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Spatial Analysis of Late Mesolithic and Neolithic surface scatters a test case of the Roerstreek (Middle Limburg)

The Prehistoric remains in the Roerstreek, an area of 144 km² south of Roermond and east of the Meuse (Middle Limburg, the Netherlands) have been inventoried. This paper concentrates on the inventory available for Late Mesolithic and Neolithic periods (5500–1700 B.C.) A model is proposed for the changes in the subsistence economy, that would be reflected in the settlement pattern. Following a a critical analysis of the possible distortions of the collected information, this model is tested by using statistical techniques for classification and spatial analysis. Although the results obtained are not unambiguous, some are unexpected. The data seem to indicate that the Early Neolithic peoples used the area mainly for transhumance. Agricultural settlements are present from the Middle Neolithic onwards. Hunting and gathering remains a significant part of the economy until the Beaker culture period.

1. Introduction

There is a conspicuous gap in knowledge about the Neolithic between the Linear Bandkeramic (LBK) in the South Limburg loess area (4500 BC, uncalibrated C14) and the semi-agrarian groups in the West Netherlands delta area (3400 BC). Much is known about the LBK from excavations at Elsloo, Geleen, Sittard, and Stein (Modderman 1970, Bakels 1978), on the one hand, and about the groups in the delta area from the excavations at Swifterbant, Bergschenhoek, Hazendonk, and Het Vormer (Deckers et al. 1980, Louwe Kooijmans 1967a, 1976b), on the other hand. But relatively little is known about the typo-chronology, material remains, and subsistence in the area and the time period in between. A number of regions in the Meuse River Valley, where amateur archaeologists, either as individuals or in organized groups, have been active for a number of years, offer good possibilities for bridging this gap in knowledge. Suitable regions of the area are, among others, the Rijk of Nijmegen, Venray, Leubeek, Roerstreek, and Montforterbroek.

Nevertheless, two factors constrain making interpretations from the results of regional investigations of this 'in-between' area. The first is that the archaeological material consists mainly of flint collected from surface scatters. The second is that the collections of these materials have been made by different amateur archaeologists, each with his/her own method and intensity of survey. Mitigating these constraints is that there is a considerable amount of data about the area, which is usually readily accessible. Moreover, since the results of regional approaches have been rewarding in other countries (Hamond 1978, Kruk 1980, Madsen 1981, 1982, Ilett et al. 1982, Bradley/Gardiner 1984), they might also be rewarding in the Meuse Valley.

The Roerstreek inventory is the first in a series of inventory projects. It serves as a pilot study to explore the analytic possibilities of the Meuse Valley region data for investigating the neolithicization of the Northwest European Plain as well as to develop methodological approaches.

The introduction of an agrarian economy and its development during the course of the Neolithic are two central themes of archaeological research. Lying within the purview of these themes, the research presented here is addressed to the Late Mesolithic (Gendel 1982) and Neolithic and is based on the idea that significant changes in subsistence patterns between the Late Mesolithic and Neolithic should be reflected in the area by the distribution and location of sites.

The model proposed here for the sandy area of the Roerstreek is that this area, in contrast to the loess area of Southern Limburg, was little used by the peoples of the LBK and Rössen cultures, and that a Mesolithic hunter-gatherer economy persisted until approximately 3400 BC. After this time agriculture played a role in the subsistence economy, as is shown by the Swifterbant and Hazendonk research. Agriculture appeared in the area as a small segment of the subsistence economy and then increased in importance during the course of the Neolithic. By the time of the Beaker cultures, which began around 2100 BC in the Southern Netherlands, a fully agrarian economy was established (Louwe Kooijmans 1985).

If the above model is correct, then two gradual changes in the proportion of site types and site locations should be visible between 3400 and 2100 BC.:

1. A transition from semi-permanent camps (occupied for a part of the year) to permanent occupations of a site (occupied for a number of years). Such a transition would

be reflected in an increase in the size of sites, in the number of artefacts in individual sites, and in the variability of artefact types (assuming that a longer duration of occupation will entail a greater number of activities at a particular location). At the same time, the location of the sites would shift from the margins of physiographic units (the more environmentally heterogenous transition zones) toward the center of these units (which are more environmentally homogeneous and more suitable for agriculture).

2. A decrease in the number of sites related to activities outside the (semi-)permanent sites (i.e., 'extraction' camps) relative to the number of (semi-)permanent sites. Extraction camps are characterized as having a lower density of materials, less variation in materials, a smaller surface area, and being located in an activity specific environment.

The following can be noted regarding the changes in the distribution patterns. The Roerstreek is an area with considerable physiographic variability or heterogeneity. In such a landscape selective choice of locations, i.e., using a restricted number of the physiographic units present, leads to a clustered site pattern. The more variable the land units utilized, the more dispersed will be the distribution of the sites. On this basis, it was expected that we would observe a more pronounced clustering of sites through time.

The following procedures were used to attempt to test the above model:

1. construction of a site typology using site size, the number of artefacts present at a site, and the variability of artefacts present at a site;
2. description of the distributional pattern of these sites using point-pattern analyses;
3. determination of the relation between site locations and the landscape using point-area association.

2. Map formation processes

2.1 THE ROERSTREEK

The inventory is restricted to the Roerstreek, an area of 144 km² south of Roermond and east of the Meuse (*fig. 1*). The center of the area is Sint-Odilienberg, where the Heemkunde Vereniging Roerstreek (HVR) has a museum and a conference center. Since 1967 the HVR has coordinated the activities of 10- 15 amateur archaeologists, and maintains a register of all the materials located.

This basic information about the archaeological research in the Roerstreek, however, gives a distorted picture of the original site types and their distribution. Two factors bias the representation of the original distribution (that is, the 'target population', or population of interest) given by the information about this distribution that can be, or has been collected (that is, the 'sample population') (Hamond 1978). These are 1) archaeological recovery practices, and

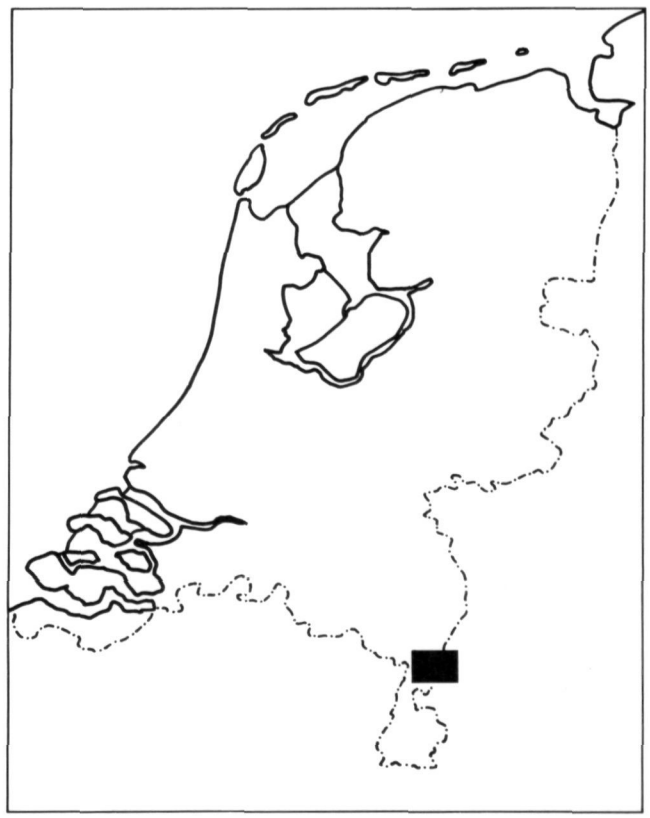

Fig. 1 Location of the Roerstreek

2) natural and cultural post-depositional processes.

Before the proposed model could be evaluated by analysing the Roerstreek data, the impact of these factors on the sample population had to be assessed.

2.2 RECOVERY PRACTICES

The archaeological data in the Roerstreek originate from excavation, field survey, and chance collection (i.e., collected in the course of doing an activity other than archaeological field work, such as recreational hiking and agricultural activities). Most of the materials registered originate from field survey, some originate from chance encounter, and very little from excavations.

Very little has been recorded in the Roerstreek about the context of or the relations among the materials collected by chance. Field survey, on the other hand, has the intentional goal of finding and documenting the location of artefacts. There are, however, two types of survey, unsystematic and systematic survey (Hamond 1978, 1980). In unsystematic survey the choice of the place(s) to be surveyed is frequently based on chance. Sometimes only fields found with high concentrations of artefacts are explored. Often the fields are not searched systematically, but criss-crossed in all different directions. And the

number of times that various fields have been visited varies considerably. In systematic survey some attempt is made to maintain similar survey coverage, e.g., by controlling the number and spacing of crossings in the fields.
Thirty-three persons who have submitted archaeological information about the Roerstreek are registered in the HVR. I interviewed five of the most active in order to elicit their research methodology, interest, and mode of artefact and site registration. The research methodologies among these persons were highly variable. Two practiced systematic survey, but a third stated that his primary interest was the Roman period. In this latter case the prehistoric finds that were recorded can be considered to be chance encounter finds.
The *potentially surveyable* part of the HVR-area, which has a total area of 144 km², is – after excluding parts covered by plaggen soils, Holocene sediments, forests, and urban areas – 79 km². Twenty-four km², or 30%, of this area has been surveyed by the five amateurs interviewed (*fig. 2*). Since, intuitively, this did not seem to be a good basis for drawing conclusions about settlement patterns, a *core area* was defined, which primarily consisted of the areas surveyed by the five amateurs. This area is 51 km², of which 34 km² is potentially surveyable. Twenty-two km² (65%) of the potentially surveyable area has been surveyed, which seemed to be a much better basis for doing spatial analyses. Within the core area the differences in survey intensity still had to be taken into account. Moreover, there are zones between the areas investigated by the amateurs where field survey is not possible.
In 1984, 258 archaeological *find locations* were registered in the HVR log, of which 209 had prehistoric artefacts. In order to distinguish between survey finds and chance encounter finds the number of *diagnostic artefacts* per find location was determined. The kinds of artefact considered to be diagnostic were:
- retouched flint artefacts
- unretouched flint macro-blades/flakes
- flint or stone adzes and axes and perforated axes
- milling stones, hammerstones, and grinding stones.

An arbitrary distinction was made between the 'small' find locations with fewer than five diagnostic artefacts, which were designated the result of chance encounter, and 'large' find locations with five or more diagnostic artefacts, which were considered the result of field survey. Of the 209 prehistoric find locations, 92 (44%) fell into the first category and 117 (56%) into the second.
The analysis of the recovery practices showed that the picture of the areal distribution of find locations was strongly influenced by the collection strategy employed. In order to eliminate the many potentially distorting factors only the large find locations in the core area were used. In summary, further analysis concerns only the field survey finds in 65% of the surveyable part of the core area.

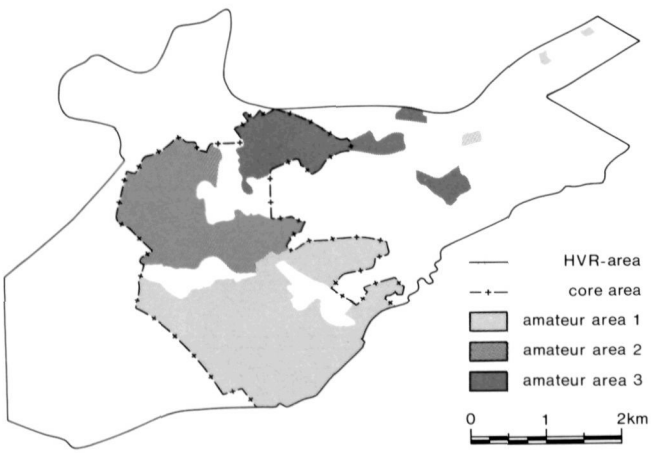

Fig. 2 Location of the areas surveyed by the five amateurs interviewed. Three main survey areas and a core area are depicted. The core area was selected as the area in which recovery practices played a less important role in the spatial distribution of find locations.

2.3 NATURAL POST-DEPOSITIONAL PROCESSES

The only geological processes that may have distorted our picture of the original find location distribution in the Roerstreek are extensive erosion and sedimentation. Since the research is addressed to the period between 5500 BC and 1700 BC, only Holocene geological changes needed to be taken into account. There are three major Holocene developments in this area:
1. peat formation. Peat growth occurred during the late Mesolithic and the Neolithic in the southern part of the Roerstreek (Put- en Echterbroek). No traces of occupation have been found in this area.
2. erosion by and sedimentation of rivers and streams. The Holocene sediments of the Meuse and the Roer were deposited during the Boreal period. The archaeological remains stemming from the younger portion of the time period under investigation in these river and stream valleys would have been continuously reworked and transported by flowing water. Stream deposits occur in only a few places in the Roerstreek.
3. erosion and sedimentation connected with steep slopes. Steep slopes are locally present in the eastern part of the Roerstreek.

All in all, natural post-depositional processes do not appear to have seriously distorted the original distribution of late Mesolithic and Neolithic find locations.

2.4 CULTURAL POST-DEPOSITIONAL PROCESSES

Cultural post-depositional processes include all those changes resulting from human activities following the period under investigation. Ninety-seven of the 117 large find locations could be assigned to cultural phases. Artefacts in 38 of these locations (39%) date to one cultural phase (*single-phase find locations*), and the rest of the locations (59, or 61%) have artefacts dating to more than one phase (*multi-phase find locations*) during the time period concerned. Virtually all find locations are 'contaminated' with Iron Age, Roman, and protohistoric ceramic artefacts. The artefact compositions of these prehistoric find locations, therefore, have been considerably altered by occupations subsequent to the period under investigation.

3. Assignment of sites to cultural phases and site typology

3.1 GUIDE FOSSILS

Once a picture of the distortions affecting the composition and distribution of the find locations had been obtained, we could begin with the 'real' archaeological analysis. The assignment of the artefact assemblages to cultural phases was the first step.

Although the assemblages in the Roerstreek consist mainly of flint artefacts, some ceramics and items of other types of stone are present as well. Organic objects, such as those of wood, bone, and antler, have not been preserved in the dry and decalcified soils. Consequently, the assemblages have been assigned to cultural periods on the basis of the flint and ceramic artefacts.

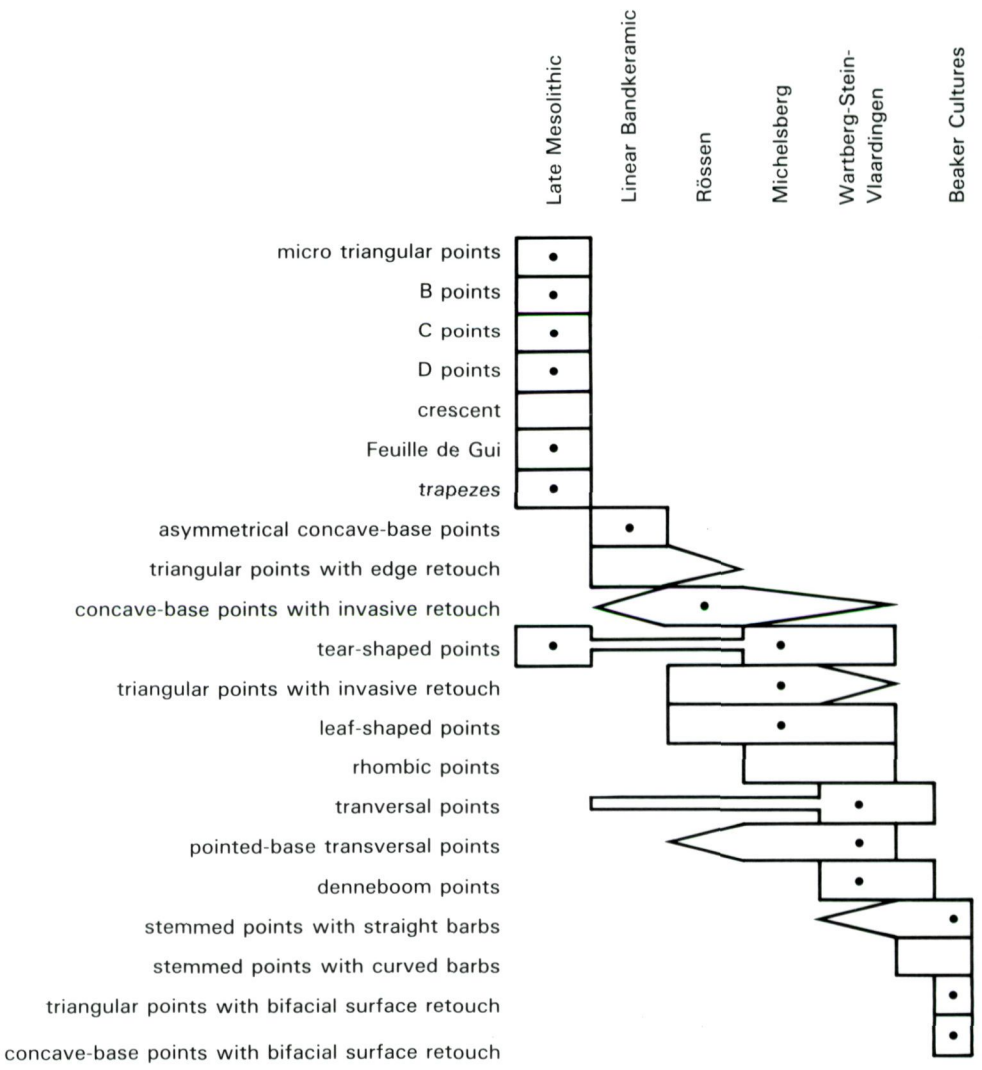

Fig. 3 Typological table of point types. The occurrence of point types for successive cultural phases is shown. The chronological 'center of gravity', i.e., the phase in which the type is most numerous, is indicated by a black dot.

Six cultural phases are distinguished in Limburg for the period under investigation: the Late Mesolithic (Gendel 1982), the Linear Bandkeramic (LBK), Rössen, Michelsberg, Wartberg-Stein-Vlaardingen (WSV) (Louwe Kooijmans 1983), and the Beaker cultures. An inventory of the composition of flint assemblages for these phases was made from the literature, and the typological development of each tool type was outlined. *Figures 3* and *4* present this development in typological tables with the cultural phases in the columns and the types in the rows. Similar tables have been made by Fiedler (1979) and Löhr (1974) for the neighbouring Rhineland. The typological tables provide the basis for the assignment of the assemblages to cultural phases. The chronological 'center of gravity' of each type, i.e., the phase in which the type is most numerous, is indicated with a black dot on the table. The type, in turn, was designated as characteristic for that period. In this way, most of the individual artefact types were used as a guide fossil for a single period, and were used to date the artefacts more precisely than is, in fact, possible. The considerable 'noise' produced by this process was accepted in order to have a simple procedure for making cultural assignments.
In addition to using typological differences, one can sometimes use differences in degrees of patination and in raw materials to distinguish Mesolithic from Neolithic artefacts. The allocation of the Roerstreek tools to the various cultural phases was as follows:

- Late Mesolithic: trapezes. Feuille de Gui, leaf-shaped, triangular, and BCD points could still be present (Newell 1973). Scrapers, borers/reamers, and burins on micro-flakes/-blades, micro-cores, bladelets, backed knives, and pick-axes, which are present throughout the Mesolithic, were dated to the Late Mesolithic on the basis of their association with the trapezes. Micro-blades were defined as having a maximum dimension of less than 3 cm and micro-flakes as having one less than 2 cm.
- LBK: asymmetrical concave-base points, adzes, and end-scrapers.
- Rössen: concave-base points with invasive retouch, Breitkeile, and perforated adzes.
- Michelsberg: triangular points with invasive retouch, leaf-shaped points, tear-shaped points, unretouched and retouched macro-blades, scrapers on macro-flakes/-blades, pointed blades, and reamers on macro-blades. Macro-blades were defined as having a maximum dimension greater than 8 cm and macro-flakes as having one greater than 5 cm.
- WSV: tanged points (the *denneboom*), transversal points, scrapers on micro-flakes (also on *Maaseitjes*, or 'Maas eggs', (which are small, distinctive, egg-shaped pebbles found in the Meuse Valley), and circular scrapers.
- Beaker cultures: stemmed points with straight barbs, triangular points with bifacial surface retouch, concave-base points with bifacial surface retouch, planoconvex knives, Grand Pressigny blades, and battle-axes.

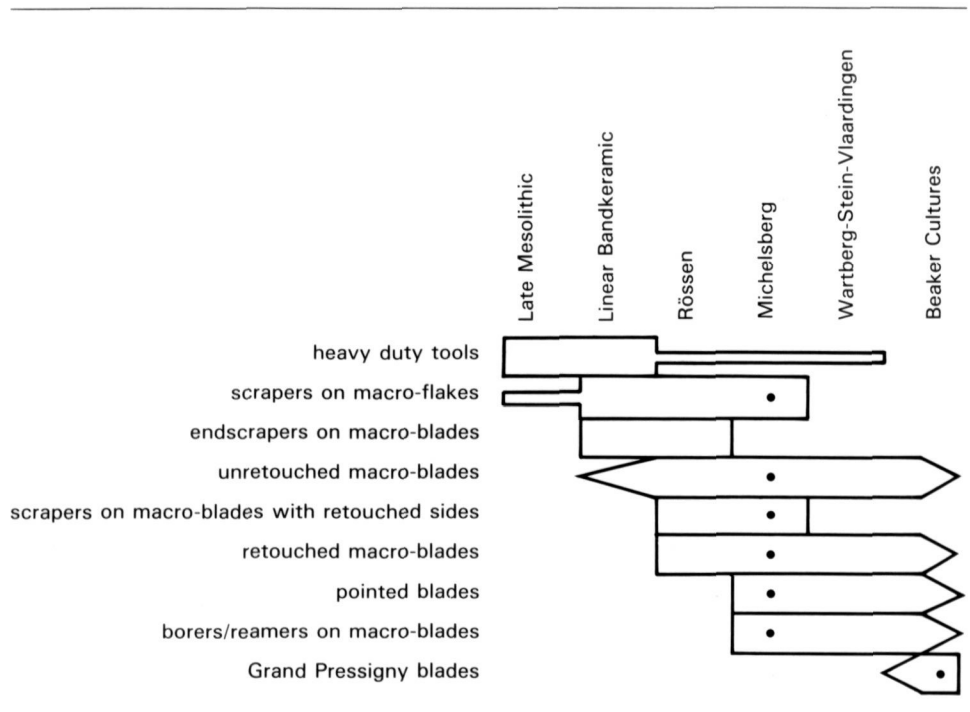

Fig. 4 Typological table of macro-artefacts. The occurrence of macro- artefacts for successive cultural phases is shown. The chronological 'center of gravity', i.e., the phase in which the type is most numerous, is indicated by a black dot.

General guide fossils for the Neolithic were ground flint and ground stone axes and ceramics. The axe typology is not sufficiently detailed for reliable assignment to cultural phases. The ceramic typology, on the other hand, is very detailed, and a cultural assignment of a find location using it is frequently possible. Ceramics were also used as guide fossils. Some find locations were dated solely on the basis of the ceramics when the flint artefacts expected for the phase concerned were absent.

One find location may be attributed to more than one cultural phase. The material deposit of one cultural phase was denoted with the term 'site', and, therefore, a find location could have more than one site.

For each cultural phase the guide fossils were cross-tabulated with the sites. Certain sites consisted of only one or a few guide fossils. Should such a site be considered to belong to the site distribution the cultural phase indicated by the guide fossil, or should the guide fossil be considered to be a stray or 'lost' artefact? To resolve this problem a minimum requirement for a site to be included in the analysis was established: either three or more guide fossils must be present or the number of guide fossil types present must be at least one-third of the number of designated guide fossil types for the cultural phase. A Michelsberg phase site, for example, must produce at least three guide fossils since nine flint guide fossil types and ceramics were used to characterize that phase. Thus, the number of guide fossil types required for sites attributed to cultural phases having fewer guide fossil types was less than that required for sites attributed to phases having more types. This solution served as a correction, so to speak, for the differences in the ability to recognize the various cultural phases. The first part of the minimum requirement meant that sites having a large number of artefacts of only one type were also included in the analysis.

In summary, use was made of those sites that were a part of a large find location (one having five or more diagnostic artefacts) and that had either one-third or more of the guide fossil types or three or more guide fossils. After the above selection procedures were completed, the number of sites for each cultural phase was: Late Mesolithic - 18; LBK - 19; Rössen - 8; Michelsberg - 55; WSV - 31; and Beaker cultures - 17. Thus, it appears that a considerable number of LBK and Rössen sites appear in the study area. So, the area was, in contrast to the model, used extensively by the peoples of these cultures. Further analysis is required in order to specify the economic functions that these sites may have had.

3.2 SITE TYPOLOGY

Before investigating the settlement patterns of the individual cultural phases, an attempt was made to distinguish different types of sites. Such prehistoric remains as features, monuments, and/or tombs were not found during field survey and thus could not be used for this purpose. But, lists of artefact types present, the number of artefacts, and the site area could be considered. The number of artefacts was not deemed a good starting point because it is dependent on (chance) temporary conditions during survey, such as the weather and the plowing conditions, and the number of times the find location was collected. The site area was also not a good basis because the five amateur archaeologists interviewed could indicate the areal extent of the different cultural phases present in only a few cases. Usually it could not be determined, for example, where Mesolithic artefacts were found and where Michelsberg artefacts were found when they were collected from the same field plot. As a consequence, a small Mesolithic occupation spot was given the same area as the Michelsberg site by which it was overlapped.

Therefore, the list of artefact types remained the only possibility for differentiating site types. The cross tabulations of guide fossils and sites were seriated for this purpose. The tables were rearranged by calculating the means of the rows and columns in which guide fossils are present and then reordering the rows and columns according to decreasing values of the means (Graham/Galloway/Scollar 1975). This method was used, in spite of its limitations, because it is easy and fast. Theoretically, if different site types are present, one should be able to distinguish groups of sites in the seriated table; one group should lack types that are characteristic for another group.

The construction of site types from the seriated table was possible only for the Michelsberg phase (*table 1*). Twenty-five assemblages with highly variable compositions appear in the middle part of the seriated table (site numbers 15-46). These assemblages are also relatively large (ca. 10 guide fossils) and have more ceramics. On the left side of the table are assemblages without leaf- and tear-shaped points, and on the right side the macro-artefacts are lacking. Nevertheless, the table presents a jumbled and ambiguous picture. The seriated tables for the other cultural phases showed even less distinct groupings, either because of lower numbers of guide fossil types and/or because of greater similarity among the site assemblage compositions.

The partitioning of the Michelsberg sites into possibly three site types might be justified if these types were to correspond to different types of local environments. The following environmental attributes were collected for each site: elevation (NAP = Dutch ordnance datum); vegetation; geology; distance to open water; relief; vegetational homogeneity; and geological homogeneity. The values for the last three attributes were measured on the appropriate maps by the number of contour lines, the number of

site number	borers/reamers on macro-blades	unretouched macro-blades	scrapers on macro-blades	scrapers on macro-flakes	pointed blades	triangular points	leaf-shaped points	retouched macro-blades	tear-shaped points	ceramic	axes
123		3									+
120		2	1								
213		2	1							+	
36		+	2	2							
81		2	2		1						
70	1	+	1					2			+
30		2			1						
72		+			1						+
53	2	8		1	6	1					
23		+		+	+						
80	+	+	+	+ +	+						+
182		4				1					
2		3		4		1					
37		1		2		1					
19	1			1	1	1					
34		+	+ +		2	1					+
20			+	+	+						+
147		1			1	1					
15		+	+	+		2	2				+
17			1	1	+	3				+	
21			+	+	+ +	1				+	+
126			1		1	1					
24			2	+			1				+
82			+	+			2				+
3		1		4		6	2				
16	+ +		+ +	+ +	+ +	4	3	+				+
187		1		5		3		3			+
84			1	4				1			+
109			+	+				4			+
14			+	+		2	3			+	+
31				1	3	1					+
114			+	+		1	1			+	
209		5	1				1	3			
141			1	1	2	3	4				
1			1	6	+	6		+		+	+
22			2	+	2	2		+		+	+
83			+	+ +	+ +	1		+		+	+
39			+	2	3	1	2	1			+
8		1					1	2			+
85				+ +		3	1				
						3	1				+
41				1				3			
99				+				+			
226			3			1	2	8			+
46					1	2		4			+
113					1	1		+		+	
119					1	1		1			
196					1	1		1			+
127				1			3	+			+
183			1			1		+	2		
96					1			3			
90						2		1			
18					+				2		+
13							3	1		+	
25							1	3			+
164								4			

Table 1 Seriated cross tabulation of guide fossils and Michelsberg sites. Assemblages with different compositions are separated. A partitioning of the Michelsberg sites into three site types seems to be present in the table: site numbers 123-147, 15-46 and 113- 164. Legend: number = number of guide fossils, + = present and + + = numerously present

vegetational units, and the number of geological units, respectively, inside a circle whose radius was one km from the site.
There appeared to be no correspondence between the three types of Michelsberg sites and their local environmental attributes. Therefore, it was concluded that partitioning of the sites into site types was not possible for any of the cultural phases. Consequently, the change in site types postulated in the model could not be tested, and it was necessary to assume that all sites within a cultural phase were functionally equivalent.

4. Spatial analysis

4.1 CONTEXT OF THE ANALYSIS

A distribution map showing the locations of the sites was made for each of the cultural phases; within each phase all sites were given equivalent weight because of the results of the analysis in the preceding section.
Spatial analyses require control over the representativeness and synchroneity of the sample. In this case, the variability in recovery practices made it highly probable that the sample was not representative, even though there was detailed information about the recovery procedures and a large part of the area in the core area had been covered. Furthermore, each of the cultural phases under consideration lasted for several hundred years, and it was thought probable that the distribution maps give a picture of an accumulation of sites over an extended period. Since we did not have sufficient control to determine the distribution pattern at one point in time in a cultural phase, we assumed that the settlement pattern throughout each phase remained unchanged and that the distribution maps more or less accurately reflect this pattern. In spite of these limitations, it seemed that spatial analyses of these data, using point-pattern analysis and point-area association, could lead to some insights and interpretations about the distribution maps.

4.2 POINT-PATTERN ANALYSIS

Two kinds of point-pattern analysis were applied to the individual distribution maps: k-means cluster analysis (Doran/Hodson 1975) and dimensional analysis of variance (DIMANOVA) (Whallon 1973). Both methods are included in the Statistical Analysis System package, which is implemented on the IBM mainframe computer in Leiden.
The compounded distribution of all the sites that had received a cultural assignment showed two large groups which corresponded to the amateur investigation areas 1 and 2, which are separated by woods (*fig. 2*). The overall settlement pattern is strongly influenced by the activities of the amateurs and current landuse. If the settlement pattern for a cultural period did not deviate from this overall pattern, nothing could be said about the original site distribution. Only a deviating settlement pattern was considered to have interpretative consequences.
K-means cluster analysis was used to cluster the x and y coordinates of the sites. These variables were not standardized because they were measured in the same units (km). The optimal number of clusters was determined by the Cubic Clustering Criterion (SAS Institute Inc. 1985). The optimal number of clusters is indicated by a peak in the graph that compares the number of clusters with the criterion (*fig. 5*). The spatial locations of the differentiated clusters (*fig. 6*) were examined.
The settlement patterns of the LBK and Beker phases deviate from the overall pattern in that several small groups of sites are present in the core area. These groups consist of 3-7 sites and are about five km apart. All the other cultural phases exhibited a clustering pattern corresponding to the survey investigation areas of the amateurs.
To apply DIMANOVA the area is partitioned into cells whose size, position, and orientation are arbitrary. In this case we imposed the grid with 1 x 1 km grid squares of the 1:25000 topographic map of the Netherlands over the area. Cells were then added to the margins in order to make a square area of 16 x 16 km. *Fig. 5* shows a graph of the blocksize versus the 'mean square between block' (Mj). A peak in this graph shows the range within which the optimal cluster size occurs. The exact form, orientation, and contents of the clusters which produce these results cannot be determined from this analysis.
All phases show the best clustering of sites at the 32 km2, 4 x 8 km, blocksize. The Michelsberg and WSV phase sites have the most distinct clustering, and the LBK and Rössen site clusters are less distinct. Virtually all the sites fall into two of the blocks, with the remaining six blocks being mostly empty. The two blocks with most of the sites once again correspond to amateur survey areas 1 and 2. At the same time the sites of the LBK and the Beaker cultures cluster at the blocksize 4 km^2, 2 x 2 km, level, and there is a tendency for the Rössen and WSV phase sites to do the same. Therefore, the DIMANOVA analysis also indicates the existence of smaller clusters.
In spite of the disadvantages/limitations of the cluster analysis and DIMANOVA (Pielou 1969, Whallon 1973, Orton 1980), it seems that it is possible to obtain interpretable results with both analytic techniques. The distributions of the LBK and Beaker culture sites, and to a lesser extent the Rössen sites, diverge from the overall pattern by exhibiting small group clusters. This, according to the model, could be interpreted as utilization of a limited number of landscape units. The two larger groups of the other phases correspond to the survey area recovery pattern, but a more dispersed settlement pattern may be present, indicating utilization of more landscape units.

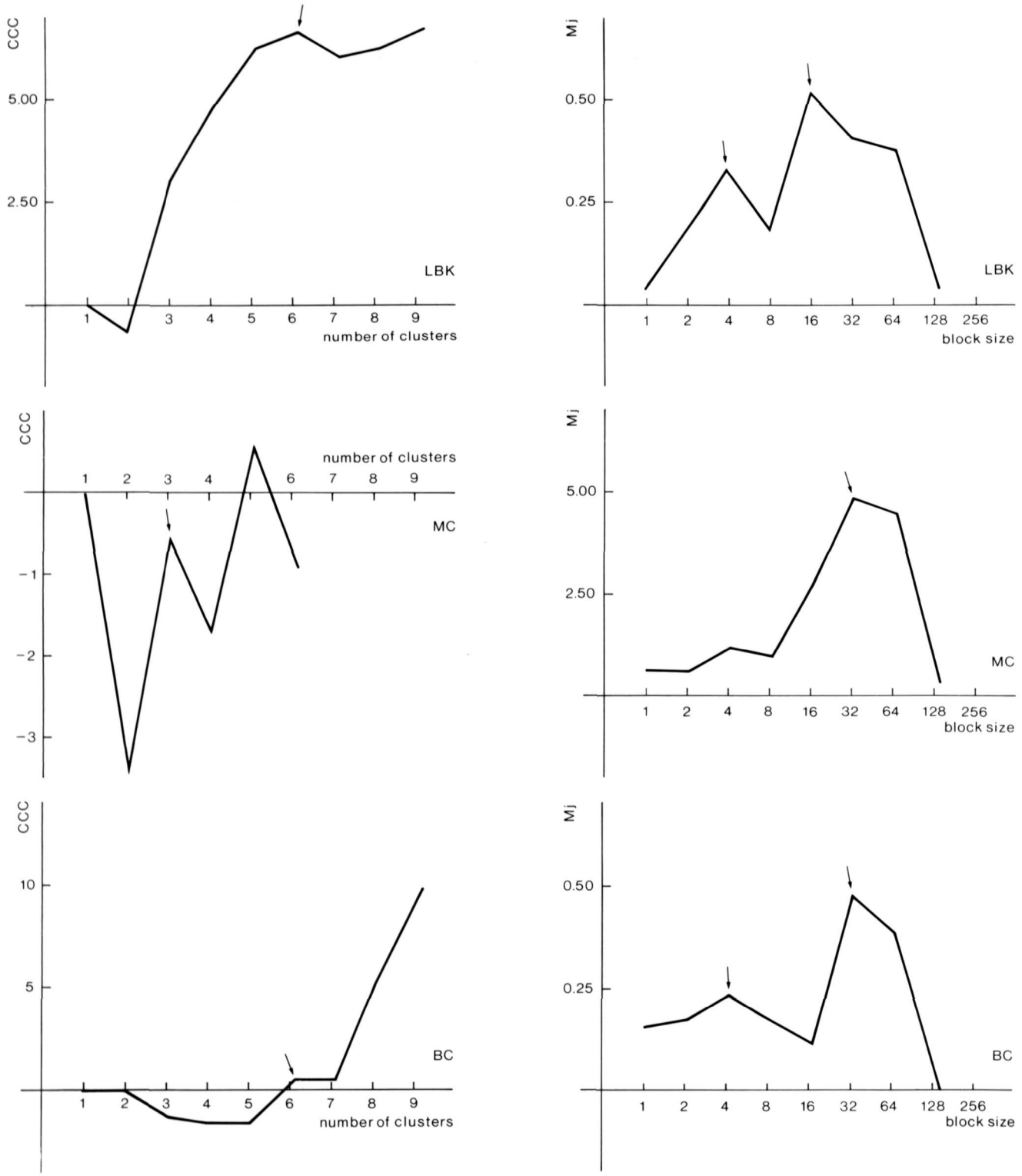

Fig. 5 Graphs for selecting the optimal number of clusters. The graphs for both the k-means cluster analysis (CCC) and DIMANOVA (Mj) are shown for the LBK, Michelsberg and Beaker culture phases. Arrows indicate the optimal number of clusters.

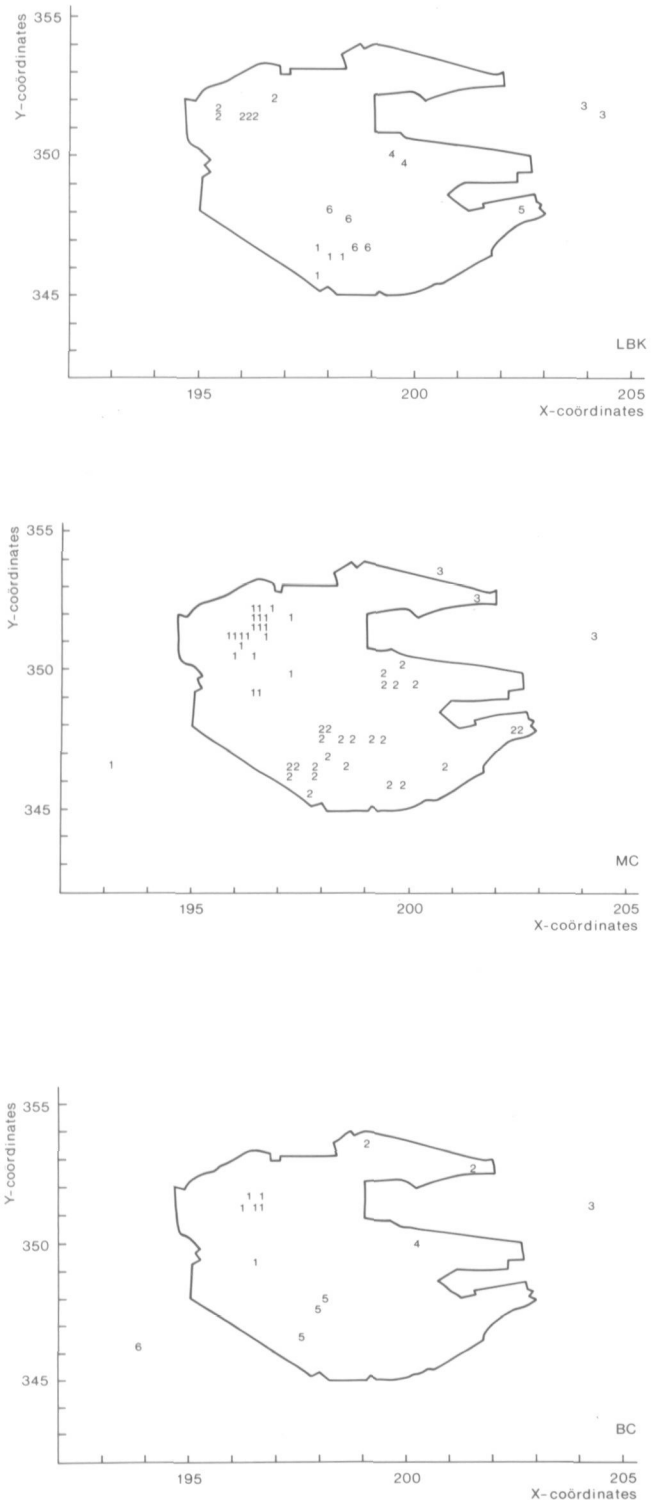

Fig. 6 Spatial distribution of the differentiated clusters obtained by k-means cluster analysis. Each site is indicated by the number of the cluster to which it belongs.

4.3 POINT-AREA ASSOCIATION

Point-area association allows investigation of the relation between the distribution of points in a landscape and the distribution of environmental or 'background' variables. Because all site types in each cultural period were weighted equally, it was possible to establish an 'average' landscape location for each phase.

The averages and standard deviations of the interval-scale environmental variables were calculated per phase (*fig. 7*), and two things were noted:

- the differences among the phases are small and not statistically significant.
- the locations of the LBK and Rössen phase sites are generally at higher elevations and in areas with more pronounced relief. Furthermore, the Rössen sites are located where there is somewhat more geological and vegetational heterogeneity, and the LBK sites lie somewhat further away from water sources.

Histograms of the different environmental variables were made for each phase (*fig. 7* and *8*), from which the following conclusions were drawn:

- the differences among the phases in site locations in the landscape are small, which would mean that use was made of a number of landscape units during each phase.
- the LBK and particularly the Rössen sites differ most from the sites of the other phases in their landscape locations.
- there is a gradual shift from the Late Mesolithic to the Rössen phase in the environmental variables which then reverses from the Rössen to the Beaker cultures.

Since it isn't easy to compare a large number of histograms, the chi-square statistic was used to test the significance of the difference between the observed distribution of the sites over an environmental variable and the expected distribution. In the expected distribution sites were allocated to the environmental variable according to the proportion of the surfaces of the different mapping units of the variable in the entire HVR area. It was reasoned that the more the distribution of a cultural phase environmental variable diverged from the expected distribution, the more selective were the locations for sites. This analysis was applied to all cultural phases individually using the elevation, geology, vegetation, and distance to water source variables (*figure 9*). It appears that more LBK and Rössen phase sites are found at higher elevations and in the Tilia-Ulmus-Quercus woods than expected. At the same time the surroundings of these sites are more heterogeneous in having more contour lines and more geological and vegetational units. A more selective choice of site locations tends to be present also in the Beaker cultures phase when the sites were at lower elevations, more on dry coversands and river drifted sands (*rivierstuifzanden*), and more in Quercus-Tilia woods than expected.

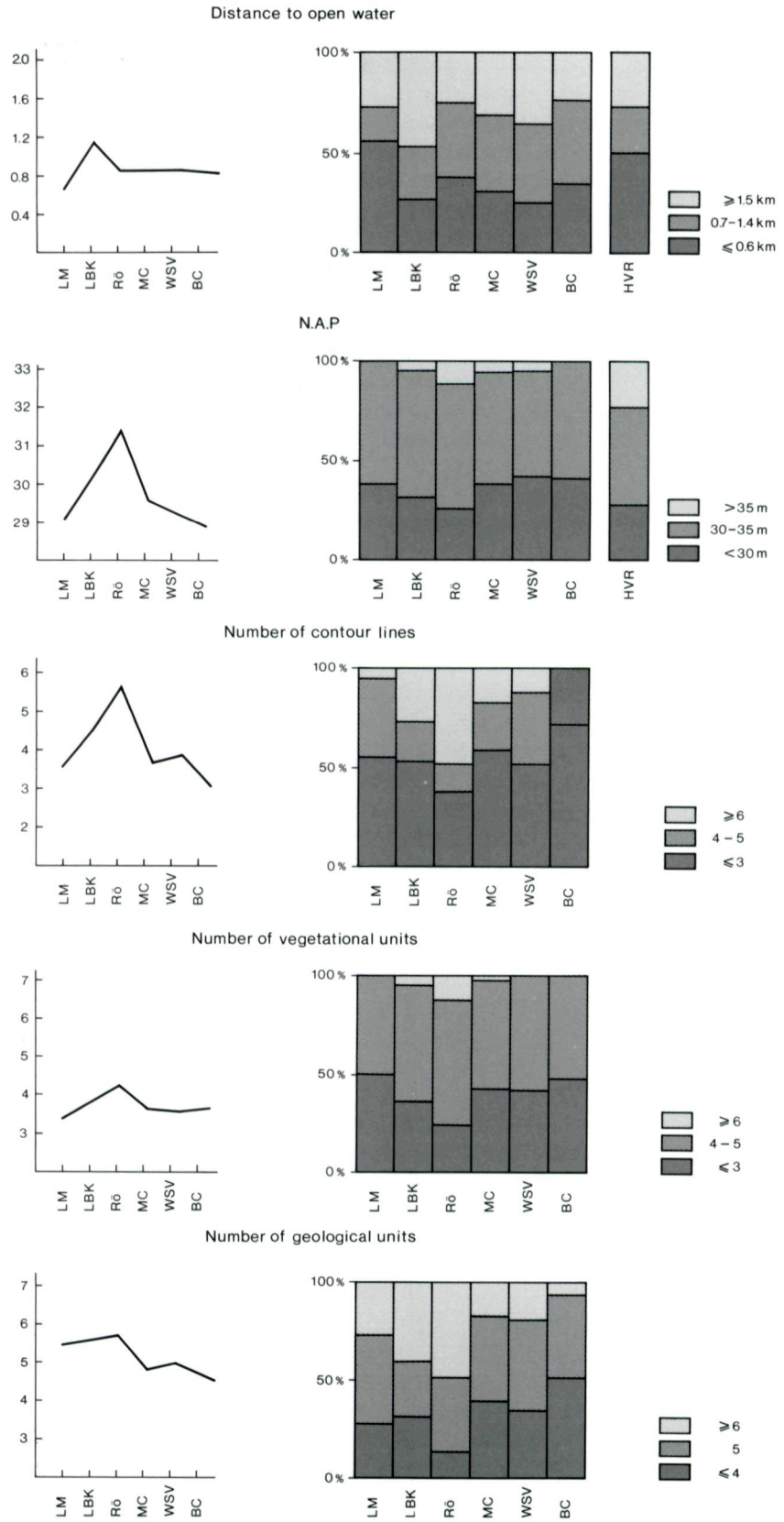

Fig. 7 Distribution of the interval-scale environmental variables for the successive cultural phases. The left part of the drawing shows the changes in 'average' landscape locations. The right part consists of the histograms. For some variabeles a bar on the far right side shows the expected distribution, obtained by observing the proportion of the mapping unit surfaces in the HVR area.
Legend: LM = Late Mesolithic, LBK = Linear Bandkeramic, Rö = Rössen, MC = Michelsberg, WSV = Wartberg-Stein-Vlaardingen and BC = Beaker cultures

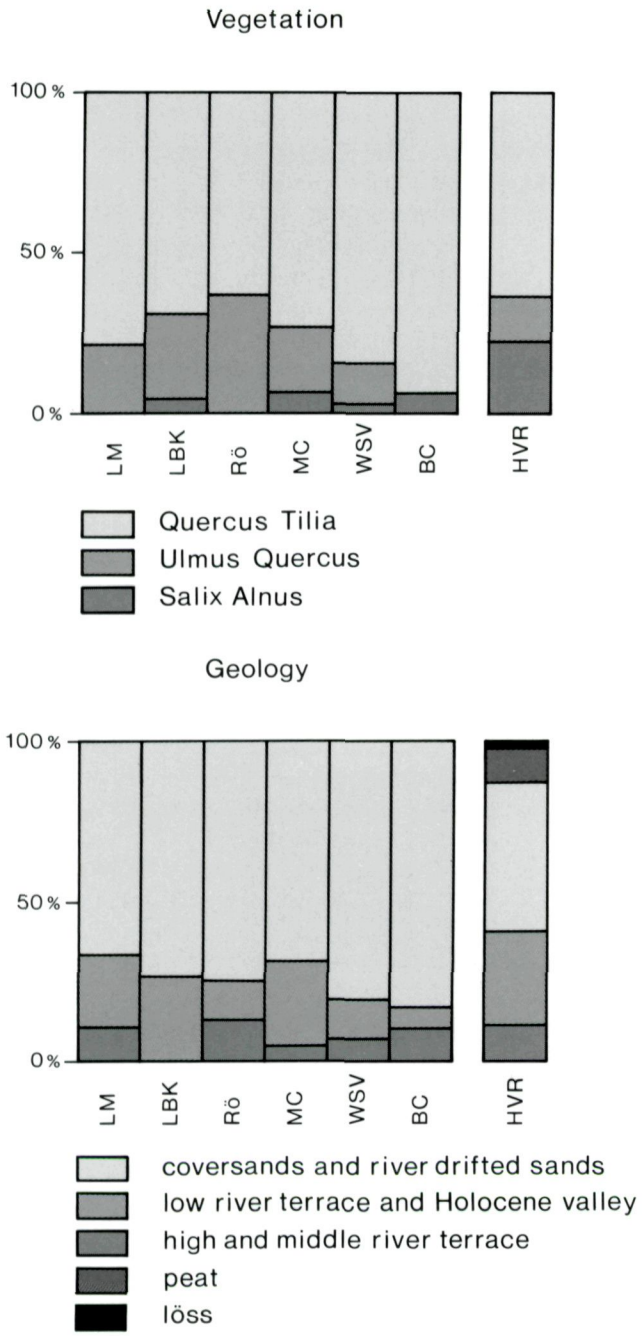

Fig. 8 Distribution of the nominal-scale environmental variables for the successive cultural phases. The histograms for the vegetation and geology, and the expected distribution, obtained by observing the proportion of the mapping unit surfaces in the HVR area, are shown.
Legend: LM = Late Mesolithic, LBK = Linear Bandkeramic, Rö = Rössen, MC = Michelsberg, WSV = Wartberg-Stein-Vlaardingen and BC = Beaker cultures

The surroundings of these sites are more homogeneous than the surroudings of sites in other phases.

5. Conclusions

5.1 ANALYTIC METHODS

The use of statistical techniques in archaeology has become more and more popular. Frequently, the large databases of a regional study can be efficiently analysed only with statistical techniques. Techniques for classification and spatial analysis seem to be the most important applications. The large supply of techniques, however, increases objectivity only slightly, since one can usually find a technique that will produce the results desired. To increase objectivity one can repeat the analysis with a different technique or use several techniques in tandem.

5.2 ARCHAEOLOGICAL INVESTIGATION

The results of the site typology, point-pattern analysis, and point-area association of the HVR collection are not unambiguous. The changes ascertained are small and gradual.
The periods from the Late Mesolithic to the Beaker cultures can be divided into four phases:
- Phase 1 – Late Mesolithic, with large groups of sites, most of which are found at low elevations with little relief and in vegetationally more homogeneous environments, consisting of Quercus-Tilia woods.
- Phase 2 – LBK and Rössen, with small groups of sites found at higher elevations with more relief and in vegetationally more heterogeneous environments, consisting of Quercus-Tilia or Tilia-Ulmus-Quercus woods.
- Phase 3 – Michelsberg and WSV, with large groups of sites, most of which are found at low elevations with little relief and in vegetationally more homogeneous environments, consisting of Quercus-Tilia woods.
- Phase 4 – Beaker cultures, with small groups of sites, found at low elevations with little relief and in vegetationally more homogeneous environments, consisting of Quercus-Tilia woods.

During phase 1 most of the local environments were used, and there seems to have been less preferential selection of site locations. This is in agreement with a presumed broad-spectrum hunter-gatherer economy.
Changes appeared in the transition from the Late Mesolithic to the LBK. By phase 2 there appears to be preferential selection of site locations. This could possibly be explained under the assumption that not all economic activities took place in the Roerstreek. The Roerstreek may have been used for pasturage, in addition to hunting and gathering, and most of the sites may have been transhumance camps (Bogucki 1982) while their associated agricultural settlements were primarily located in the loess areas (Bakels 1978, 1982). Since there was not sufficient

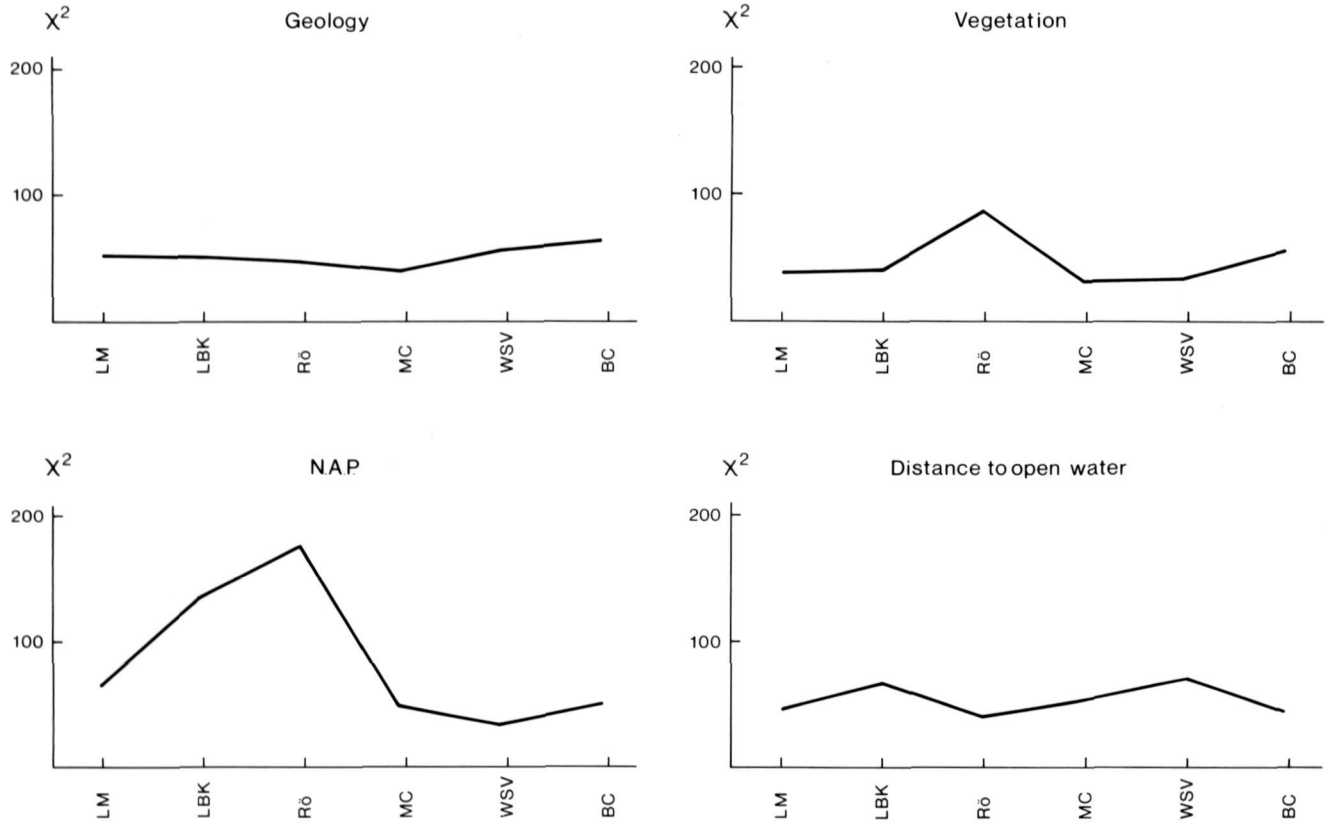

Fig. 9 Chi-square statistics for some environmental variables for the successive cultural phases. Legend: LM = Late Mesolithic, LBK = Linear Bandkeramic, Rö = Rössen, MC = Michelsberg, WSV = Wartberg-Stein-Vlaardingen and BC = Beaker cultures

space on the loess to support the presumed size of the herds (Bakels 1978), a solution could have been to graze the stock seasonally in the sandy areas lying to the north. By phase 3 the situation had clearly changed again, and this phase is remarkably similar to phase 1, not only in site associations with landscape units, but also in the settlement pattern. But we can be rather certain, in view of the data from the delta area, that agriculture was being practiced in the Roerstreek by this time. The subsistence economy in this phase, besides being based on agriculture and raising of stock, could, therefore, still be based partly on hunting and gathering.

Phase 4 sites are located in less specific environments than those of phase 2, but in more specific ones than those of phase 3. The apparent preference for more homogeneous local environments could be interpreted as a result of the increased importance of agricultural production.

The development from the Late Mesolithic to the Beaker cultures seems to agree rather well with the model proposed. The introduction of agriculture did occur in the Roerstreek between 3400 and 2100 BC (Louwe Kooijmans 1976a, 1976b). Although playing a role subordinate to agriculture in the subsistence economy, hunting and gathering appears to have continued until the Beaker culture period. The presumed absence of LBK and Rössen sites is not correct. These sites, because they represent a limited number of economic activities, even occupy a special position.

6. Discussion

The ideas presented above are only a first concept. The models of the individual cultural periods should be more detailed. In the investigation presented here the necessary data to do this, except for the Michelsberg phase, were either not available or did not emerge from the analyses. This situation means that the slight differences/shifts that were found in the data do not provide a justifiable basis either. The excavation of several find locations, especially ones having preserved organic materials (bones) that may help answer queries about the subsistence economy, would be an important contribution to the construction of more detailed models.

The Michelsberg cultural period is the only period for which a more detailed model could be made. Throughout

Northwestern Europe causewayed enclosures are found dating to this period; these monuments presumably fulfilled a social/economic function for larger aggregations of the population (Madsen 1982). It is of interest to trace to what extent comparable sites appear in this cultural period in the Netherlands.

Compared to the other phases, our knowledge of the Michelsberg phase is less likely to be changed by additional collection of artefacts, whose number is already relatively large. The number of artefacts could be used as a starting point for classifying the Michelsberg sites. If there is a site that could be considered to have had a 'central' function in the Roerstreek, it would be the largest and richest site, find location 16 at Linne-Mortelshof. In 1984 the Instituut voor Prehistorie performed a test excavation of this site. No features were located and little archaeological material was encountered. The Michelsberg assemblage included only 25 guide fossils, and moreover, the area of the site was relatively small, not more than 7000 m^2. Madsen (1981) estimates the size of a causewayed enclosure to be at least several tens of thousands of square meters. It is probable that there are no causewayed enclosures in the Roerstreek and that find location 16 was only a very intensively surveyed spot.

Permanent residential sites are characterized by relatively more material and greater variability in types of materials (such as milling stones and ceramics). The proportion of the Michelsberg sites that may be interpreted as residential sites is difficult to determine. In the middle part of the seriated table are a number of sites with more variable materials and with approximately 10 guide fossil artefacts. There are 21 sites that could, on the basis of the presence of milling stones and ceramics and more than 8 guide fossils, be considered as residential sites. The small number of artefacts makes single house sites more probable than hamlets or villages. If it were accepted that each site represented one house and that the average duration of occupation of a house was 35 years (Lüning, 1982), then, since it is known that the Michelsberg period lasted about 800 years, approximately one house was occupied at any one time in the core area. This estimate seems a little low for an area of 51 km^2. In addition to the 21 'house sites' there are 34 smaller sites. These could have been formed as a result of activities outside of the 'house sites' (hunting, collecting, cultivation), but also they could be the result of less complete recovery of materials.

This model that proposes that at least one house site and attending smaller sites for adjunct activities were occupied/used throughout the Michelsberg phase is only an example. Such a detailed model should be made for each cultural phase in order to be able to follow closely the changes in the settlement pattern and thereby changes in the subsistence economy. Nevertheless, it seems reasonable that regional investigation in the Meuse Valley be continued. The knowledge about the neolithicization process in the Netherlands can certainly be expanded by critical analyses of the archaeological sample and by using statistical techniques.

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