger objects to end up farther away from the hearth is called the 'centrifugal effect'. A clear centrifugal effect would be expected especially if a backward toss zone existed.

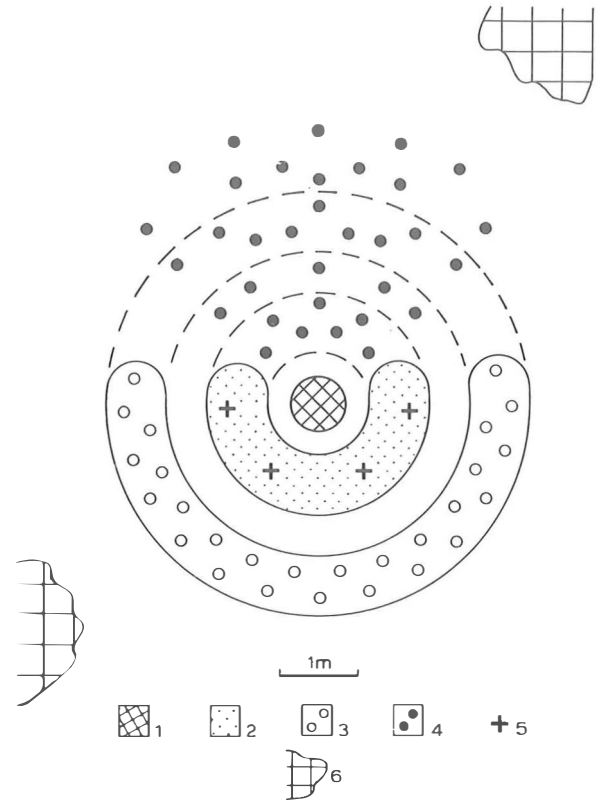


Fig. 5. Sketch of Binford's hearth model (after Binford, 1983: p. 153, with minor alterations). 1. Hearth; 2. Drop zone; 3. Backward toss zone; 4. Forward toss zone; 5. Seating positions of four people; 6. Dumps.

The strength of the centrifugal effect can easily be quantified by means of the 'centrifugal index': mean D of the cores/mean D of the tools (D is distance to the hearth centre). In a sample of 18 Upper/Late Palaeolithic sites, all of them supposed to have had open-air hearths, this index was found to range from 0.61 to 2.35 (Stapert, 1989). An important finding was that not all sites show a clear centrifugal effect; at some sites cores were on average even somewhat closer to the hearth than tools. In the case of Barmose I the centrifugal effect is only weakly developed. The centrifugal index in this case is 1.07, which is too close to 1 to be significant.

It is easy to see why the ring method is well suited for studying the centrifugal effect. It should show up in ring distributions if we divide the artefacts into size-classes.

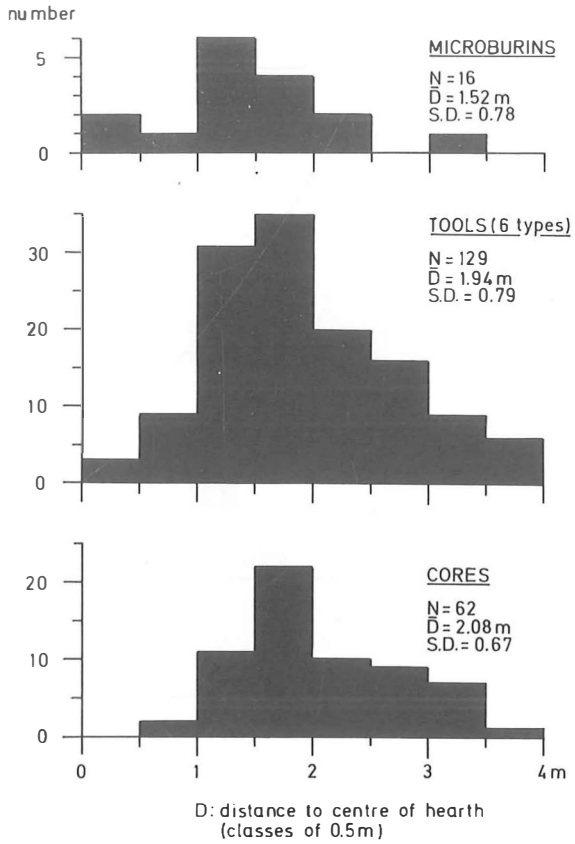


Fig. 6. Barmose I. Ring diagrams of 'microburins' (notch remnants), tools of six formal types (microliths + burins + denticulated/notched pieces + blade/flake knives + scrapers + core/flake axes) and cores. On the X-axis, 0 is the centre of the hearth. Note that the data from sector 2 are omitted, because of the test pit located in that sector (see fig. 1). It can be seen that the three distributions are clearly unimodal.

For this purpose I have divided the artefacts of Barmose I into three groups, from small to large: 'microburins', tools (6 types, i.e. without splintered pieces) and cores. Artefact frequencies of these three groups in rings 0.5 m wide (excluding the locations in sector 2) are presented in figure 6. It can be seen that no clear centrifugal is present within 4 m from the hearth centre: the distribution of the cores has the same mode as that of the tools (in the 1.5-2 m class). There is a small difference, however, in the mean distances of tools and cores, as we have noted above. After combining the data into frequencies per 1 m rings, it is possible to test the difference between the cores and the tools by means of the chi-square two-sample test in a valid way (Siegel, 1956). The conclusion must be that there is no clear difference between the tools and the cores in this respect: $0.5 < p$ (two-tailed) < 0.7. Therefore, Blankholm's argument regarding the more peripheral location of cores with respect to the hearth, compared to that of tools, cannot be upheld. There is only a weak tendency, which cannot be shown to be significant in a statistical sense.[4]

Table 1. Barmose I. Mean distances to the centre of the hearth. Only locations within 4 m from the hearth centre, excluding the locations in sector 2 (see main text, section 2). D: Distance to the hearth centre.

	N	Mean D	Stand. dev.
Microliths	33	1.81	0.78
Burins	16	1.77	0.67
Denticulated/notched pieces	20	1.91	0.70
Blade/flake knives	14	1.91	0.63
Scrapers	30	2.06	0.84
Core (3) and flake axes (13)	16	2.19	1.00
Total 6 types	129	1.94	0.79
Splintered pieces	166	1.94	0.79
Total 7 types	295	1.94	0.79
'Microburins'	16	1.52	0.78
Cores	62	2.08	0.67

Barmose I seems to belong to a group of sites where the centrifugal effect was largely absent. Other sites showing no clear centrifugal effect are Marsangy N19 (Schmider, 1979; 1984), Bro I (Andersen, 1973) and the three units at Pincevent Habitation 1 (Leroi-Gourhan & Brézillon, 1966). In fact, these sites show no clear evidence for the existence of either forward or backward toss zones. It has been hypothesized that such sites were occupied by men only; they may, for example, have been hunting camps (see section 10). In all cases the hearths at these sites appear to have been located in the open air, not within dwellings. At sites where a dwelling structure can be observed archaeologically, as at two concentrations of Gönnersdorf (see section 5), there is always a marked centrifugal effect (Stapert, 1989; 1990a). Thus, the absence of a clear centrifugal effect in Barmose I can be considered to be an indication for the absence of a hut around the hearth. Apart from establishing the presence or absence of the centrifugal effect, the ring method provides us with yet another way of approaching this important question, which will be discussed in the next section.

5. UNIMODAL AND BIMODAL RING DISTRIBUTIONS

Within a dwelling with a central hearth, the centrifugal movements are of course restricted by the walls. Therefore, one may expect much of the refuse to be carried outside and dumped en masse. One type of dump is characteristic of dwellings: the door dump (Binford, 1983). People simply throw their larger pieces of rubbish out through the entrance, to the left or to the right. This phenomenon in itself can be considered as contributing to the strength of the centrifugal effect. However, inside the dwelling the centrifugal effect will also be operative, though generally not in all directions.

The walls of the dwelling then serve as a barrier. The refuse gradually accumulates against them in the course of the occupation, again with a relatively high proportion of coarse material. This I have termed the 'barrier effect'.

When we consider the ring distribution of all the tools taken together, the sites investigated so far with the help of the ring and sector method seem to fall into two groups: those with unimodal and those with bimodal ring distributions (Stapert, 1989; 1990a; 1990b). Most analysed sites show unimodal ring distributions; this applies for example to all 12 analysed concentrations at Pincevent (Leroi-Gourhan & Brézillon, 1966; 1972; Julien et al., 1988), Oldeholtwolde (Stapertet al., 1986), Bro I, Marsangy N 19, Olbrachcice 8 East (Burdukiewicz, 1986) and concentrations I and IV of Niederbieber (Bolus et al., 1988; Winter, 1986; 1987). As an example, the unimodal distribution of Niederbieber I is illustrated in figure 7. At none of the sites for which I have obtained unimodal ring distributions were any archaeological traces of tents of huts observed.

At the site of Gönnersdorf two concentrations occur with clear traces of the existence of tents. At Gönnersdorf I the presence of a tent is evident from a circular arrangement of postholes (Bosinski, 1979), at Gönnersdorf IV from the presence of a ring of large stones around the hearth, which can be interpreted as a tent ring (Bosinski, 1981; Terberger, 1988). At both concentrations the centrifugal effect is very strong: it not only resulted in the cores being far away from the hearth – in fact, most are located outside the dwellings –, but also affected the tools. When we consider the ring distributions of all tools combined in Gönnersdorf I and IV, their bimodal character is immediately apparent (see fig. 7 for the distribution of Gönnersdorf IV). The first peak lies at c. 1 m from the hearth centre; a second, higher one at c. 2.5 m. This second peak is generated mainly by the larger tools (such as blade scrapers and burins), and it coincides with the tent ring. The first peak can be interpreted as the drop zone near the hearth. It is made up especially of the small backed bladelets, with hardly any larger tools. In other words: only small objects are left near the hearth, while the larger ones, including tools, are removed from the central part of the tent.

In my opinion, the second peak results from the combined centrifugal and barrier effects. Two important points emerge from investigating the tents of Gönnersdorf: a) in a dwelling the centrifugal effect is stronger than it is around a hearth in the open air; b) the tent wall is made visible through the barrier effect, which results in a bimodal ring distribution. In other words: my interpretation of the second peak is that the centrifugal movements occurring inside a dwelling with a central hearth are stopped by the walls, in due time resulting in a second peak in the ring distribution that roughly coincides with the walls of the dwelling. More than 4 m away from the hearths, we often see a third peak at Gönnersdorf (not illustrated in fig. 7),

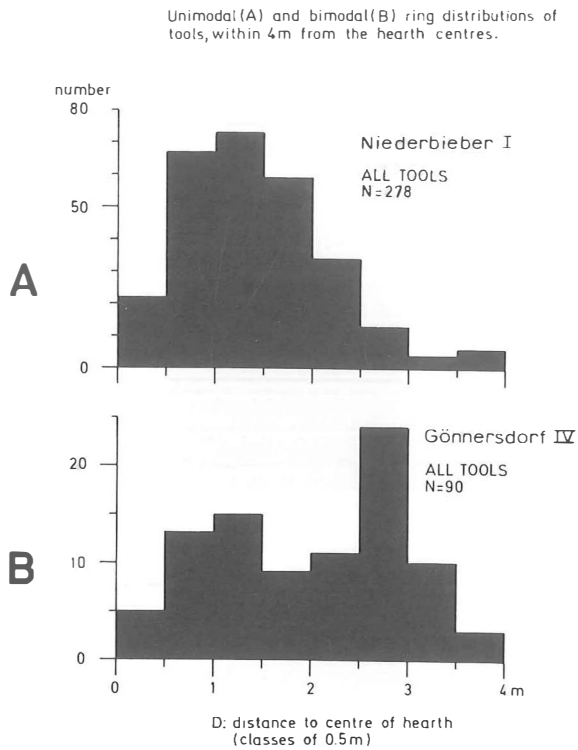


Fig. 7. Examples of unimodal and bimodal ring distributions of tools within 4 m from the hearth centres. Unimodal distributions, such as A, are considered to be characteristic of open air hearths, while bimodal ones, such as B, are associated with hearths inside dwellings (see main text, section 5). Compare with fig. 6.

which can be interpreted as resulting largely from the door dumps. For a more detailed discussion of Gönnersdorf, the reader is referred to other texts (Stapert, 1989; 1990a; Stapert & Terberger, 1989). It should be noted here, however, that at Concentrations II and III, where dwelling structures are not visible archaeologically, the same type of bimodal ring distributions have been obtained, suggesting that these sites too had tents (at least during one of their occupation phases: Stapert & Terberger, 1989). Other archaeologically 'invisible' tents have been demonstrated at Etiolles P15 (Olive, 1988) and at Verberie D1 (Audouze et al., 1981; Symens, 1986).

The analysis of the tents at Gönnersdorf I and IV has provided us with a method of demonstrating the presence of a dwelling with the help of the ring method. We can now classify archaeological residues with a central hearth into two types: those with unimodal and those with bimodal (or trimodal) frequency distributions of distances between tool locations and the hearth centres.

In the case of bimodal distributions we are dealing with hearths inside dwellings. Unimodal ring distributions will in general be characteristic of hearths in the open air. Of course, there are various complications. For example, if the hearth was located

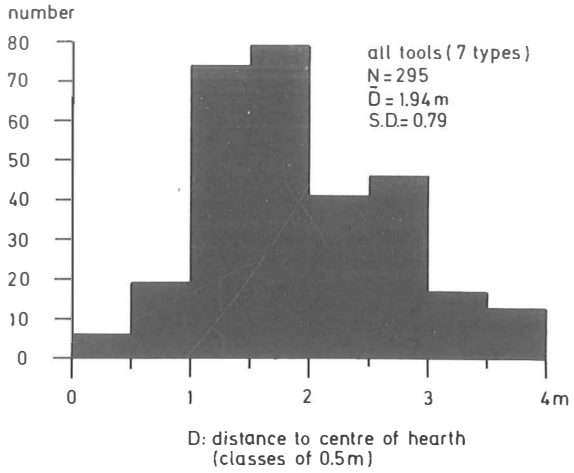


Fig. 8. Barmose I (7 sectors). Ring distributions of all the tools. of seven types: the six formal types represented in figure 6 and the splintered pieces. It can be seen that this distribution is slightly bimodal. which is caused by the splintered pieces (see fig. 15).

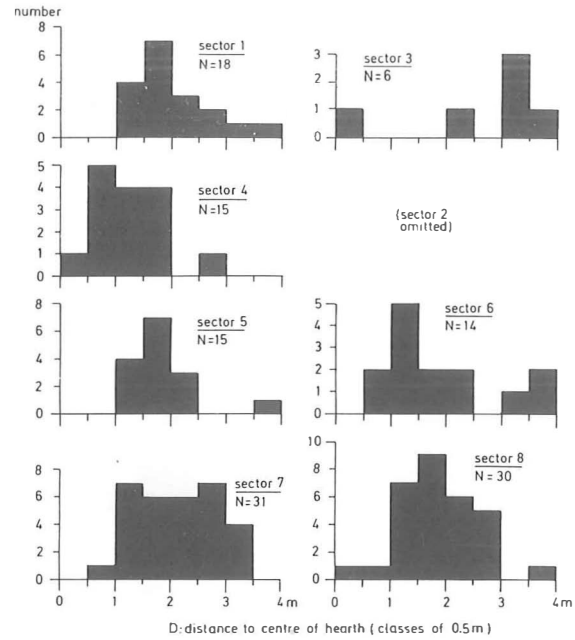


Fig. 9. Barmose I (7 sectors). Ring distributions persector of the tools of the six formal types. Note the almost empty area within 3 m from the hearth centre in sector 3. Compare with figures 10 and 11, where the same phenomenon can be observed.

eccentrically inside a dwelling, we would need ring distributions per sector to demonstrate the presence of walls, and it will usually be profitable to study such distributions. Forthis, however, the numbers of artefacts per sector should not be too low. In many cases such a detailed approach is ruled out because of insufficient frequencies. In the case of Barmose I, fortunately, numbers of artefacts are sufficiently high to allow a sectorwise study of ring distributions.

In the following section I will investigate what the ring and sector method can contribute in this case, as regards the presence or absence of a hut around the hearth.

6. BARMOSE I: THE DWELLING HYPOTHESIS

The ring distributions of 'microburins', tools of the six formal types taken together, and cores, are illustrated in figure 6. The data from the area within 4 m from the hearth centre are used, excluding sector 2. It can be seen that all three distributions are unimodal. This suggests that the hearth at Barmose I was in the open air. However, if we include the splintered pieces in the analysis, the resulting diagram of all the tools (fig. 8) becomes slightly bimodal. Still, this distribution is not really comparable to the diagram of Gönnersdorf IV (fig. 7), as the second peak is not very conspicuous. As noted, the small second peak in figure 8 is mainly caused by the splintered pieces, which is immediately apparent from the ring distribution of that artefact group, illustrated in figure 15.

Given this situation, we need to investigate this matter more fully in this case, by studying the ring distributions persector. In figures 9-11, Ihavepresented the ring distributions for seven sectors (not sector 2) of the splintered pieces, the tools of the 6 formal types taken together, and the cores. Most distributions are clearly unimodal. The second peak noted above is caused by a phenomenon that shows up in the distributions of all three artefact groups: a distant peak in sector 3, while the space within 2.5 to 3 m from the hearth centre in that sector is almost empty. It is possible that this phenomenon is the result of the first test pit, of which we do not know the exact location (see section 2). This seems unlikely, however, because the other sectors do not show high peaks between 2.5 and 3.5 m from the hearth centre. If the empty space in sector 3 was caused by testpitting, and if sector 3 originally possessed a unimodal distribution similar to those of sectors 1 and 4, the number of artefacts in sector 3 must have been extremely high to account for the frequencies in the rings between 2.5 and 3.5 m. This seems unlikely, because the western half of the site of Barmose I as a whole is characterized by low tool frequencies (see also section 7). We get the impression, therefore, that an area near the hearth in sector 3 was avoided during occupation. Possibly this area remained largely devoid of artefacts because it was covered by organic material that left no archaeological trace (wood?). I shall come back to this phenomenon in later sections of this article.

The conclusion of the analysis of the ring distributions at Barmose I can be no other than that the hearth was located in the open air. Of course, this conclusion does not exclude the possibility that a hut or other type of dwelling was present at Barmose I. There could have

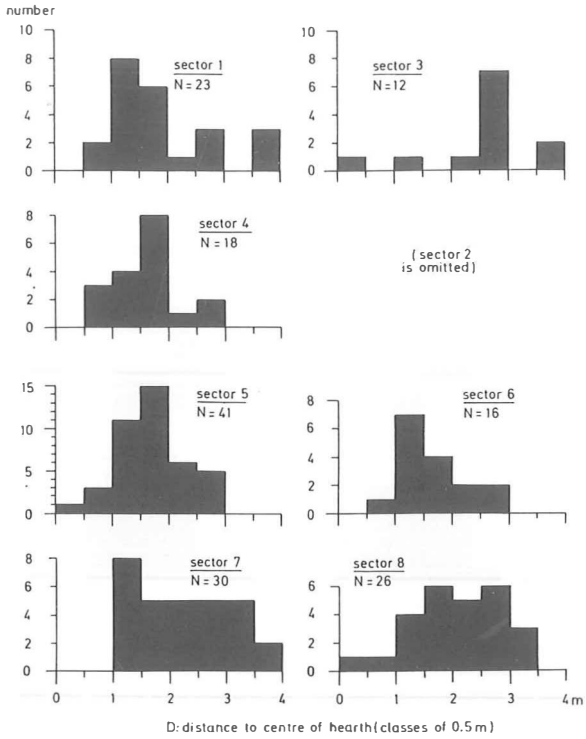


Fig. 10. Barmose I. Ring distributions per sector of the splintered pieces.

been a dwelling at some distance from the hearth, possibly outside the excavated terrain. We have no way of investigating this possibility, however.

In the above, two arguments were presented for the hypothesis that the hearth of Barmose I was not located inside a dwelling: 1) the absence of a strong centrifugal effect; 2) the fact that the ring distributions of tools (and cores) are essentially unimodal. Furthermore, it was noted earlier that, quite apart from these arguments, we would in any case expect such a large and dirty hearth area to be located outside. Evidently, the presence of bark floors does not seem to be associated exclusively with the interior of a dwelling, as supposed by Blankholm.

At the site of Duvensee several concentrations around large hearths were excavated by Bokelmann, and here too bark floors were present near the hearths (e.g. Bokelmann, 1986; 1989; Bokelmann et al., 1981; 1985). Bokelmann is of the opinion that the hearths of Duvensee were open-air ones (e.g. Bokelmann, 1989: p. 17); according to him the bark floors functioned to insulate the occupied area against groundwater. Grøn (e.g. 1987a: p. 304), however, has proposed that these were the sites of 'single-family dwellings'. The sites of Duvensee 8 and 13 were analysed with the ring and sector method. In both cases unimodal ring distributions were obtained, suggesting that Bokelmann is quite right: the bark floors were not inside dwellings. As an example the

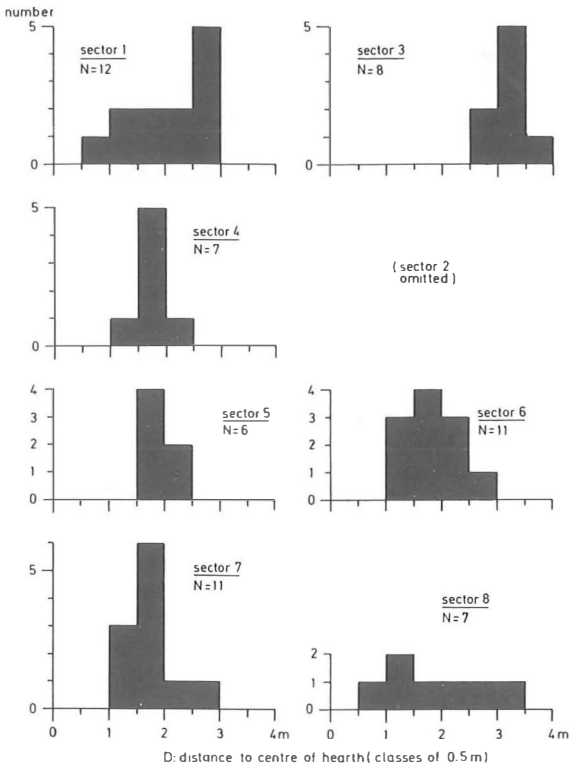


Fig. 11. Barmose I. Ring distributions per sector of the cores.

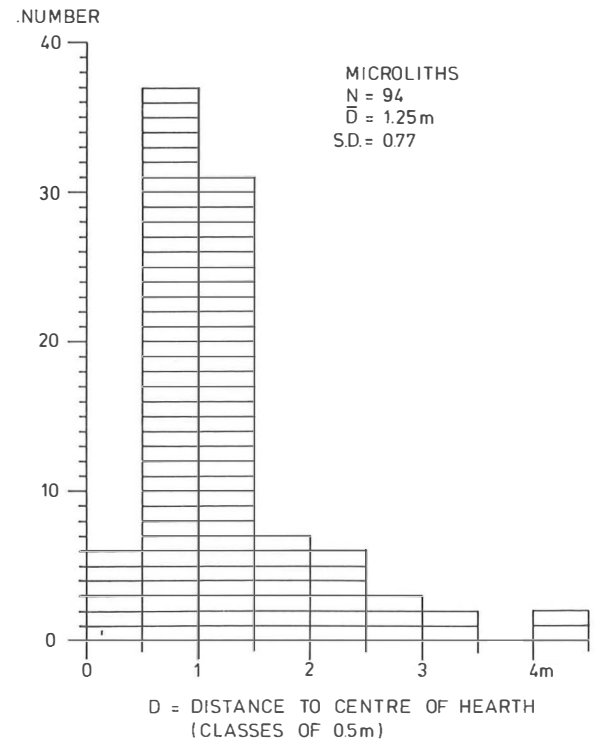


Fig. 12. Duvensee 8. Ring distribution of the microliths. Based on data

diagram for the microliths of Duvensee 8 i s reproduced (fig. 12).

7. DROP AND TOSS ZONES

If we look at distribution maps of tools, many sites of the type discussed here, artefact concentrations around central hearths, show a marked asymmetry, in the sense that many more tools are found on one side of the hearth than on the opposite side. If artefact concentrations around hearths were created in the open air, as at Barmose I, the existence of a prevailing wind direction is a likely explanation.

First, however, I want to quantify this asymmetry and to establish that it is real. In order to investigate this, the concentration is divided into two halves so as to maximize the difference between the numbers of tools in the two halves. In other words, we seek four adjacent sectors that have a higher total of tools than all other combinations of four adjacent sectors. Although the number of tools in sector 2 must be considered as a minimum estimate, I do not expect this to affect our analysis very much, as in the western half of the site tool frequencies are relatively low everywhere. Throughout this article the site-half with the highest total number of tools will be called the 'richest site-half' or 'R', and the other half the 'poorest site-half' or 'P'. In the case of Barmose I, the richest site-half is composed of sectors 5, 6, 7 and 8, i.e. the eastern half of the concentration (fig. 13). The asymmetry can be quantified easily by calculating what percentage of the total number of tools is present in R. In Barmose I this is 63%: almost two-thirds of all the tools are in the eastern half. We then want to investigate whether this difference could have arisen by chance. It is usual to apply the chi-square one-sample test in such cases (Siegel, 1956). It was found that the asymmetry is significant: p (two-tailed) < 0.001.

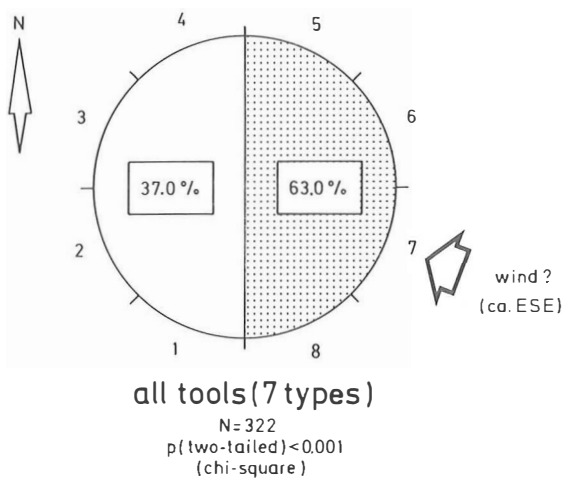


Fig. 13. Barmose I. Reconstruction of the prevailing wind direction during habitation. The site is divided into two halves so as to maximize the difference between the numbers of tools (7 types) in the two halves. The percentages of N tools in the two halves are indicated. See main text, section 7.

We have seen that the residue of Barmose I was most probably created in the open air. This means that people would have sat mainly on one side of the hearth: to windward, in order to avoid the smoke. The next question therefore is: was the occupied side of the hearth located in the richest site-half or in the poorest? In other words: is the drop zone in the site-half with high tool density, or in the opposite half? This is not a trivial question, because we cannot know a priori where most of the tools were eventually discarded: in the forward toss zone, or in the drop zone and the backward toss zone (see fig. 5). I have discussed this question *in extenso* in another article (Stapert, 1989), and do not want to repeat all the arguments here. The answer is unambiguous: the drop zone was (mostly) located in the richest site-half.

One of the problems with ethnoarchaeological observations such as Binford's hearth model, if we want to use them for archaeological interpretations, can be elucidated by the concept of time depth. The model depicted in figure 5 in fact illustrates the situation at a given moment. With archaeological sites, however, we are mostly dealing with a residue of an occupation of some duration, perhaps in the order of weeks or even months. Even if at any given moment during occupation the spatial 'organization' of the site at Barmose I resembled the model of figure 5, its lay-out did not necessarily remain unchanged. For example, if during occupation the wind direction changed several times, the whole system would have rotated around the hearth repeatedly. If the wind mostly came from the same direction, the resulting residue would still roughly resemble the model.

Table 2. Barmose I. Frequencies in rings of 0.5 m width around the centre of the hearth, excluding the locations in sector 2. Groups of artefacts: 1. Microliths; 2. Burins; 3. Denticulated/notched pieces; 4. Blade/flake knives; 5. Splintered pieces ('square knives'); 6. Scrapers; 7. Core/flake axes; 8. Total tools (7 types); 9. 'Microburins'; 10. Cores.

Rings	Groups of artefacts									
	1	2	3	4	5	6	7	8	9	10
0-0.5 m	3	0	0	0	3	0	0	6	2	0
0.5-1	1	1	2	1	10	2	2	19	1	2
1-1.5	11	4	3	4	43	7	2	74	6	11
1.5-2	5	8	8	3	44	7	4	79	4	22
2-2.5	6	1	4	2	21	5	2	41	2	10
2.5-3	5	1	1	4	30	4	1	46	0	9
3-3.5	2	0	1	0	8	3	3	17	1	7
3.5-4	0	1	1	0	7	2	2	13	0	1
Total	33	16	20	14	166	30	16	295	16	62

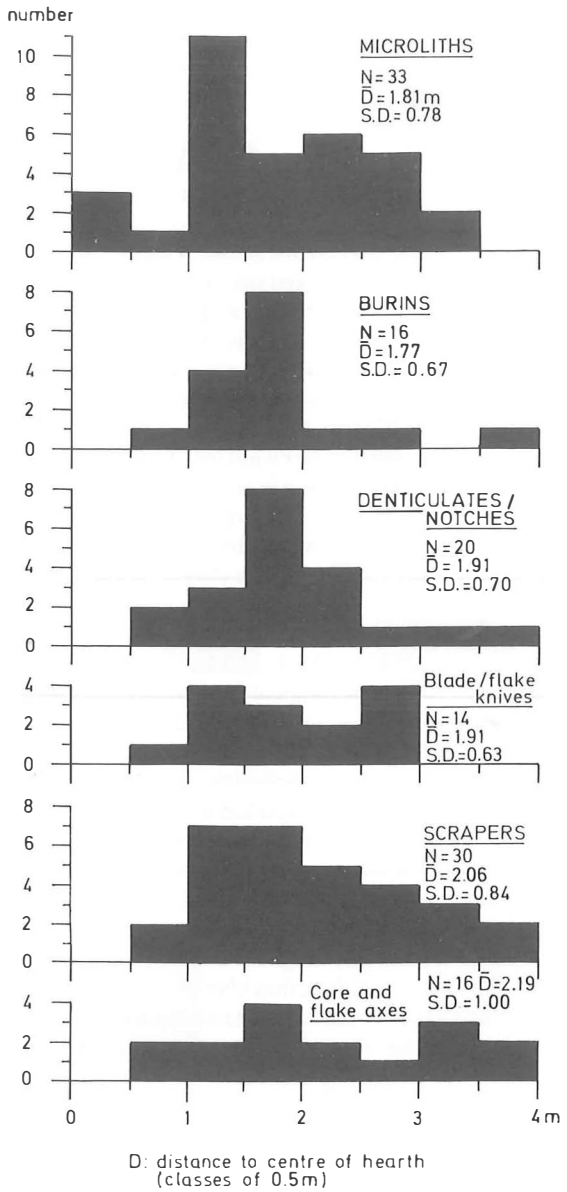


Fig. 14. Barmose I (7 sectors). Ring distributions of six formal tool types.

However, if there was no prevailing wind direction during the period of occupation, the end product would definitely be a palimpsest residue, even if at any given moment the site's structure was similar to Binford's model.

All this leaves us with at least three possible processes to account for the presence of artefacts in the poorest site-half, which may all have been operative in the course of occupation. The first possibility is that also the poorest site-half contained the drop zone for some time, but for a shorter timespan than the richest site-half did. The second is that the poorest site-half was the forward toss zone for most or all of the time. The third possibility is that in the poorest site-half some special activities, which were not very time- and flint-consuming, were performed while the drop zone was located in the richest site-half.

The sector method provides us with a way of investigating whether or not the poorest site-half was the forward toss zone. We have noted that especially larger pieces of refuse tend to end up in the toss zones. Thus, if a forward toss zone existed in the poorest site-half, we would expect the proportion of cores, with respect to that of tools, to be higher in that site-half than in the richest site-half. In the case of Barmose I we would expect this all the more since a backward toss zone seems to have been only weakly developed (no clear centrifugal effect can be demonstrated: section 4).

The numbers of tools (7 types) and cores in the two site-halves will be found in table 4. It can be seen that the proportion of cores in the poorest site-half indeed is somewhat higher than that of tools. Of all the cores, 47% are present in P, of all the tools only 37%. However, the difference is not very large, and cannot be shown to be significant according to the chi-square two-sample test (Siegel, 1956): $0.1 < p$ (two-tailed) < 0.2. Though the poorest site-half probably served as the forward toss zone during occupation, this tendency towards spatial segregation of tools and cores is only weakly developed, just as in the case of the backward toss zone. We should reckon, therefore, that part of the tools present in the poorest site-half were left there after playing a functional role in that area. Thus, either the drop zone was in that half during a part of the occupation period with a deviating wind direction, or some special activities went on there while the drop zone was in the eastern half of the concentration. For the last possibility at any rate

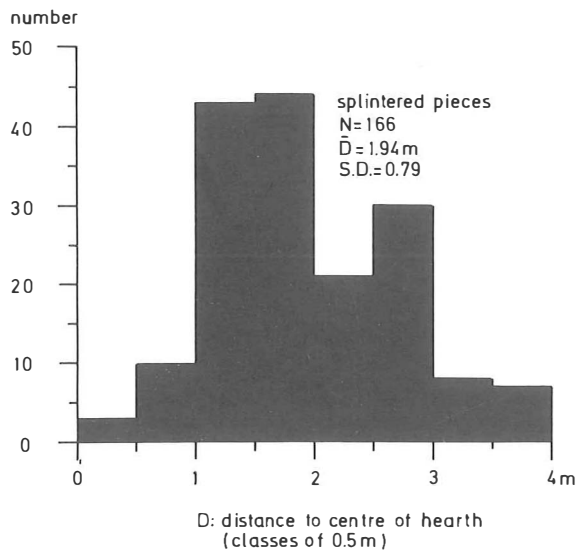


Fig. 15. Barmose I (7 sectors). Ring distribution of the splintered pieces ('square knives').

there are some arguments, which I will discuss in section 8.

It is of interest to note here that the presence of toss zones cannot be demonstrated very clearly in the case of Barmose I. Both tendencies towards spatial segregation of cores and tools which would indicate toss zones – a strong centrifugal effect, and a clearly higher proportion of cores in P compared to that of tools – are only weakly developed at Barmose I, and cannot be proven to be significant in a statistical sense. The occupants clearly did not bother very much about clearing up during occupation; this conclusion at any rate seems to apply to flint artefacts.

As concluded above, the drop zone must have been located in the eastern half of the concentration (R) most of the time. Since it is probable that the hearth of Barmose I was in the open air, it seems possible to reconstruct the prevailing wind direction during occupation. As the southern quarter within R contains more tools than the northern quarter (see table 5), and also because sector 1 has more tools than sector 4 (see note 3), the wind arrow in figure 13 is not placed in the middle of R, but is shifted somewhat towards the south, suggesting that the prevailing wind direction was roughly ESE.

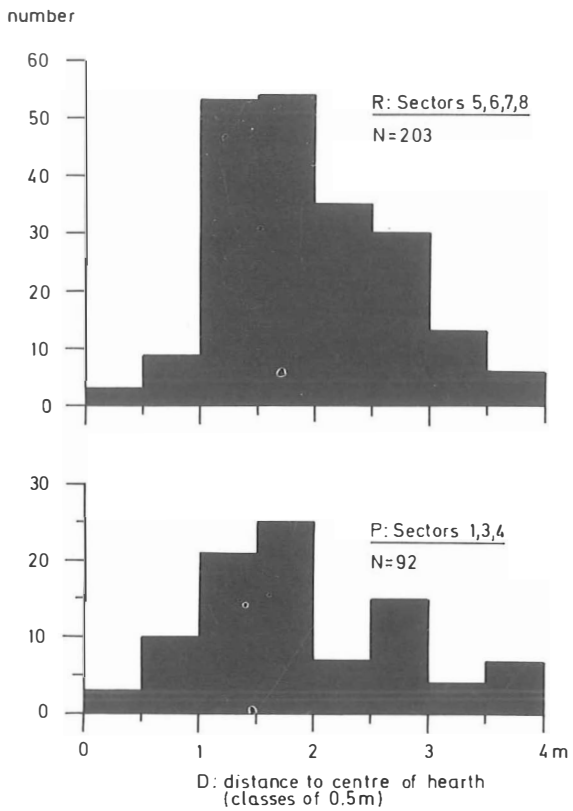


Fig. 16. Barmose I (7 sectors). Ring distributions of all tools, for the richest and poorest site-halves separately (see fig. 13). Note that the diagram for the richest site-half (R) is regularly unimodal. The diagram of the poorest site-half (P) is bimodal. In this case we are not dealing with a real bimodality (see the sectorwise ring diagrams in figs 9-11); this pattern is the result of the deviating situation in sector 3 (see main text, section 8).

8. TOOL TYPES AND RING DISTRIBUTIONS

It is of interest to study the ring distributions for the various tool types separately. The ring diagrams of the six formal tool types are presented in figure 14; the diagram of the splintered pieces is given in figure 15. Most diagrams are reasonably unimodal. However, especially the distribution of the splintered pieces seems to be bimodal. It was noted above that this bimodality is largely due to the fact that in sector 3 the area within 2.5 m from the hearth centre is almost devoid of artefacts, while the only peak in that sector occurs between 2.5 and 3.5 m; this applies especially to the splintered pieces (see figs 9-11). At this point it was decided to prepare separate ring diagrams of the richest and the poorest site-halves, for all the tools (7 types) taken together (fig. 16). It can clearly be seen that the diagram of the richest site-half, where the people would mostly have sat and worked, is a regular and unimodal distribution; most of the tools are located between 1 and 2 m from the hearth centre. This diagram supports the conclusion reached above, viz that the hearth of Barmose I was in the open air. The diagram of the poorest site-half (sector 2 omitted) shows bimodality, which, as we have seen, is largely caused by the distant peak in sector 3.

In view of this situation, it would perhaps have been better to prepare ring diagrams for the separate tool types, based only on the locations in the richest site-half. However, numbers per tool type would then become so low that these diagrams would no longer be very informative. Moreover, more than two-thirds (69%) of all the tools represented in figures 9-11 occurred in the richest site-half, so any patterns present in that half would dominate the picture (see also Stapert, 1989).

The diagram of the microliths among all the tool types has its mode closest to the hearth centre: in the 1-1.5 m class. Most other tool types have the mode in the 1.5-2 m class. The core and flake axes are on average located farthest from the hearth. Also scrapers are on average located relatively far from the hearth. This pattern, with 'projectiles' (microliths) located close to the hearth and scrapers away from it, seems to be very common at sites where scrapers were made on blades. For example, it applies to 11 of the 12 analysed concentrations of Pincevent (Stapert, 1989), and to many other Upper or Late Palaeolithic sites. I have explained this pattern as due to 'retooling' (Keeley, 1982). It is probable that heat was needed when new flint insets were fixed into their shafts with the help of, for example, birch tar (Moss & Newcomer, 1981; Moss, 1983), and

this could be the reason why the repairing of weapons (and other tools with flint insets) took place close to the hearth. During the Upper and Late Palaeolithic, scrapers were mostly used to work hides (see e.g. Juel Jensen, 1988). Because of the fact that many types of hide-working required quite a lot of working space, scrapers would have ended up farther away from the hearth. During the Mesolithic, however, many scrapers were used to work wood (Juel Jensen, 1988). Most tasks carried out by means of tools such as borers and burins possibly required neither fire nor a large amount of space, so that these tools tended to be used and discarded at intermediate distances from the hearth.

It is possible to quantify the above-mentioned pattern by a simple index, analogous to the centrifugal index: the ratio of mean D of the scrapers to mean D of the microliths. In the case of Barmose I this index has a value of 1.14. This is a relatively low figure. In the case of Pincevent, this index is mostly above 1.5 (Stapert, 1989). Moreover, the difference between microliths and scrapers cannot be proved to be significant in a statistical sense (after combining the frequencies in two rings of 2 m width, the Fisher Test results in a p of 0.37). Of course, it is true that 'a behaviourally meaningful or relevant relationship is not necessarily statistically significant' (Blankholm, 1991: p. 43). However, in such cases we must have good arguments for believing that any patterns are indeed meaningful. The pattern of microliths (or other insets of projectiles) lying close to the hearth with scrapers farther away, shows up in many sites, and in several of them can be proved to be significant. Therefore, I believe that the same types of formation processes could have been at work at Barmose I. It is also possible, however, that this pattern is weakly developed in Barmose I because wood-working was dominant over hide-working in the case of the scrapers.

I shall now return to the deviating picture in the poorest site-half (fig. 16). In sector 3, the area up to 2.5-3 m from the hearth centre is relatively empty. This is most probably a real phenomenon, and not one caused by testpitting. One way to approach this phenomenon is to investigate in what proportions the various tool types are present in the richest and poorest site-halves. The data can be found in table 4. We noted above that about 63% of all the tools are located in the richest site-half. If we look at the individual tool types, however, some variation is apparent. The most conspicuous deviation from the general picture is exhibited by the axes. Whereas all the other types show proportions above 50%, and mostly above 60%, in the richest site-half, of the axes only 33% are present in this area. Moreover, there is a marked concentration in sector 2 (see table 3). This is all the more surprising since this sector is heavily disturbed by the 2x1 m testpit, of which the contents are unknown to us. Therefore, we may expect that the number of axes in sector 2 originally was even higher. Core and flake axes make up 8.4% of all the tools (7 types) within 4 m

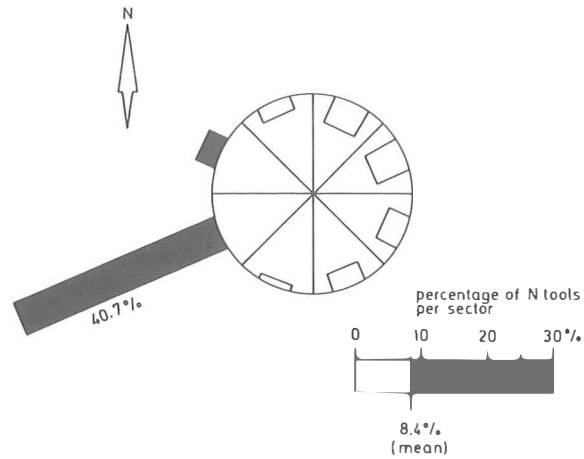


Fig. 17. Barmose I. Sector percentages of axes (N = 27), based on the total numbers of tools (7 types) per sector. Note the high percentage in sector 2.

from the hearth centre (see section 3). In figure 17, I have indicated the percentages per sector (based on the total number of tools per sector). Axes make up more than 40% of all the tools in sector 2.

This is a remarkable phenomenon. Clearly, the spatial distribution of axes is completely different from that of all the other tool types. This can also be shown statistically (see table 4: remarks 2 and 3). Moreover, we may be fairly sure that the concentration of axes in sector 2 is behaviourally relevant. For example, it is unlikely that most axes ended up in sector 2 because they were tossed out there. If the concentration of axes in the poorest site-half were due to their having been discarded in the forward toss zone, we would expect the same or a higher proportion of cores also to be located in that site-half, which is not the case (of all the axes 67% are in P, of the cores only 47%).

The concentration of axes is found immediately to the south of the relatively empty area in sector 3. If axes played a functional role in the working of wood (this seems to be the case, according to unpublished research by N. Symens; see Grøn, 1987a: p. 314), we can now offer the following explanation. Sector 3 might have contained a wood pile, for example as a fuel supply. This would make sense in several ways. It would explain the empty area in sector 3, and the concentration of axes in sector 2. Moreover, if a wood pile was indeed present, sector 3 would have been the most logical choice for its location. As we have seen, it is probable that the hearth of Barmose I was in the open air, and we have reconstructed the prevailing wind direction during occupation as ESE (fig. 13). Sector 3 is located opposite the tool-richest part of the site, which is composed of sectors 7 and 8 (see table 3). Moreover, the presence of a wood pile relatively close to the hearth does seem to be a reasonable proposition, given the fact that the large hearth of Barmose I contained quite a lot of charcoal.

Table 3. Barmose I. Artefact frequencies in 8 sectors around the centre of the hearth (for sector boundaries see fig. 1). Only locations within 4 m from the centre of the hearth. Note: frequencies in sector 2 should be considered as minimum estimates (see main text, section 2). Artefact groups: 1. Microliths; 2. Burins; 3. Denticulated/notched pieces; 4. Blade/flake knives; 5. Splintered pieces ('square knives'); 6. Scrapers; 7. Core and flake axes; 8. Total tools (7 types); 9. 'Microburins'; 10. Cores.

Sectors	Groups of artefacts									
	1	2	3	4	5	6	7	8	9	10
1	5	2	1	2	23	5	3	41	1	12
2	0	2	0	2	7	5	11	27	0	4
3	2	0	0	1	12	1	2	18	0	8
4	3	3	1	1	18	5	2	33	1	7
5	3	1	4	2	41	3	2	56	5	6
6	3	3	3	2	16	2	1	30	2	11
7	10	3	5	3	30	7	3	61	5	11
8	7	4	6	3	26	7	3	56	2	7
Total	33	18	20	16	173	35	27	322	16	66

The use of fire must have been of considerable importance to the inhabitants.

9. THE TWO QUARTERS WITHIN THE RICHEST SITE-HALF

Although women of several hunter/gatherer groups participate in some forms of hunting, this is usually the work of men. The sexual division of labour with 185 ethnographically studied peoples is discussed by Murdock & Provost (1973). Hunting large land fauna is done exclusively by men with 96.5% of the 144 peoples for which there are relevant data in the tables of Murdock & Provost (1973). With the remaining 3.5%, hunting is done predominantly by men. A very interesting aspect of this matter is that even in cases where women participate in hunting, there is a world-wide taboo on their handling weapons that cut or penetrate the animals, thus drawing blood (Testart, 1986). Although we shall never know for sure, this pattern may well have been in existence in Late Palaeolithic and Mesolithic times. This assumption leads to the conclusion that 'projectiles', such as microliths, most probably were made and left behind by men. Therefore, microliths would be the only tool type to be associated with one of the sexes. If used microliths are found, located relatively close to the hearth, we may be fairly sure that at least one man was present at the site, who among other things repaired his hunting equipment.

What about the women? Is it possible to find evidence relating to their presence or absence at a given site? The topic of gender in archaeology has been discussed recently in several publications (e.g. Conkey & Spector, 1984; Gero & Conkey, 1991). It has to be admitted, however, that sound empirical evidence regarding such questions is often lacking at Stone Age sites. We have no a priori indications to postulate sex-specificity for tool types such as burins and scrapers, though there seems to be a tendency among subrecent hunter/gatherers for most hide-working to be done by women. Among the 185 peoples studied by Murdock & Provost (1973), there are 40 which can be classified as hunter/gatherers, i.e. peoples whose livelihood is provided for more than 90% by hunting, fishing and gathering. For 27 peoples among these 40, data concerning the sex-specificity of hide-working are available. With c. 59% of these 27 groups hide-working was done exclusively by women, and with 11% predominantly by women. With 22%, hide-working was done exclusively or predominantly by men. This would mean that scrapers, most of which played a functional role in hide-working (e.g. Juel Jensen, 1988), were used more frequently by women than by men. Even if this were true, however, it would not help us very much in the interpretation of individual sites, because it is probable that men also engaged in hide-working, for example at hunting camps.

In preceding sections I concluded that the richest site-half, in terms of tool numbers, is the area where people would have sat and worked most of the time. Let us assume that a nuclear family lived here. In that case we may postulate that of the two quarters constituting the richest site-half, one was occupied by a man and the other by a woman. We know that a sexual division of domestic space within dwellings is a common phenomenon with hunter/gatherers (e.g. Faegre, 1979; Grøn, 1989). Fixed areas for men and women may also

Table 4. Barmose I. Frequencies and proportions in 'R': the richest site-half (sectors 5, 6, 7, and 8) and 'P': the poorest site-half (sectors 1, 2, 3 and 4). Only locations within 4 m from the centre of the hearth. Artefact groups: 1. Microliths; 2. Burins; 3. Denticulated/notched pieces; 4. Blade/flake knives; 5. Splintered pieces ('square knives'); 6. Scrapers; 7. Core/flake axes; 8. Total tools (7 types); 9. 'Microburins'; 10. Cores.

Artefact groups	R		P		N
	Number	%	Number	%	
1	23	69.7	10	30.3	33
2	11	61.1	7	38.9	18
3	18	90.0	2	10.0	20
4	10	62.5	6	37.5	16
5	113	65.3	60	34.7	173
6	19	54.3	16	45.7	35
7	9	33.3	18	66.7	27
8	203	63.0	119	37.0	322
9	14	87.5	2	12.5	16
10	35	53.0	31	47.0	66

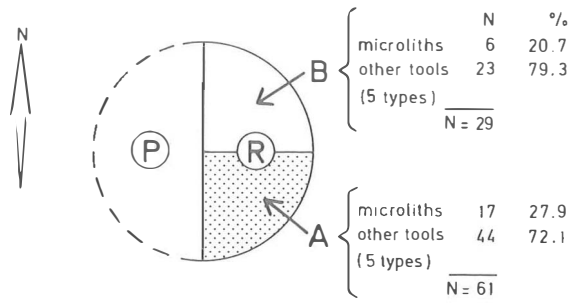
Remarks: 1. The difference between cores and all tools (7 types) is not significant: $0.1 < p$ (two-tailed) < 0.2 (chi-square two-sample test: Siegel, 1956).
2. The difference between core/flake axes and splintered pieces is significant: $0.001 < p$ (two-tailed) < 0.01.
3. The difference between core/flake axes and all the other tools (except splintered pieces) is significant: $0.001 < p$ (two-tailed) < 0.01.

be expected around hearths in the open air (Marshall, 1959; 1973; Tindale, 1972). With the Bushmen, the building of shelters mostly is the work of women. 'It takes the women only three-quarters of an hour to an hour to build their shelters, but half the time at least the women's whim is not to build shelters at all. In this case they sometimes put up two sticks to symbolize the entrance of the shelter so that the family may orient itself as to which side is the man's side and which the woman's side of the fire." (Marshall, 1973: p. 97).

We would then expect the proportions of microliths and 'other tools' to be different in the two quarters. This would be because hunting gear was repaired only by men. Even if the other tool types were used by both men and women, this would lead to differences in the proportion of microliths with respect to the other tools. Of course, there are many problems to consider. Since we are dealing with a small and intensively used area, we have to anticipate smearing processes. If the wind direction changed several times, mixing would occur as a result of rotation around the hearth, blurring such patterns.

Moreover, if a larger group was occupying the site, consisting of several men and women, it would be much harder to demonstrate sexual division of space. In the case of Barmose I, however, we have reasons to believe that the group of occupants was relatively small. The drop zone is located quite close to the hearth (see fig. 20). Since only a semicircle is available for sitting near to an open-air hearth, the distance between the drop zone and the hearth will become larger when a greater number of people are present (Binford, 1983; Stapert, 1989). In the case of Barmose I, the presence of only two or three adults seems to be a reasonable proposition.

Despite such problems, we should, when dealing with open-air hearths occupied by families, expect a difference between the two quarters to be demonstrable in many cases, which we would not expect if several persons of the same sex were present. This implication can be investigated statistically. The richest site-half is divided into two quarters. The quarter with the highest proportion of 'projectiles' is called 'A', the other 'B'. The frequencies of 'projectiles' and of 'other tools' in A and B are counted (table 5). In the case of Barmose I the 'projectiles' are microliths, and the 'other tools' are scrapers + burins + denticulated/notched pieces + blade/flake knives + core/flake axes. (The splintered pieces will be considered separately.) We then want to test the null hypothesis, which states that there are no differences between A and B, regarding the proportions of 'projectiles' to 'other tools' present in them. The alternative hypothesis is that the proportion of 'projectiles' is significantly higher in A than in B. This can be investigated by the Fisher Exact Probability Test (Siegel, 1956). In the case of Barmose I, there is no significant difference between the two quarters: p = 0.32 (see fig. 18). Moreover, I have also tested the



Difference in proportions of microliths and other tools between A and B is not significant.

Fisher Test: p = 0.32.

Fig. 18. Barmose I. The richest site-half (R) is divided into two quarters, A and B. These two quarters are not demonstrably different as regards the proportions of microliths and other tools (see also table 5).

difference between A and B for all possible combinations of two tool types (among the six formal types). All 15 combinations produced Fisher p's above 0.30. Therefore, as far as the six formal tool types are concerned, no differences between A and B can be demonstrated. Since microliths were found to be located relatively close to the hearth, the conclusion of this exercise should be that one or several men were present, but probably no women.

Another argument in this respect is the spatial distribution of the small 'microburins'. These are waste from the production of microliths. Of their total of 16, 14 are in R: the eastern site-half (87.5%). Because these small objects will have been tossed away less frequently than larger artefacts, this again indicates that the drop zone was in R. Quarters A and B in R contained equal numbers (7) of microburins, suggesting that microliths were produced in both quarters during occupation.

It was concluded that the two quarters within R do not differ as regards the proportions of the six formal tool types. However, they are different in two other respects. The first is that A is about twice as rich in tools of the six formal tool types as B (totals are 61 and 29, respectively). The numbers of splintered pieces in the two quarters, however, are about the same (56 and 57, respectively). The difference in proportion of the splintered pieces, with respect to the total of the other tools, can be shown to be significant (see table 5: remark 3). Thus, the situation can be summarized as follows: in both quarters the amount of splintered pieces is the same, but in quarter A there are twice as many other tools as in B, though their proportions are similar in both quarters. Though in no way conclusively, this seems to suggest the presence of at least two men, who performed similar types of activity, but with a different intensity as regards the tools other than splintered pieces.

Table 5. Barmose I. Comparison between the two quarters A and B within 'R', the richest site-half (sectors 5, 6, 7 and 8).

	B Sectors 5+6 Number	%	A Sectors 7+8 Number	%	N
Scrapers	5	17.2	14	23.0	19
Burins	4	13.8	7	11.5	11
Microliths	6	20.7	17	27.9	23
Core/flake axes	3	10.3	6	9.8	9
Dentic./notched pieces	7	24.1	11	18.0	18
Blade/flake knives	4	13.8	6	9.8	10
Total 6 types	29	99.9	61	100.0	90
Splintered pieces	57	66.3	56	47.9	113
Total 6 other types	29	33.7	61	52.1	90
Total 7 types	86	100.0	117	100.0	203

Remarks: 1. Differences between all pairs among the 6 formal tool types, regarding their proportions in the two quarters, are not significant: all 15 p's resulting from application of the Fisher Exact Probability Test (Siegel, 1956) are above 0.30.
2. The difference between microliths and total tools of 5 other types (i.e., without splintered pieces) is not significant: p = 0.32 (Fisher Test).
3. The difference between splintered pieces and total other tools (6 types) is significant: p = 0.01 (Fisher Test).

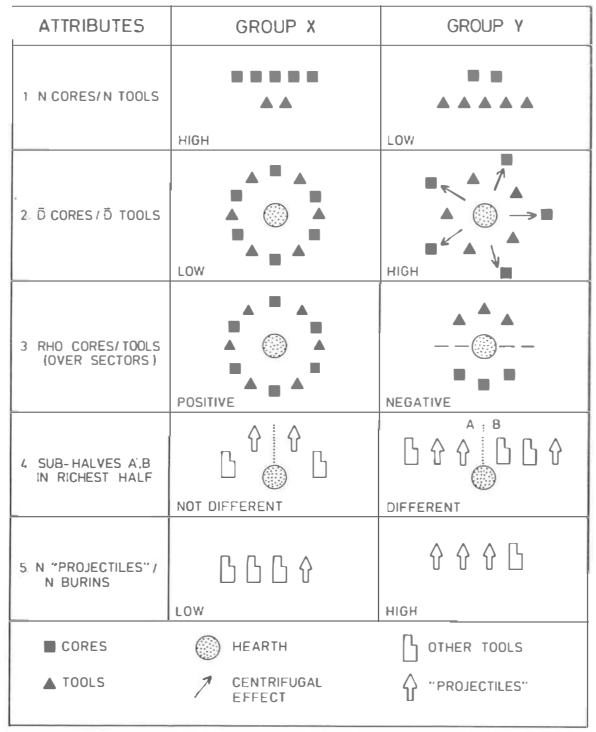


Fig. 19. Classification of 18 Upper/Late Palaeolithic sites with open-air hearths into two groups, X and Y (Stapert, 1989). The sites of Group X show no centrifugal effect, nor any spatial segregation of tools and cores in their sector distributions; moreover, these sites show a relatively large number of cores in proportion to tools, and a large number of burins in proportion to 'projectiles'. For the sites of Group Y the reverse is true. Sites in Group Y show a tendency for quarters within the richest site-halves to differ in terms of proportions of 'projectiles' to other tools, while this is not the case at sites assigned to Group X. One explanation could be that most sites of Group Y were occupied by families, and those of Group X by small groups of men (e.g. hunting camps). Barmose I can be placed in Group X.

10. COMPARING BARMOSE I WITH SEVERAL OTHER ANALYSED SITES

In a previous article (Stapert, 1989), I have analysed eighteen other sites (Upper/Late Paleolithic) for which it is probable that the hearths were in the open air (on the basis of the tools' showing a unimodal ring distribution). It was found that some sites show a significant difference between quarters A and B within the richest site-halves, and others do not. It was also found that the sites with different A's and B's are furthermore characterized by the presence of a clear centrifugal effect, and of spatial segregation of tools and cores in their sector distributions. Thus, sites showing clear indications of the presence of both forward and backward toss zones also tend to have different quarters within R, whereas sites that appear not to have had clear toss zones also show no differences between the two quarters in R. On the basis of these attributes, therefore, it seems as if two site-types can be defined, which I have called 'Group X' and 'Group Y', and it was found that these two groups also differ in several other aspects (fig. 19).

Group X includes sites such as Habitation 1 at Pincevent (Leroi-Gourhan & Brézillon, 1966), Marsangy N19 (Schmider, 1979; 1984; 1988), and Bro I (Andersen, 1973). These sites do not show a clear centrifugal effect ('centrifugal index' smaller than 1.15), there is no tendency towards spatial segregation of cores and tools in sector distributions (% of N cores in R not significantly smaller than that of tools), there is a relatively high proportion of cores to tools, the ratio of 'projectiles' to burins is low ('projectile/burin index' mostly smaller than 1.25), and there is no clear difference between the two quarters within the richest site-half.

Group Y includes sites such as Niveau IV-20 at Pincevent (Leroi-Gourhan & Brézillon, 1972; Julien et al., 1988), Oldeholtwolde (Stapert et al., 1986), Olbrachcice 8 east (Burdukiewicz, 1986) and Niederbieber (Bolus et al., 1988; Winter, 1986; 1987). These sites show a clear centrifugal effect ('centrifugal index' above 1.20), a tendency towards spatial segregation of cores and tools in sector distributions (% of N cores in R clearly smaller than that of tools), a relatively low proportion of cores to tools, a high ratio of 'projectiles' to burins ('projectile/burin index' mostly above 1.25), and clear differences between the two quarters within the richest site-half.

It was hypothesized that most sites of Group X were occupied by men only, while at most sites of Group Y women were also present. In other words: Group X

might represent hunting camps or male 'special purpose camps', and Group Y family camps. For more details concerning this site grouping, the reader is referred to a previous publication (Stapert, 1989).

Barmose I clearly belongs to Group X, as defined above. Toss zones seem to have been only weakly developed (spatial segregation of cores and tools in their ring and sector distributions cannot be shown to be significant in a statistical sense), there is a relatively large proportion of cores compared to tools, and the two quarters within R cannot be shown to be different. Compared to the Upper/Late Palaeolithic sites placed in Group X, however, there are fewer burins in proportion to 'projectiles'.

All in all, indications are that Barmose I was occupied by a few men only; we have no sound indications for the presence of women.

11. DISCUSSION AND SOME CONCLUSIONS

This section consists of two parts. First I will summarize my results for the site of Barmose I. In the second part I will evaluate the performance of the ring and sector method.

The hypothesis of a dwelling structure around the hearth of Barmose I has to be rejected on the basis of the ring distributions: occupation took place in the open air.

People must have been sitting and working to the east of the hearth most of the time, which suggests a prevailing wind from the east. Apart from some variability in local tool density, the whole eastern half, which is the richest site-half in terms of tool numbers, seems to have been a single 'general activity area'. Probably many different activities went on here, including flint-working, and I cannot see much reason for functional differentiation within this area. Most artefacts in this area seem to be located in a drop situation, as described by Binford (1983). Indications for the existence of distinct toss zones are weak, and not significant in a statistical sense. In other words, continual clearing up during occupation hardly took place. This suggests that the occupants of the site anticipated only a short stay at this locality.

A second 'activity area' is located on the opposite side of the hearth, to the west of it. Here a more specific activity is indicated, involving the use of axes; it can be suggested that especially wood-working took place here from time to time. This activity seems to be associated with a relatively empty space near the hearth where possibly a wood pile was present. Though not significantly so, microliths are found relatively close to the hearth, and scrapers farther away. This pattern, which is also common at Upper and Late Palaeolithic sites, can be explained by assuming that in the retooling of 'projectiles' (microliths) heat was needed, while hide-working (scrapers) required quite a lot of space. The two quarters within the drop zone in the eastern half of the site cannot be shown to be different, in terms of the proportions in which six formal tool types are represented. This suggests that a few persons of the same sex were present, which, in view of the presence of microliths relatively close to the hearth, must have been men. Perhaps the most likely interpretation of the site would be that it was a hunting camp. However, it should be remembered that we do not really know what tasks were carried out with the help of the numerous splintered pieces. The hypotheses resulting from my analysis have been summarized in a general sketch of the site (fig. 20). The large stone (diameter about 30 cm, see fig. 1) is now seen to be located in the drop zone to the east of the hearth. A reasonable suggestion therefore is that it was a seat.

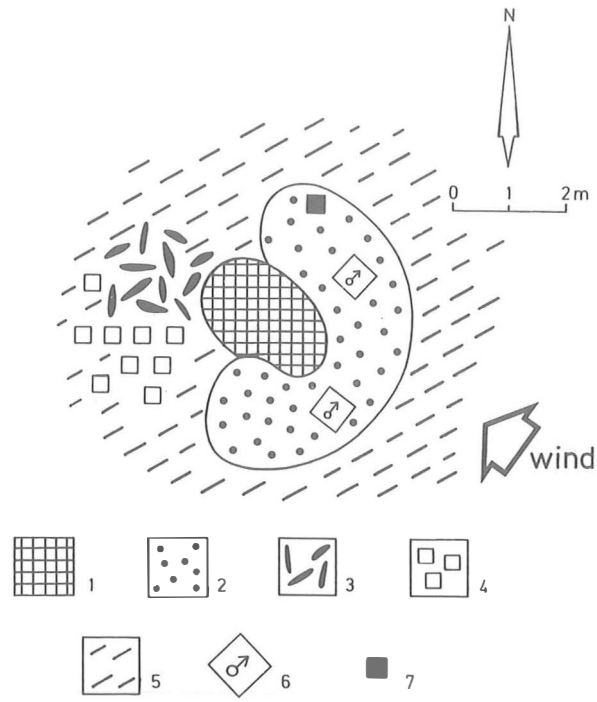


Fig. 20. Barmose I. Sketch in which the interpretations resulting from the analysis by the ring and sector method have been summarized. It is concluded that the hearth of Barmose I was in the open air. The prevailing wind during habitation is thought to have been roughly from the east. Perhaps two men were present; there are no good reasons for assuming the presence of women. Key: 1. Hearth; 2. Drop zone; 3. Wood pile?; 4. Concentration of axes; 5. Toss zones; 6. Suggested seating positions; 7. Large stone (seat?).

In my opinion the ring and sector method has performed well in this case. The effectiveness of the method seems to be due to several factors. First of all, it is adapted to the global structure of sites such as Barmose I, where a central hearth, which clearly was the focus of all sorts of activities, defines the spatial 'organization'. It links up with ethnoarchaeological models, such as Binford's hearth model. For example, the presence or absence of toss zones can be investigated satisfactorily with the help of ring and sector distri-

butions. Moreover, the method is simple and, above all, transparent. It contains no inherent assumptions of a statistical nature, which encumber many of the more complex approaches to intrasite spatial analysis.

The method seems to make it possible to demonstrate whether hearths lie in the open or inside a tent, which in my opinion is a prerequisite for any meaningful spatial analysis. Another important aspect is that the ring and sector method makes it possible to compare different sites as to their global spatial layout. Several attributes which are investigated with this method, can be summarized in the form of simple indexes. For example, it is possible to describe quantitatively two different tendencies towards spatial segregation of cores and tools – both suggesting the presence of toss zones – by the 'centrifugal index' and the 'tools/cores in R index'. This has resulted in a grouping of the analysed sites into two types: sites with and without clear indications for the existence of toss zones (Groups Y and X, respectively: fig. 19). Interpretations attached to this finding may be arbitrary, but the statistical patterns seem to be quite convincing, and hence are interesting.

One general result of my analysis is, once again, that archaeological residues around 'domestic hearths' in the open air present us with a somewhat frustrating situation, as far as intrasite spatial analysis is concerned. In such cases we should not attempt to demonstrate discrete 'activity areas' by complex procedures. Since the central hearth attracted many different activities, it can hardly be expected that the separate activity areas should still be recognizable, as these would have become blurred in this small but intensively used area. Of various types of activity many episodes must have occurred around the hearth, and these will have had different results in terms of the numbers of tools that were discarded, and the size and shape that waste scatters took, and it is to be expected that the residues of many episodes of different activities will overlap in space. As Carr has put it: "Co-occurrences between different artefact types in this situation reflect the common social context in which they were used, rather than use in a common activity." (Carr, 1984: p. 115). In other words, the level of resolution of most of the complex techniques, as used by Blankholm, is set much too high to be appropriate in such cases. It seems unrealistic to produce 15, 16 or 19 'clusters' by mathematical means (unconstrained clustering, correspondence analysis and 'presab', respectively) in the case of Barmose I and similar sites. Such outcomes are hardly interpretable, because these techniques expect too much 'expressiveness' from archaeological sites of this type. In such cases we are dealing with a kind of spatial 'autocorrelation' within the richest site-halves (e.g. Simek, 1984; Yellen, 1977). Therefore, we should concentrate first of all on global patterns, and try to make sense of these in the light of, for example, ethnoarchaeological observations, instead of expecting miracles from very detailed mathematical procedures. This problem was recognized by Blankholm, as appears from the following citation: "... Simek (1984) has convincingly demonstrated the need to take the effect of spatial autocorrelation of behaviourally independent tasks around features, fixtures and centres of social activity into account." (Blankholm, 1991: p. 48). Evidently, given the detailed analyses in the rest of his book, Blankholm did not consider Barmose I to be an example of this problem. In my opinion, however, Barmose I is a typical example, and the same is true for many other sites.

Complex techniques are often applied rather mechanically, without an adequate theoretical framework to guide interpretation of the results. One only needs to imagine a site which had several occupations, and where during each occupation a great deal of rotation around the hearth occurred because of changing wind directions. The resulting residue will be a palimpsest. Cluster techniques will still produce clusters, however, because this is what they are designed to do, and archaeologists will then try to interpret these clusters in terms of 'activity areas'. This is because even in such situations the spatial distributions will not have become totally random – there will always be local irregularities. Therefore, what we need are ways to bridge the gap between the static data, including patterns produced by computer procedures, and realistic interpretations. To do this, interpretive models are needed. One of the best ways to obtain these is by making ethnoarchaeological observations operational for archaeology; this is what Binford (1983) has called 'decoding the archaeological record'.[5]

12. ACKNOWLEDGEMENTS

Thanks are due to Miriam Weijns and J.M. Smit (B.A.I.) for drawing work, and to Xandra Bardet for expertly improving my English text. I thank Tineke Looijenga (Groningen) for translating parts of Blankholm (1984). A first draft of this article was critically read by Bjarne Grønnow (Copenhagen), whose comments I have very much appreciated. Thanks are due to Jeannette van der Post (Groningen), for removing several typing errors.

13. NOTES

1. In Blankholm (1984: p. 63; 1987: pp. 109, 110), it is stated that the best approximation of the hut outline at Maglemosian sites is the contour line of the mean number of artefacts per square metre, calculated over the site as a whole.
2. Somewhat similar methods were employed by Dekin (1976) and Hull (1987). What distinguishes these methods from the ring and sector method is that they are not hearth-oriented (though they could be adapted in this sense).
3. In reality, the drop zone probably was mostly somewhat larger than a semicircle (see e.g. Binford, 1983: figs 89, 90). It may cover 5 or even 6 sectors (of a total of 8). Gallay (1989) describes groups

of 4 to 7 Touareg men, drinking tea around a fire. In his figure (Gallay, 1989: fig. 3), a group of 6 men is indicated, sitting inside a 'drop zone' 1 to 2 m from the hearth centre, to windward of it. Of the total circumference of 360°, they occupy about 260°.

4. B. Grønnow (Copenhagen) kindly informed me of the following. 'The core- and in particular the flake-axes of the Barmose group are the largest and most heavy flint objects, so I guess that they have to be taken into consideration in the centrifugal analysis.' (letter of 16-VIII-1991). Therefore, in this case it would be appropriate to compare the axes to all the other tools taken together, as regards their distance to the hearth centre. As can be seen in table 1, the core- and flake-axes indeed are, on average, located farthest from the hearth among the tool classes. After combining the data in two rings of 2 m width, it is possible to apply the chi-square two-sample test (Siegel, 1956) in a valid way. Again, however, the difference cannot be shown to be significant in a statistical sense ($0.5 < p$ (two-tailed) < 0.7), though there is a tendency towards it.
5. In 1993, Blankholm critically reacted to this article; his comments are published in this volume of *Palaeohistoria*, as is the case with my reply.

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